Regional differences in health resource allocation: a longitudinal study in the Chengdu-Chongqing economic circle, China

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ABSTRACT
Objective To analyse regional differences in health resource allocation in the Chengdu-Chongqing economic circle.
Design A longitudinal analysis that collected data on health resource allocation from 2017 to 2021.
Setting The number of beds, health technicians, licensed (assistant) physicians, registered nurses and financial allocations per 1000 population in the 42 regions of Chengdu-Chongqing economic circle were used for the analysis.
Methods The entropy weight technique for order preference by similarity to an ideal solution (TOPSIS) method and the rank sum ratio (RSR) method were used to evaluate the health resource allocation.
Results The number of licensed (assistant) physicians per 1000 population in the Chengdu-Chongqing economic circle (3.01) was lower than the average in China (3.04) in 2021. According to the entropy weight–TOPSIS method, Yuzhong in Chongqing and Chengdu and Ya’an in Sichuan Province had higher C-values and were ranked in the top 10. Jiangjin, Hechuan, Tongnan and Zhongxian in Chongqing and Guang’an in Sichuan Province had lower C-values and were all ranked after the 30th place. According to the RSR method, the 42 regions were divided into three grades of good, medium and poor. The health resource allocations of Yuzhong, Jiangbei, Nanchuan, Jiulongpo and Shapingba in Chongqing and Chengdu and Ya’an in Sichuan Province were of good grade, those of Tongnan, Jiangjin, Yubei and Dazu in Chongqing and Guang’an and Dazhou in Sichuan Province were of poor grade, and the rest of the regions were of medium grade.
Conclusion The regional differences in health resource allocation in the Chengdu-Chongqing economic circle were more obvious, the health resource allocation in Chongqing was more polarized and the health resource allocation in Sichuan Province was more balanced, but the advantaged regions were not prominent enough.

INTRODUCTION
The Chinese government is committed to building a healthy China, focusing on people’s health and promoting the regional balanced development of health resources. China’s comprehensive healthcare reform policy has improved the allocation of regional health resources. However, there is still a shortage of total health resources, an imbalance in the allocation of urban and rural health resources, an irrational allocation structure and inefficiencies in the utilisation of resources. The unbalanced allocation of health resources has led to the phenomenon of ‘long registration time, long payment time, long medicine collection time and short consultation time’, which makes it difficult for the allocation of health resources to meet the multilevel and diversified medical needs of the people. Under the background of international regional economic integration, the Chengdu-Chongqing economic circle is an important regional strategy along with Beijing-Tianjin-Hebei, Yangtze River Delta and Guangdong-Hong Kong-Macao Greater Bay Area, and it has a unique and important
strategic position in the overall situation of national development. To achieve equalisation of medical and health services and improve the health service level of the people in the Chengdu-Chongqing economic circle, it is important to promote a balanced allocation of health resources throughout the region.3

Currently, there are four main areas of research related to health resource allocation in China. First, in terms of the study area, it mainly includes provincial administrative regions such as Guangdong Province,5 Jiangsu Province and Shanghai Municipality.6 Second, in terms of the resources studied, it mainly includes primary healthcare resources,7 traditional Chinese medicine health resources, and maternal and child healthcare resources.8 Third, in terms of research content, it mainly includes the equity and efficiency of health resource allocation. Equity research methods mainly include Gini coefficient,9 Theil index10 and agglomeration degree,11 and efficiency research methods mainly include data envelopment analysis method12 and Malmquist index.13 Fourth, health resource allocation is analysed in combination with geography and operations research methods. This mainly includes geographical detector models and geographically weighted regression methods,14 as well as fixed effects regression models.15 The allocation of health resources and regional disparities within the Chengdu-Chongqing economic circle are topics that require further investigation. Comprehensive evaluation of health resources in the Chengdu-Chongqing economic circle is targeted to benefit the leading advantages of the areas with good health resource allocation and supplement the deficiencies of the areas with weak health resource allocation. Promoting the regional balanced development of health resources in the Chengdu-Chongqing economic circle can serve as a scientific reference for achieving balanced development of health resources in China and even in the world.

In this study, the researcher extracted the number of beds, health technicians, licensed (assistant) physicians, registered nurses and financial allocations per 1000 population in 42 regions in Chengdu-Chongqing economic circle from 2017 to 2021. The entropy weight–TOPSIS (technique for order preference by similarity to an ideal solution) method and the rank sum ratio (RSR) method were used to comprehensively evaluate the health resource allocation of Chengdu-Chongqing economic circle so as to provide a scientific basis for promoting the regional coordinated development of health resources in the Chengdu-Chongqing economic circle.

MATERIALS AND METHODS

Data sources

Data on health resources for the 42 regions in the Chengdu-Chongqing economic circle from 2017 to 2021 were obtained from the Sichuan Health Statistical Yearbook (2017–2021) and the Chongqing Health Statistical Yearbook (2018–2022).

Regional division

According to the ‘Planning Outline for the Construction of the Chengdu-Chongqing Twin Cities Economic Circle’,16 the planning scope of the Chengdu-Chongqing economic circle includes 27 regions in Chongqing and 15 regions in Sichuan Province. The 27 regions in Chongqing are Yuzhong, Dadukou, Jiangbei, Shapingba, Juulongpo, Nanan, Beibei, Yubei, Banan, Wanzhou, Fuling, Qijiang, Dazu, Qianjiang, Changshou, Jiangjin, Hechuan, Yongchuan, Nanchuan, Bishan, Tongliang, Tongnan, Rongcheng, Liangping, Fengdu, Dianjiang and Zhongxian. The 15 regions in Sichuan Province are Chengdu, Zigong, Luzhou, Deyang, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guang’an, Dazhou, Ya’an and Ziyang.

Indicators

Health resources include indicators such as physical resources for health, human resources for health and financial resources for health, where physical resources for health mainly refer to the number of institutions, number of beds and other health facilities. Human resources for health are the most dynamic resource, including human resources such as health technicians, licensed (assistant) physicians and registered nurses, while financial resources for health mainly refer to health expenditure. Based on the principles of scientificity and feasibility, and combined with the evaluation indicators commonly used in related studies,17 five evaluation indicators were selected as the evaluation indicators for this study, where the number of beds represents the physical resources for health; the health technicians, practising (assistant) physicians and registered nurses represent the human resources for health; and financial allocations represent financial resources for health. The five evaluation indicators are all positive indicators, namely the number of beds per 1000 population, health technicians per 1000 population, licensed (assistant) physicians per 1000 population, registered nurses per 1000 population and financial allocations per 1000 population.

Research methods

The entropy weight method was used to calculate the weights of each evaluation index. The TOPSIS method was used to calculate the C-value of the relative closeness of each evaluation index value to the optimal solution. The C-value was combined with the RSR method to calculate the results, and finally the calculated results were graded. (Due to space limitations, detailed steps and formulas for the analytical methods are presented in online supplemental appendix 1.)

Entropy weight–TOPSIS method

Entropy weight–TOPSIS method is a combined entropy weight method and the TOPSIS method, which is basically an improvement of the TOPSIS method.18 The steps of the calculation are the following: first, calculate the weight of evaluation indexes by using the entropy
weight method; second, calculate the relative proximity C-value of evaluation indexes to the optimal solution by combining the TOPSIS method; and finally, calculate the ranking of each evaluation index by ranking the C-value. The larger the C-value, the better the health resource allocation of the region.\textsuperscript{19}

**RSR method**
The RSR method is a comprehensive evaluation method that constructs an n×m matrix, converts the evaluation indexes into rank to obtain the RSR value of dimensionless statistics, and ranks and grades the evaluation indexes based on the RSR value.\textsuperscript{20} The steps of the calculation are the following: first, rank the RSR values from smallest to largest by C-value instead and calculate the downward cumulative frequency p value, and then convert the probability p value to probit value by referring to the ‘Comparison Table of Percentages and Probability Units’. Second, using the probit value as the independent variable and the C-value as the dependent variable, the regression equation, \( Y = a + b \text{probit} \), was established. Finally, the RSR was graded according to the best RSR grading method and the grading table.\textsuperscript{21}

**Statistical analysis**
Excel V.2010 was used for data entry and management, and SPSS V.22.0 was used for statistical analysis, including the construction of regression equations and tests, with a test level of \( \alpha = 0.05 \).

**Patient and public involvement**
None.

**RESULTS**

**Health resource allocation per 1000 population**
The number of beds, health technicians, licensed (assistant) physicians, registered nurses and financial allocations per 1000 population in the Chengdu-Chongqing economic circle increased from 6.84 beds, 6.55 people, 2.40 people, 2.87 people and ¥334 700 in 2017 to 7.77 beds, 8.02 people, 3.01 people, 3.71 people and ¥537 200 in 2021. In 2021, the number of beds, health technicians, registered nurses and financial allocations per 1000 population in the Chengdu-Chongqing economic circle was higher than the average in China, while the number of licensed (assistant) physicians per 1000 population was lower than the average in China. In 2021, the health resources per 1000 population were mainly concentrated in Yuzhong and Jiangbei in Chongqing and Zigong and Ya’an in Sichuan Province, while those of Tongnan and Yubei in Chongqing and Guangan and Dazhou in Sichuan Province were relatively insufficient, with more than half of the regions having a lower level of health resource allocation per 1000 population than the average level of the Chengdu-Chongqing economic circle. (Due to space limitations, health resource allocation per 1000 population in Chengdu-Chongqing economic circle is presented in online supplemental table 1.)

**Weights of health resource allocation indicators**
Using the entropy weight method for each evaluation indicator, compared with 2017, the weight of the number of beds, licensed (assistant) physicians and financial allocations per 1000 population decreased and the weight of health technicians and registered nurses per 1000 population increased in 2021 (table 1).

**C-value and ranking of comprehensive evaluation by the entropy weight–TOPSIS method**
The health allocation of the Chengdu-Chongqing economic circle from 2017 to 2021 was evaluated by the entropy-weighted TOPSIS method. Yuzhong in Chongqing had the largest C-value and the highest ranking from 2017 to 2021. Jiangbei in Chongqing and Chengdu and Ya’an in Sichuan Province had higher C-values from 2017 to 2021 and were all ranked in the top 10. Jiangjin, Hechuan, Tongnan and Zhongxian in Chongqing and Guangan in Sichuan Province had lower C-values from 2017 to 2021 and were all ranked after the 30th. (Due to space limitations, the C-values and ranking of comprehensive evaluation by the entropy weight–TOPSIS method are presented in online supplemental table 2.)

**Frequency distribution and probability values by the RSR method for health resources**
The C-value of health resource allocation in the Chengdu-Chongqing economic circle from 2017 to 2021 was used instead of the RSR value sorted from smallest to largest, and the number of times, cumulative number of times, average rank and downward cumulative frequency p values were calculated, and the last term of the p value was corrected with \((1−1/4n×100\%)\). Then the p value was converted to the probit value by referring to the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Weights of health resource allocation indicators in Chengdu-Chongqing economic circle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicators</td>
<td>2017</td>
</tr>
<tr>
<td>Number of beds per 1000 population</td>
<td>12.56</td>
</tr>
<tr>
<td>Health technicians per 1000 population</td>
<td>20.76</td>
</tr>
<tr>
<td>Licensed (assistant) physicians per 1000 population</td>
<td>16.39</td>
</tr>
<tr>
<td>Registered nurses per 1000 population</td>
<td>20.11</td>
</tr>
<tr>
<td>Financial allocations per 1000 population</td>
<td>30.19</td>
</tr>
</tbody>
</table>
‘Comparison Table of Percentages and Probability Units’. Using the probit value as the independent variable and the C-value as the dependent variable, the regression equation was obtained as \( Y = -0.346 + 0.093 \text{probit} \), with \( R^2 = 0.405 \), \( F = 27.227 \) and \( p < 0.001 \), and this regression equation was statistically significant (table 2).

Table 2 Frequency distribution and probability values by the rank sum ratio method for health resources in Chengdu-Chongqing economic circle

<table>
<thead>
<tr>
<th>Regions</th>
<th>C-value</th>
<th>Number of times</th>
<th>Cumulative number of times</th>
<th>Average rank</th>
<th>Downward cumulative frequency (%)</th>
<th>Probit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tongnan</td>
<td>0.039 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2.4</td>
<td>3.022 6</td>
</tr>
<tr>
<td>Yubei</td>
<td>0.043 5</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4.8</td>
<td>3.335 4</td>
</tr>
<tr>
<td>Dazhou</td>
<td>0.051 1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>7.1</td>
<td>3.531 6</td>
</tr>
<tr>
<td>Jiangjin</td>
<td>0.051 8</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>9.5</td>
<td>3.689 4</td>
</tr>
<tr>
<td>Guang’an</td>
<td>0.053 2</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>11.9</td>
<td>3.820 0</td>
</tr>
<tr>
<td>Dazu</td>
<td>0.053 6</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>14.3</td>
<td>3.933 1</td>
</tr>
<tr>
<td>Hechuan</td>
<td>0.054 4</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td>16.7</td>
<td>4.033 9</td>
</tr>
<tr>
<td>Nanan</td>
<td>0.143 6</td>
<td>1</td>
<td>35</td>
<td>35</td>
<td>83.3</td>
<td>5.966 1</td>
</tr>
<tr>
<td>Jiulongpo</td>
<td>0.150 7</td>
<td>1</td>
<td>36</td>
<td>36</td>
<td>85.7</td>
<td>6.066 9</td>
</tr>
<tr>
<td>Chengdu</td>
<td>0.159 9</td>
<td>1</td>
<td>37</td>
<td>37</td>
<td>88.1</td>
<td>6.180 0</td>
</tr>
<tr>
<td>Ya’an</td>
<td>0.160 9</td>
<td>1</td>
<td>38</td>
<td>38</td>
<td>90.5</td>
<td>6.310 6</td>
</tr>
<tr>
<td>Shapingba</td>
<td>0.168 9</td>
<td>1</td>
<td>39</td>
<td>39</td>
<td>92.9</td>
<td>6.458 4</td>
</tr>
<tr>
<td>Nanchuan</td>
<td>0.203 9</td>
<td>1</td>
<td>40</td>
<td>40</td>
<td>95.2</td>
<td>6.664 6</td>
</tr>
<tr>
<td>Jiangbei</td>
<td>0.263 3</td>
<td>1</td>
<td>41</td>
<td>41</td>
<td>97.6</td>
<td>6.977 4</td>
</tr>
<tr>
<td>Yuzhong</td>
<td>0.999 0</td>
<td>1</td>
<td>42</td>
<td>42</td>
<td>99.4</td>
<td>7.512 1</td>
</tr>
</tbody>
</table>

Table 3 Grade results by the rank sum ratio method for health resources in Chengdu-Chongqing economic circle

<table>
<thead>
<tr>
<th>Grades</th>
<th>Cumulative frequency (%)</th>
<th>Probit</th>
<th>Grading results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>&lt;15.866</td>
<td>&lt;4</td>
<td>Tongnan, Yubei, Dazhou, Jiangjin, Guang’an and Dazu</td>
</tr>
<tr>
<td>Medium</td>
<td>15.866–84.134</td>
<td>4–6</td>
<td>Hechuan, Qijiang, Zhongxian, Fuling, Liangping, Meishan, Fengdu, Bishan, Nanchong, Beibei, Yongchuan, Suining, Ziyang, Neijiang, Deyang, Rongchang, Yibin, Banan, Tongliang, Leshan, Changshou, Mianyang, Wanzhou, Dianjiang, Luzhou, Qianjiang, Dadukou, Zigong and Nanan</td>
</tr>
<tr>
<td>Good</td>
<td>&gt;84.134</td>
<td>&gt;6</td>
<td>Jiulongpo, Chengdu, Ya’an, Shapingba, Nanchong, Jiangbei and Yuzhong</td>
</tr>
</tbody>
</table>

**DISCUSSION**

From 2017 to 2021, benefiting from socioeconomic development and health policy emphasis, the Chengdu-Chongqing economic circle has seen a gradual increase in health resource allocation per 1000 population.\(^2\) The number of licensed (assistant) physicians per 1000 population was lower than the average level in China, indicating that there was a shortage in the number of licensed (assistant) physicians in the Chengdu-Chongqing economic circle. We believe there were three reasons for this. First, the Chengdu-Chongqing economic circle was located in the western region of China, and the historical foundation of healthcare was weak, the development of licensed (assistant) physicians was relatively slow and the level of licensed (assistant) physician allocation had a large gap with the average level in China. Second, there is insufficient training of licensed (assistant) physicians and insufficient numbers of specialised categories in medical schools. Third, the loss of licensed (assistant)
physicians was more obvious; the long working hours of licensed (assistant) physicians, work intensity, poor practice environment and other factors resulted in the loss of licensed (assistant) physicians to other industries. Therefore, the Chengdu-Chongqing economic circle should further strengthen the introduction and training of licensed (assistant) physicians, improve the practice environment of licensed (assistant) physicians, and improve the training of treatment skills to improve the medical service ability of licensed (assistant) physicians.

More than half of the 42 regions in the Chengdu-Chongqing economic circle had a health resource allocation level per 1000 population lower than the average level of the Chengdu-Chongqing economic circle, indicating an unbalanced health resource allocation within the Chengdu-Chongqing economic circle. In 2021, the number of beds, health technicians, licensed (assistant) physicians, registered nurses and financial allocations in Yuzhong, which had the best health resource allocation per 1000 population, reached 27.25 beds, 40.08 people, 12.84 people, 20.42 people and ¥4 810 500, respectively, while the number of beds, health technicians, licensed (assistant) physicians, registered nurses and financial allocations per 1000 population in Yubei in the same period was 3.23 beds, 4.88 people, 1.96 people, 22.6 people and ¥388 100, respectively. The difference in health resource allocation between these two regions was more than six times, indicating a more serious imbalance of health resources within the Chengdu-Chongqing economic circle. The unbalanced distribution of health resources has made it difficult for the people to enjoy equitable and accessible medical and health services, especially in remote and poor areas, where medical and health service coverage was even more inadequate. Therefore, it is necessary to strengthen the construction of basic health service system, supplement medical and health personnel in areas with insufficient health resources, and gradually narrow the gap in the allocation of health resources within the region.

The regional differences in health resource allocation in the Chengdu-Chongqing economic circle were more obvious, with better health resource allocation in Yuzhong and Jiangbei in Chongqing and Chengdu and Ya’an in Sichuan Province, and worse health resource allocation in Jiangjin and Tongnan in Chongqing and Guanzhong and Dazhou in Sichuan Province. We believe there are three reasons for this. First, the allocation of health resources is related to the level of regional economic development. Regions with higher levels of economic development have richer financial resources, which can be better invested in health construction, thus promoting the growth of health resources in these regions. This is consistent with the findings of the study that medical resource allocation in the Yangtze River Economic Belt is concentrated in the better economic areas. Second, the central urban areas where health resources are better allocated and the concentration of population in these regions bring a large demand for healthcare services, thus stimulating the growth of health resources. Third, there are many medical and health institutions in the central urban areas, which have the advantages of more room for development and better remuneration levels, thus attracting a large number of health resources. Consistent with the overall situation of health resource allocation in the western region, there is a constant loss of health resources in remote and poor areas, further increasing the gap in health resource allocation. Therefore, it is necessary to fully play the leading role of the administration in the allocation of health resources, to improve the quality and efficiency of medical services in regions with better allocation of health resources and to increase the investment in regions with poorer allocation of health resources to continuously reduce the regional disparity in the allocation of health resources.

There are five regions in Chongqing with good health resource allocation and four regions with poor health resource allocation, all of which account for the majority of the percentage, indicating that the polarisation of health resource allocation in Chongqing is more serious. This is consistent with the findings that there are significant regional and urban–rural differences in the accessibility of medical resources in Chongqing. The central urban area of Chongqing has a high level of economic development, a high population density and a better allocation of health resources. The central urban area of Chongqing has more medical schools and more large hospitals, which attract a lot of medical and healthcare talents. The other areas of Chongqing have lower levels of economic development and poorer levels of health development relative to the central urban areas, resulting in a more serious inadequate allocation of health resources. Therefore, Chongqing should focus on the balanced allocation of health resources and further improve the level of allocation in regions with poor health resource allocation. It should strengthen counterpart support from health resource-rich areas to weaker areas and promote the coordinated regional development of health resources.

There are two regions with good resource allocation and two regions with poor health resource allocation in Sichuan Province, and the vast majority of the regions are in the medium grade, indicating that the health resource allocation in Sichuan Province is more balanced, but the advantaged regions are not prominent enough. Chengdu has a relatively good allocation of health resources in the Chengdu-Chongqing economic circle, but it does not have the advantage of health resource allocation within Sichuan Province. Health resources in Sichuan Province are mainly concentrated in the eastern regions, and most of these regions are within the scope of the Chengdu-Chongqing economic circle. The western part of Sichuan Province, where the level of health resource allocation is poor, is not part of the Chengdu-Chongqing economic circle, and the difference of health resource allocation in Sichuan Province in the Chengdu-Chongqing economic circle is not obvious. There are problems of unscientific...
allocation of health resources, inefficient allocation of health resources and significant regional differences in Sichuan Province, which affect the balance of health resource allocation. Therefore, Sichuan Province should strengthen the expansion and development of high-quality medical resources, further improve the allocation level of high-quality medical resources and actively play a leading role in high-quality medical resources on the basis of balanced allocation of health resources in the Chengdu-Chongqing economic circle.

Limitations
Although we used the entropy weight–TOPSIS method and the RSR method to comprehensively evaluate the health resource allocation in the Chengdu-Chongqing economic circle from 2017 to 2021, there are still some limitations to this study. First, the evaluation indexes were selected based on the evaluation indexes commonly used in similar studies. Second, the Chengdu-Chongqing economic circle is a major regional strategy along with Beijing-Tianjin-Hebei, Yangtze River Delta and Guangdong-Hong Kong-Macao Greater Bay Area, so we can make a horizontal comparative study, but this study does not. Third, this study mainly analyses from the perspective of health resource allocation, without considering the aspect of health resource allocation efficiency.

CONCLUSION
In order to promote the coordinated regional development of health resources in the Chengdu-Chongqing economic circle, this study collected the number of beds, health technicians, licensed (assistant) physicians, registered nurses and financial allocations per 1000 population in 42 regions in the Chengdu-Chongqing economic circle from 2017 to 2021 and used the entropy weight–TOPSIS method and the RSR method to comprehensively evaluate the allocation of health resources. The study found there is a shortage of licensed (assistant) physicians per 1000 population and there are greater regional differences in the allocation of health resources in the Chengdu-Chongqing economic circle. The health resource allocation in Chongqing was more polarised, and the health resource allocation in Sichuan Province was more balanced, but the advantaged regions were not prominent enough. We suggest that the Chengdu-Chongqing economic circle should increase the training of licensed (assistant) physicians and further improve the balance of health resource allocation. Chongqing should focus on the balanced allocation of health resources, and Sichuan Province should strengthen the expansion of high-quality medical resources. Through the comprehensive evaluation of health resource allocation in the Chengdu-Chongqing economic circle, it helps the administration to pay attention to the health resource allocation in major strategic regions and further promote the regional coordinated development of health resources in the Chengdu-Chongqing economic circle.

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