



# BMJ Open Equity of health resource allocation in Chongqing, China, in 2021: a cross-sectional study

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## ABSTRACT

**Background** Chongqing, the most populous city in Southwest China. This study aims to examine the equity of health resource allocation in Chongqing using the latest statistics, analyse possible shortcomings and propose strategies to address these issues.

**Methods** This cross-sectional study used healthcare resource, population, area and gross domestic product data from the Seventh National Census Bulletin of Chongqing, the National County Statistical Yearbook, the Chongqing Municipal Bureau of Statistics and the Chongqing Health Statistical Yearbook 2022. We also studied the equity of health resource allocation in Chongqing by using the Gini coefficient, Lorenz curve and Theil index, and used the Analytical Hierarchy Process and Technique for Order of Preference by Similarity to Ideal Solution (AHP–TOPSIS) method to comprehensively evaluate the health resources in the four major regions of Chongqing.

**Results** The Gini coefficient of health resources in Chongqing in 2021 was the highest when allocated according to geographical area, between 0.4285 and 0.6081, both of which exceeded 0.4, and the Gini coefficient of medical equipment was the highest and exceeded 0.6. The inter-regional Theil index of each resource was greater than the intraregional Theil index, and the contribution of inter-regional differences ranged from 64.83% to 80.21%. The results of the AHP–TOPSIS method showed that the relative proximity between health resources and ideal solutions in four regions of Chongqing ranged from 0.0753 to 0.9277.

**Conclusion** The allocation of health resources in Chongqing exhibits pronounced inequities, particularly in the distribution of medical equipment according to geographical area. Moreover, there exists a substantial gap in the equity of health resource allocation among the four regions of Chongqing. As such, this study emphasises the need for Chongqing, China, to prioritise the equitable allocation of health resources and increase consideration of geographic factors. Implementing measures to promote equitable allocation of health resources, particularly in geographic terms, is critical.

## INTRODUCTION

As China continues to relax its COVID-19 prevention and control policies, people's production and life gradually recovered, leading to an increased demand for medical

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Few studies have focused on the distribution of health resources in mountainous cities, making the findings of the present study valuable.
- ⇒ This study emphasises the need to consider the distribution of resources based on geographic units in addition to per 1000 residents.
- ⇒ Future research will be conducted on the distribution of health resources and inequity in health resource allocation in Chongqing over the past 5 years to provide valuable policy recommendations for China and other countries.
- ⇒ The measurement of inequity in this study does not take into account the actual population health status and health resource needs in each region of Chongqing.

treatment. During this particular time, ensuring equitable access to health resources is critical. Health resources, including human, material and financial resources, are not only the foundation for maintaining people's health, but also an objective response from the state and society to healthcare services. They are also a vital indicator used to measure the health status of a country or region.<sup>1 2</sup> However, equity is not the same as equality. Health equity means that everyone should have a fair chance to realise their full health potential, and the concept of health equity focuses on the distribution of health resources and other processes that contribute to certain health inequities, requiring that there be no systematic differences in health between advantaged and disadvantaged social groups.<sup>3 4</sup> The allocation of health resources directly affects the demand and utilisation of health services due to their scarcity.<sup>5–7</sup> Therefore, allocating health resources in a fair and reasonable manner is necessary to maximise their effectiveness and promote more equitable protection of people's health.<sup>8</sup> As such, studying the equity of health resource allocation is crucial, as it is the key to achieving health equity.<sup>9</sup>

In recent years, with the development of the social economy, an ageing population, and the increasing health literacy of people, concerns about the equity of medical and health resource allocation have grown.<sup>10–12</sup> In 2016, the Chinese government issued the Outline of the Healthy China 2030 Plan, which emphasised that the construction of a Healthy China should follow the principle of equity and aim to narrow the gaps in basic health services and health levels between urban and rural areas, regions and populations, comprehensively improving people's health.<sup>13</sup> The plan aims to promote social fair and orderly development. China has been increasing its investment in medical and healthcare, expanding medical insurance coverage and improving the health of the people.<sup>14</sup> However, studies indicate that due to population, geographic, economic and other factors, the development of China's eastern, western and central regions is unbalanced, resulting in the unfair distribution of medical and health resources.<sup>15 16</sup>

Chongqing, situated in the western region of China, is one of the four major municipalities with 38 districts or counties including Yuzhong, Yubei, Wanzhou and Shapingba. Chongqing is the most populous city in China, with a complex terrain dominated by mountains and hills, of which mountainous areas account for 76% and transportation is difficult. The economy has fallen behind, and the development of the city is uneven.<sup>17 18</sup> These factors have made Chongqing a unique city in China. According to the seventh census of China, the population of Chongqing is 32.054 million, making it the largest city in the country.<sup>19</sup> In 2021, Chongqing's total gross domestic product (GDP) reached ¥2789.402 billion, ranking fifth among all cities in China, while its per capita GDP was only ¥86 900, ranking 84th among all cities in China.<sup>20</sup> Therefore, research on the allocation of healthcare resources in Chongqing has great research value and significance.

Given its status as a megacity, it is critical to assess the equity of health resources in Chongqing. The Chongqing Municipal Government has issued a plan for the medical and health service system during the 14th Five-Year Plan (2021–2025), which has strong significance as it is the first year of the plan. However, there have been insufficient studies on the equity of healthcare resource allocation in Chongqing in recent years. Therefore, this study aims to describe the inequitable distribution of healthcare resources in Chongqing in 2021. This research provides a reference for improving people's health, promoting the development of Chongqing's medical industry, and better implementing the 14th Five-Year Plan. Previous studies in China have focused on health resource equity in a number of large cities, including Chongqing, but have not focused on geographic factors. This study uses newer data and more methods to analyse health resource equity in Chongqing and contributes to the study of health resources in mountainous cities.

## METHODS

### Data resources and region division

Data for this study were collected from various sources. Population data are from the Seventh National Census Bulletin of Chongqing, area data are from the National County Statistical Yearbook, GDP data are from the Chongqing Municipal Bureau of Statistics and healthcare resources data are from the Chongqing Health Statistical Yearbook 2022.

Chongqing, as a municipality in western China, consists of 38 administrative districts and counties, as well as 3 economic and technological development zones. Due to differences in statistical standards, this study incorporated the data from the 3 economic and technological development zones into the 38 administrative districts and counties. These 38 administrative districts and counties were then divided into 4 regions based on their geographic location: Chongqing main urban district, West Chongqing, Northeast Chongqing and Southeast Chongqing.

The regional division of Chongqing is shown in online supplemental figure 1. The Chongqing main urban district includes nine districts, namely Yubei, Jiulongpo, Shapingba, Nan'an, Ba'nian, Jiangbei, Beibei, Yuzhong and Dadukou. West Chongqing includes 12 districts, namely Jiangjin, Hechuan, Yongchuan, Fuling, Qijiang, Dazu, Bishan, Changshou, Tongnan, Tongliang, Rongchang and Nanchuan. Northeast Chongqing includes 11 districts or counties, namely Wanzhou, Kaizhou, Yunyang, Fengjie, Zhongxian, Dianjiang, Liangping, Fengdu, Wushan, Wuxi and Chengkou. Southeast Chongqing includes six districts or counties, namely Youyang, Pengshui, Xiushan, Qianjiang, Shizhu and Wulong. The three economic and technological development zones, namely Liangjiang New District, High-tech Zone and Wansheng Economic Development Zone, are merged into Yubei District, Shapingba District and Qijiang District, respectively.

### Indicators and measurement tools

Previous studies have evaluated the equity of health resources using different combinations of indicators related to human, material and financial resources.<sup>21–23</sup> In this study, we selected six indicators based on previous research, including the number of medical institutions, the number of health technicians (including licensed physicians, licensed assistant physicians, registered nurses, pharmacists, testing and imaging technicians, health supervisors and related trainees), the number of practicing (assistant) physicians, the number of registered nurses, the number of hospital beds and the number of medical equipment valued at over ¥10 000.

### Gini coefficient and Lorenz curve

The Gini coefficient and Lorenz curve are commonly used tools in public health research to evaluate the equity of health resource allocation, although they were

originally developed in economics to measure income distribution.<sup>24,25</sup>

The Gini coefficient (G) is calculated as the ratio of the area between the Lorenz curve and the line of perfect equity to the area below the line of perfect equity. The value of G ranges from 0 to 1, where 0 indicates perfect equity and 1 represents complete inequality. A Gini coefficient of 0.4 is considered the 'warning line' for disparities in health resource distribution, with a coefficient less than 0.2 indicating absolute equity, between 0.2 and 0.3 indicating relatively even distribution, between 0.3 and 0.4 indicating basically reasonable distribution and between 0.4 and 0.5 indicating a large gap in distribution. A Gini coefficient above 0.5 indicates a wide gap in distribution.<sup>26</sup> The formula for the Gini coefficient is as follows:

$$G = 1 - \sum_{i=1}^n (X_i - X_{i-1}) (Y_i + Y_{i-1})$$

$Y_i$  is the cumulative percentage of health resources (eg, number of institutions, number of health technicians, etc) in the  $i$ th district;  $X_i$  is the cumulative percentage of population or geography in the  $i$ th district;  $n$  is the total number of districts; and  $G$  is the value of the Gini coefficient.

On the Lorenz curve, the x-axis represents the cumulative percentage of population or geography, while the y-axis represents the cumulative percentage of health resources (number of medical institutions, number of health technicians, number of practicing (assistant) physicians, number of registered nurses, number of hospital beds and number of medical equipment over ¥10000). The degree of curvature of the Lorenz curve can reflect the level of equity, with smaller curvature indicating more equitable resource allocation and larger curvature indicating more inequitable resource allocation. The 45° line on the Lorenz curve represents the absolute equity curve.<sup>27</sup>

### Theil index

The Theil index is a widely used measure for assessing equity in the distribution of social resources, originally developed for income evaluation and now commonly employed in the health sector to measure equity in the allocation of health resources. This index enables the evaluation of both intraregional and inter-regional disparities, and thus provides a comprehensive picture of overall inequality in resource distribution.<sup>28</sup> The Theil index formula yields values between 0 and 1, with values closer to 0 indicating better equity, while higher values indicate greater inequity.

$$T = \sum_{i=1}^n P_i \log \frac{P_i}{E_i}$$

In the above formula,  $T$  represents the value of the total Theil index,  $P_i$  denotes the percentage of the population or geographic area or GDP in each district or county of Chongqing,  $E_i$  indicates the percentage of health resources in various districts and counties of Chongqing

and  $T$  can also be further decomposed into  $T_{intra}$  and  $T_{inter}$ .<sup>29</sup> The further decomposition process is shown in the online supplemental data 1.

### Analytical Hierarchy Process and Technique for Order of Preference by Similarity to Ideal Solution (AHP–TOPSIS)

The Analytical Hierarchy Process (AHP) is a widely used multicriteria decision-making method for the quantitative analysis of qualitative problems, originally proposed by Professor Saaty.<sup>30</sup> The AHP approach assists decision-makers in determining the weight of various indicators by employing pairwise comparisons. The steps for solving the problem using the AHP method are shown in online supplemental data 2 and table 1.<sup>31</sup>

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was developed by Hwang and Yoon, to solve multiple criteria decision-making problems.<sup>32</sup> The main concept is to first choose a positive ideal solution and a negative ideal solution, and then find the solution closest to the positive ideal solution and furthest from the negative ideal solution as the optimal solution. In TOPSIS, relative closeness is used as a way to balance the two distances and assess the outcome. The steps for solving the problem using the TOPSIS method are shown in online supplemental data 3.

In this study, we first used the AHP method to obtain the weights of each medical resource evaluation indicator by consulting with several experts in health management. Next, we applied the TOPSIS method to rank the quality of healthcare resources in Chongqing.

This study comprehensively uses the Gini coefficient, the Lorenz curve, the Theil index and AHP–TOPSIS to describe the equity of health resource allocation in Chongqing. The Gini coefficient and the Lorenz curve can reflect the overall equity of Chongqing's health resource allocation in different dimensions, but they cannot distinguish whether the inequity is intraregional or extraregional, so the combination of the Theil index can effectively remedy this problem. Meanwhile, the AHP–TOPSIS method can clearly show the ranking of health resource allocation in each region under certain weights.

## RESULTS

### Basic situation of health resource allocation in Chongqing in 2021

A descriptive analysis of the distribution data for health resources in Chongqing in 2021 is shown in online supplemental table 2A–C.

In terms of human resources, the number of health technicians in Chongqing is 246 615, of which Chongqing main urban district have the most with 104 552 (42.39%), while Southeast Chongqing has the least with only 17 849 (7.24%). The number of practicing (assistant) physicians in Chongqing is 92 131, of which 38 315 (41.59%) are the most in Chongqing main urban district, while only 6568 (7.13%) are the least in Southeast Chongqing. The



number of registered nurses in Chongqing is 114 011, of which the most in Chongqing main urban district is 50 934 (44.67%), while the least in Southeast Chongqing is only 7713 (6.77%).

In terms of material resources, the total number of medical institutions in Chongqing is 21 361, of which West Chongqing has the most with 6930 (32.44%) and Southeast Chongqing has the least with only 2168 (10.15%). The actual number of hospital beds in Chongqing is 240 741, of which the most in Chongqing main urban district is 78 497 (32.61%), while the least in Southeast Chongqing is only 22 497 (9.34%). Chongqing city, the number of medical equipment above ¥10 000 a total of 242 303, of which Chongqing main urban district has the most 102 816 (42.43%), while the least in Southeast Chongqing only 17 111 (7.06%).

In terms of financial resources, the total financial allocation income of medical institutions in Chongqing is ¥2 045 100 000, of which the most in Chongqing main urban district is ¥9 054 000 000 (44.27%), while the least in Southeast Chongqing is only ¥142 400 000 (6.96%).

When analysing the allocation of health resources in Chongqing by population distribution, the maximum number of institutions per 1000 people in Northeast Chongqing is 0.79, while the minimum number in Chongqing main urban district is only 0.57. The maximum number of hospital beds per 1000 people in Southeast Chongqing is 7.85, while the minimum number is 7.20 in West Chongqing. In addition, the number of health technicians per 1000 people, the number of licensed physicians per 1000 people, the number of registered nurses per 1000 people, the number of medical equipment over ¥10 000 per 1000 people and the financial allocation income per 1000 people for medical institutions were the highest in Chongqing main urban district (10.11, 3.70, 4.92, 9.94 and 87.53) and the lowest in Southeast Chongqing (6.23, 2.29, 2.69, 5.97 and 49.67).

When analysing the allocation of health resources in Chongqing by geographical area distribution, in general, Chongqing main urban district have the most health resources, West Chongqing is the second, Northeast Chongqing is the third and Southeast Chongqing is the least. The health resources in Chongqing main urban district are 3.63–7 times more than those in West Chongqing, 5.8–14.06 times more than those in Northeast Chongqing and 9.9–23.93 times more than those in Southeast Chongqing.

## Equity analysis of health resource allocation in Chongqing in 2021

### Analysis results of Gini coefficient and Lorenz curve

The results of our analysis are presented in [table 1](#), which displays the calculated Gini coefficients for the allocation of healthcare resources across different dimensions. Our findings indicate that the allocation of healthcare resources based on geographical area is the least equitable, while the allocation based on population or GDP dimensions is relatively more equitable.

Specifically, the population dimension yielded the lowest Gini coefficients for institutions, health technicians, practicing (assistant) physicians and hospital beds, with values of 0.1209, 0.1695, 0.1544 and 0.1443, respectively, indicating a higher degree of equity in resource allocation. On the other hand, the GDP dimension had the lowest Gini coefficients for registered nurses, medical equipment over ¥10 000 and financial allocations, with values of 0.1838, 0.2694 and 0.2659, respectively. In contrast, the geographic dimension had the highest Gini coefficients for institutions, health technicians, practicing (assistant) physicians, registered nurses, hospital beds, medical equipment over ¥10 000 and financial allocations, with values of 0.4285, 0.5689, 0.5673, 0.5955, 0.4742, 0.6081 and 0.5894, respectively. These values all exceeded 0.4, and some even exceeded 0.5, indicating a significant degree of inequity in the allocation of resources across geographic areas.

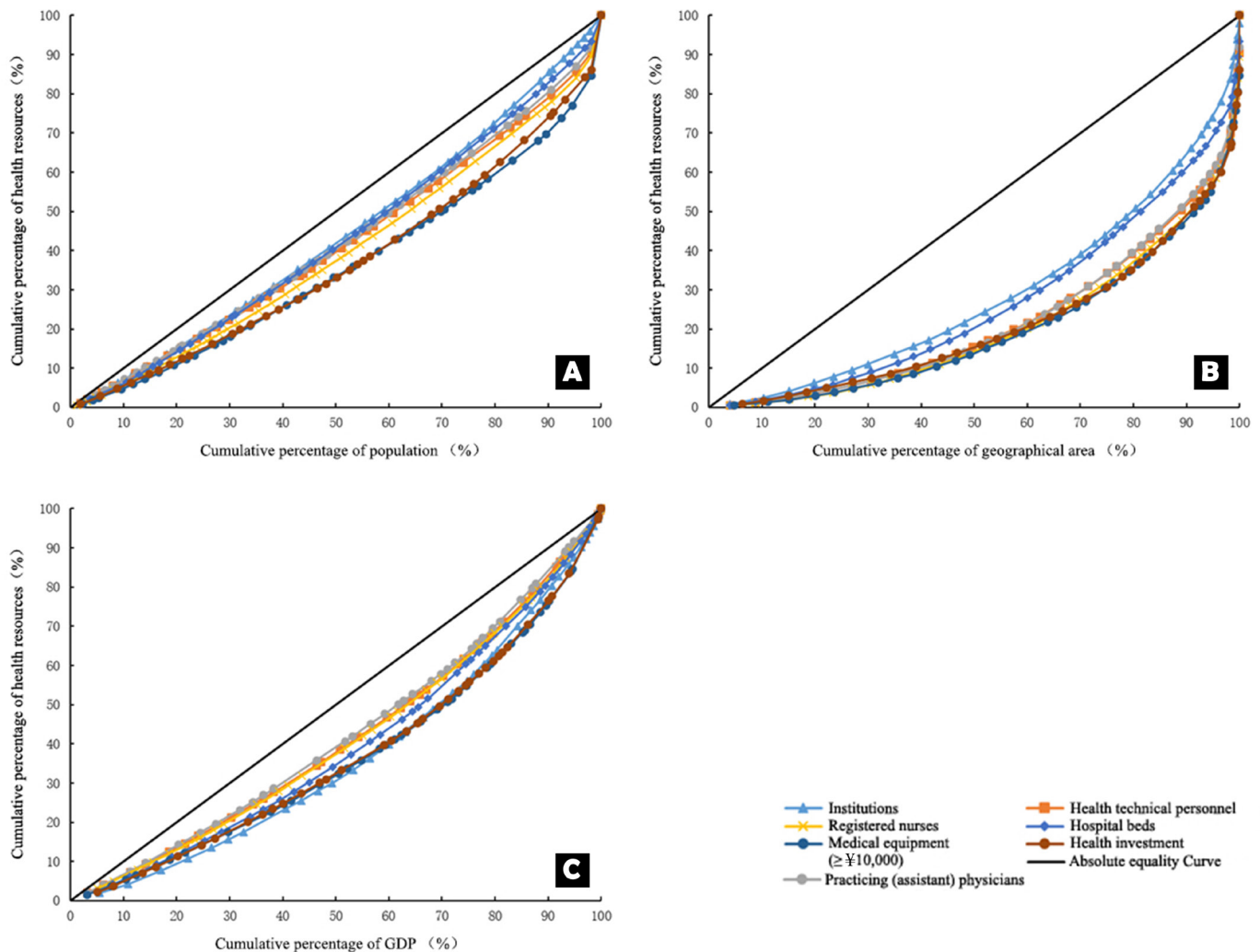
The results presented in [figure 1](#) demonstrate that health resource allocation in Chongqing according to the population or GDP dimensions is relatively equitable compared with the allocation based on the geographic dimension. The Lorenz curves for both the population and geographic dimensions indicate that the number of healthcare facilities in Chongqing is closer to the absolute equity line, while the number of medical equipment is farthest from the absolute equity line. However, it is noteworthy that both indicators exhibit better equity lines in the population dimension than in the geographic dimension. Similarly, the GDP dimension reveals that the number of practicing (assistant) physicians is closest to the absolute equity line, while the number of medical facilities is furthest from the absolute equity line.

In addition, the Gini coefficients for the practicing (assistant) physicians, registered nurses, medical equipment and health input indicators are all lower in the GDP

**Table 1** Gini coefficient of health resources allocation in Chongqing in 2021

Gini coefficient	Institutions	Health technical personnel	Practicing (assistant) physicians	Registered nurses	Hospital beds	Medical equipment*	Health investment
Allocation by population	0.1209	0.1695	0.1544	0.2054	0.1443	0.2843	0.2664
Allocation by geographical area	0.4285	0.5689	0.5673	0.5955	0.4742	0.6081	0.5894
Allocation by gross domestic product	0.2727	0.1749	0.1573	0.1838	0.2160	0.2694	0.2659

\*Number of medical equipment (≥ ¥10 000).



**Figure 1** Lorenz curve of health resources in Chongqing in 2021. (A) Allocation by population. (B) Allocation by geographical area. (C) Allocation by gross domestic product (GDP).

dimension than in the population and geographic area dimensions.

### Analysis results of Theil index

Table 2 presents the total Theil index, inter-regional and intraregional Theil indices and contribution rates for the three dimensions of population, geographic area and GDP. The analysis revealed that the total Theil index for each health resource in Chongqing in 2021 ranged from 0.0102 to 0.2943. The allocation of health resources according to geographic area resulted in the largest Theil's index and the worst equity for the number of medical institutions and the number of hospital beds, with  $T_{\text{geographic area}} > T_{\text{GDP}} > T_{\text{population}}$ . Conversely, for all other indicators, such as the number of health technicians, the number of practicing (assistant) physicians, the number of registered nurses, the number of medical equipment over ¥10000 and the financial allocation income, the order of the size of the total Theil index was  $T_{\text{geographic area}} > T_{\text{population}} > T_{\text{GDP}}$ , indicating greater equity in the allocation of health resources according to population or GDP dimensions.

It is worth noting that the Theil coefficients for the indicators of health technicians, practicing (assistant) physicians, registered nurses, medical equipment and health inputs are all lower in the GDP dimension than in the population and geographic area dimensions.

In terms of intraregional and inter-regional variation, the analysis found that for almost all indicators under the dimensions of population and GDP, the intraregional Theil index was greater than the inter-regional Theil index. Moreover, the contribution of intraregional variation was greater than that of inter-regional variation. Notably, for the number of hospital beds indicator, the intraregional variation contribution rate was 98.9% in the population dimension, indicating that the inequity in the allocation of hospital bed resources was largely due to intraregional variation.

According to the results of the study, the Theil index was used to measure the equity of health resource allocation in Chongqing, China. The analysis was performed based on two dimensions, namely, population and geographic area. The findings revealed that the inter-regional Theil

**Table 2** Theil Index of Chongqing health resources in 2021

Indicator	Dimension	T	T <sub>inter</sub>	T <sub>intra</sub>	Theil index by region			
					Chongqing main urban district	West Chongqing	Northeast Chongqing	Southeast Chongqing
Institutions	Population	0.0102	0.0035 (34.37)	0.0067 (65.63)	0.0212 (28.20)	0.0052 (6.96)	0.0180 (23.96)	0.0049 (6.52)
	Geographical area	0.1352	0.0900 (66.60)	0.0452 (33.40)	0.0412 (6.64)	0.0173 (2.80)	0.0585 (9.42)	0.0901 (14.53)
	GDP	0.0523	0.0290 (55.33)	0.0234 (44.67)	0.0588 (19.00)	0.0248 (8.02)	0.0400 (12.94)	0.0146 (4.71)
Health technical personnel	Population	0.0298	0.0095 (31.76)	0.0204 (68.24)	0.0382 (30.36)	0.0205 (16.25)	0.0190 (15.10)	0.0082 (6.53)
	Geographical area	0.2529	0.1865 (73.76)	0.0664 (26.24)	0.0535 (4.64)	0.0046 (0.40)	0.1191 (10.33)	0.1255 (10.88)
	GDP	0.0205	0.0078 (38.18)	0.0127 (61.82)	0.0134 (10.93)	0.0419 (34.09)	0.0142 (11.54)	0.0065 (5.25)
Practicing (assistant) physicians	Population	0.0241	0.0082 (33.84)	0.0160 (66.16)	0.0356 (29.68)	0.0178 (14.85)	0.0171 (14.28)	0.0088 (7.36)
	Geographical area	0.2513	0.1833 (72.92)	0.0681 (27.08)	0.0529 (4.73)	0.0068 (0.61)	0.1159 (10.37)	0.1271 (11.36)
	GDP	0.0168	0.0071 (42.31)	0.0097 (57.69)	0.0102 (8.30)	0.0389 (31.75)	0.0155 (12.67)	0.0061 (4.97)
Registered nurses	Population	0.0391	0.0143 (36.58)	0.0248 (63.42)	0.0456 (27.41)	0.0223 (13.42)	0.0267 (16.07)	0.0108 (6.52)
	Geographical area	0.2838	0.2062 (80.21)	0.0775 (19.79)	0.0550 (2.51)	0.0030 (1.03)	0.1317 (8.25)	0.1325 (8.00)
	GDP	0.0227	0.0080 (35.18)	0.0147 (64.82)	0.0223 (18.11)	0.0440 (35.65)	0.0088 (7.14)	0.0048 (3.92)
Hospital beds	Population	0.0192	0.0002 (1.10)	0.0190 (98.90)	0.0015 (11.86)	0.0062 (50.31)	0.0028 (22.91)	0.0017 (13.82)
	Geographical area	0.1782	0.1197 (67.16)	0.0585 (32.84)	0.0459 (6.16)	0.0165 (2.22)	0.0834 (11.19)	0.0988 (13.26)
	GDP	0.0314	0.0151 (48.00)	0.0163 (52.00)	0.0312 (16.38)	0.0259 (13.57)	0.0294 (15.43)	0.0126 (6.61)
Medical equipment	Population	0.0703	0.0098 (13.91)	0.0605 (86.09)	0.0384 (38.18)	0.0172 (17.10)	0.0218 (21.67)	0.0092 (9.14)
	Geographical area	0.2943	0.1908 (64.83)	0.1035 (35.17)	0.0535 (6.02)	0.0073 (0.83)	0.1236 (13.91)	0.1280 (14.41)
	GDP	0.0499	0.0065 (13.03)	0.0434 (86.97)	0.0136 (16.90)	0.0382 (47.53)	0.0123 (15.25)	0.0059 (7.29)
Health investment	Population	0.0592	0.0134 (22.59)	0.0459 (77.41)	0.0443 (33.63)	0.0331 (25.11)	0.0149 (11.30)	0.0097 (7.38)
	Geographical area	0.2686	0.1931 (71.90)	0.0755 (28.10)	0.0547 (5.08)	0.0060 (0.55)	0.1123 (10.43)	0.1295 (12.03)
	GDP	0.0493	0.0127 (25.65)	0.0367 (74.35)	0.0208 (15.55)	0.0561 (41.90)	0.0171 (12.76)	0.0055 (4.13)

The value in brackets is the contribution rate (%).

\*Number of medical equipment ( $\geq$  ¥10 000).

GDP, gross domestic product.

index was greater than the intraregional Theil index for all indicators under the geographic area dimension, and the contribution of inter-regional differences ranged from 64.83% to 80.21%. These results indicate that the degree of inequity in health resources in Chongqing is primarily due to inter-regional differences.

To gain a deeper understanding of the Theil index and contribution rate of health resource allocation in the four regions of Chongqing, the Theil index and contribution rate were calculated for Chongqing main urban district, West Chongqing, Southeast Chongqing and Northeast Chongqing. The study revealed that Chongqing main urban district had the best equity of all health resources allocated by geographic area, while the equity of health resources allocated by population, except for the number of hospital beds, was the worst. Similar to Chongqing main urban district, the equity of all health resources by geographic area in West Chongqing was the best, while the equity of all health resources, other than the number of hospital beds by GDP, was the worst. Additionally, the equity of all health resources by geographic area was the best in Northeast Chongqing, and the equity of all health resources by population, except for financial allocation income, was the worst. In contrast, the equity of almost

all health resources allocated by geographic area was the worst in Southeast Chongqing, while the equity of all health resources allocated by GDP was the best. The analysis of the overall contribution revealed that the intra-regional variation mainly came from West Chongqing and Chongqing main urban district, which had the largest contribution and were very close to each other.

### Analysis results of AHP–TOPSIS

Four experts in health management were invited to complete the pairwise comparison matrix of main indicators and sub-indicators using the AHP. The arithmetic means of expert judgement results and the consistency ratio (CR) of each matrix are presented in online supplemental table 3A–C. The CRs for all matrices were less than 0.1, indicating good consistency among the expert judgements. The weights of medical resource evaluation indicators and subindicators obtained through the AHP method are presented in table 3.

The results of the weighted TOPSIS method are presented in table 4. The relative closeness of medical resources to the ideal solution ( $S_i$ ) in each region of Chongqing was 0.9277, 0.0947, 0.1604 and 0.0753 for Chongqing main city, West Chongqing, Northeast

**Table 3** The weights of medical resources evaluation indicators obtained by the AHP method

Indicator	Indicator weights	Subindicator	Subindicator weights	Global weights
Human resources	0.197	Health technical personnel	0.094	0.018
		Practicing (assistant) physicians	0.279	0.055
		Registered nurses	0.627	0.123
Material resources	0.215	Institutions	0.147	0.032
		Hospital beds	0.457	0.098
		Medical equipment ( $\geq$ ¥10 000)	0.395	0.085
Financial resources	0.588	Health investment	1.000	0.589

AHP, Analytical Hierarchy Process.

Chongqing and Southeast Chongqing, respectively. Based on these results, the quality of medical resources in each region of Chongqing was ranked as follows: Chongqing main city had the highest quality, followed by Northeast Chongqing, West Chongqing and Southeast Chongqing had the lowest quality.

## DISCUSSION

This study investigates the allocation of health resources in Chongqing, China, analyses the equity of health resources in Chongqing using the Gini coefficient, Lorentz curve and Theil index and employs AHP–TOPSIS to comprehensively evaluate health resources in four regions of Chongqing.

The research findings reveal that the Gini coefficient of health resources allocated based on geographical dimension in Chongqing exceeds 0.4, significantly higher than that of population or GDP dimension. Additionally, the AHP–TOPSIS method calculates the  $S_i$  value of medical resources in each region of Chongqing, indicating significant regional disparities in health resource allocation. This further validates the results of the Gini coefficient and provides an order of the abundance of medical resources in each region of Chongqing. Specifically, health resources are abundant in the Chongqing main urban district and the West Chongqing, while they are scarce in the Southeast Chongqing and Northeast

Chongqing. This result is consistent with prior research by various scholars.<sup>2 22 33</sup> Several reasons may contribute to this phenomenon. First, government health resource planning is mainly based on the number of health resources per thousand or 10 000 people, rather than per 10 000 km<sup>2</sup>, reducing the equity of health resource allocation.<sup>34</sup> Second, Chongqing's numerous mountains and scattered areas make it prone to an uneven distribution of health resources based on geography.<sup>35</sup> Third, the level of economic development varies across Chongqing, with the main urban district having the most developed economy and the largest number of high-level hospitals, making it easier to form rich and high-quality health resources. In contrast, some districts and counties in Chongqing lack the conditions for high-level health resource allocation due to poor economic conditions.<sup>1</sup> These possible reasons may impede residents' fair access to health resources, hamper the improvement of the population's health status and decrease the equity of health resource allocation in Chongqing. Therefore, we suggest that in planning health resources, the geographical characteristics of different regions, such as changes in the age structure of the regional population and healthcare needs, should be taken into account, so as to equalise the distribution of health resources as much as possible. In addition, financial support for health resources should be appropriately tilted towards regions with weak health resources, and the allocation of health resources should be dynamically and scientifically regulated.

The results of this study show that the allocation of medical equipment above ¥10 000 based on geographical latitude in different regions of Chongqing is highly inequitable, with a Gini coefficient greater than 0.6. This inequitable distribution of medical equipment can have significant consequences, including increased medical treatment costs for patients in underserved areas, delayed diagnosis and treatment of diseases, reduced regional medical treatment capacity and lower health service quality.<sup>36</sup> Moreover, this inequitable allocation can lead to differences in regional mortality rates.<sup>37</sup> This phenomenon may be related to regional economic disparities and hospital development. High-level hospitals or hospitals in economically developed areas often receive

**Table 4** Evaluation and ranking of medical resources by region in Chongqing

Region	$D_i^+$	$D_i^-$	$S_i$	Rank
Chongqing main urban area	0.0213	0.2727	0.9277	1
West Chongqing	0.2547	0.0266	0.0947	3
Northeast Chongqing	0.2358	0.0450	0.1604	2
Southeast Chongqing	0.2726	0.0222	0.0753	4

$D_i^+$  Euclidean distance of the evaluation object from the positive ideal solutions.

$D_i^-$  Euclidean distance of the evaluation object from the negative ideal solutions.

$S_i$  the relative closeness to the ideal solution.

more economic support, enabling them to maintain a leading position in material conditions. Meanwhile, more patients will choose to go to these hospitals, which will also increase the hospital's income. Therefore, it is recommended that each region maintain equity in the necessary medical equipment and not blindly compare the number of medical equipment. Instead, consideration should be given to the actual medical needs of the population in each region to avoid waste such as low utilisation of medical equipment. In addition, it is recommended to strengthen attention to the supply and demand of medical equipment and establish a special fund to ensure the supply of medical equipment in areas with shortages.

In addition, the study finds that the Theil index is the highest when allocating health resources based on geographical area, indicating that the equity of allocating health resources based on this criterion is the lowest. The contribution rate of the Theil index is highest in Southeast Chongqing, followed by Northeast Chongqing. These regions have poor economic development, small and dispersed populations, and this situation may lead to the uneven distribution of health resources.<sup>1</sup> The problem of sparsely populated healthcare services often arises in rural or remote areas. It is suggested that in optimising the layout of medical institutions, rural or remote areas can shift from a centralised healthcare model to a distributed healthcare model. Human and material resources should be equipped according to the characteristics of the regional population and common diseases and illnesses, so as to avoid wasting limited medical resources.

It is also worth noting that in both the Gini coefficient and the Theil index, some human resources (such as health technicians, practicing (assistant) physicians, registered nurses), some material resources (such as medical equipment) and financial resources (health investment) show the best equity in the GDP dimension. This phenomenon of GDP equity being higher than population equity and geographic area equity is likely to be related to a variety of social factors. First, more and more medical personnel may prefer to work in economically developed regions or high-level hospitals for reasons of income and career development. Second, patients tend to choose to go to high-level hospitals for treatment, while fewer patients choose ordinary hospitals, resulting in a higher demand for both human and material resources in high-level hospitals, manifesting the Matthew effect, a phenomenon that will further aggravate the inequity in the distribution of medical resources. Therefore, it is recommended that patients should adhere to the principle of hierarchical diagnosis and treatment according to the needs of their own medical conditions, and choose appropriate medical institutions for consultation. At the same time, health planning should think positively about hospital functions and positioning, and gradually guide patients to hierarchical diagnosis and treatment from the perspective of top-level design, playing the function of the baton.

Although this study has revealed the existence of inequity in the allocation of healthcare resources in Chongqing, it is noteworthy that the Chongqing Municipal Government

has strengthened its attention to this issue. The fairness of healthcare resource allocation has been included in the 14th Five-Year Plan for Chongqing's healthcare service system. By 2025, Chongqing aims to achieve balanced allocation of high-quality healthcare resources, uniformity of basic medical and healthcare services, and equity of basic public health services, forming a high-quality medical and healthcare service cluster and continuously improving the radiation and influence of medical and healthcare services.<sup>38</sup> It is anticipated that in the near future, the allocation of healthcare resources in Chongqing will be more scientific and reasonable in terms of geography, economy and population, making it more accessible to the people.

This study has some limitations, such as the use of health resource data from only 1 year in Chongqing. Therefore, future studies should consider collecting data from multiple years to provide a longitudinal analysis of health resources changes. Additionally, the analysis of the equity of health resource allocation in Chongqing was mainly limited to three dimensions, population, geographic area, and GDP, without considering the actual population health status and health resource demand in each region of Chongqing.

## CONCLUSIONS

The findings of this study reveal that health resource allocation in Chongqing based on geographic area is the least equitable, with significant disparities among regions. While the Chongqing main urban district and West Chongqing have ample health resources, Southeast Chongqing and Northeast Chongqing have relatively scarce and unequal health resources. Moreover, the study shows that medical equipment allocation over ¥10000 is more inequitable than other health resources. Thus, it is recommended that the government prioritise the equity of health resource allocation, consider geographic factors and facilitate the transfer of high-quality health resources to areas with limited resources while fostering cooperation between medical institutions across regions. Additionally, increasing investment in medical equipment can enhance access to health resources. These measures can improve the quality of health services in Chongqing, minimise regional health resource disparities, and promote the scientific and equitable development of health resources in the region. However, future studies should collect data from multiple years to examine health resource changes over time and also consider the actual population health status and health resource demand in each region.

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