Analysis on equity of health human resource allocation in Hubei Province based on the Gini coefficient and a HRDI model

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Abstract. In order to fully understand the current situation of health human resources in Hubei Province, two mathematical models, Gini coefficient and health resource density index, were used to analyze the equity of health human resources in Hubei Province, and the Lorenz curve was drawn. After clarifying the distribution of four types of health technical personnel, the result showed that the fairness of distribution by population was better, and the fairness of distribution by geography area needed to be improved. It was suggested that policy makers should consider the geographical area as the factor of resource allocation, and encourage medical college graduates to work in less developed areas. Regions with rich health human resources and regions with less rich health human resources can promote the balance of health capacity through remote construction of medical consortium.

1. Introduction
Since the new health care reform in 2009, the state has issued a number of health care reform policies, striving to continuously improve the uneven distribution of medical and health resources in China, and improve the accessibility and fairness of medical services. The theme of the current healthy China strategy is "health for all, health for all"[1], the core of which is to achieve the equity and accessibility of health. The reasonable allocation of health resources is the basic guarantee to achieve health equity, and the equity of health resource allocation has always been the research hotspot of many scholars.

In 1994, Ding Hansheng and Hu Shanlian [2] used Gini coefficient and Lorentz curve to analyze the fairness of doctors, nurses and beds according to population distribution among provinces and cities in China. Then in 1996, Zheng Xiaohua proposed to use health resource density index to describe the basic situation of health resource allocation [3]. In the past 20 years, a large number of other scholars have used Lorenz curve and Gini number to analyze the equity of health resources [4-6].

However, the health resource density index can only describe the individual allocation, while the Lorenz curve and Gini coefficient can only describe the overall degree of fairness. Therefore, I decided to use two methods to comprehensively describe the health human resource allocation in Hubei Province in 2018, in order to provide a research basis for the rational planning of health resources for the country.

In order to describe health human resources accurately, four types of health technical personnel are selected, including licensed doctors, registered nurses, pharmacists and technicians. This paper mainly describes the equity of these four types of health human resources.
2. Data sources and methods

2.1. Date sources
In the data of this study, the specific quantity of all kinds of health human resources comes from the health statistical yearbook of Hubei Province in 2018. The population is the number of permanent residents in 2018, and the area is the area under the jurisdiction of each city. The data is from the statistical yearbook of each city.

It mainly studies the number and distribution of health technicians. Health technicians include licensed (assistant) doctors (hereinafter abbreviated as licensed doctors), registered nurses, pharmacists and technicians.

2.2. Analysis method
This paper makes a descriptive analysis of the allocation of four types of health technical personnel in 17 cities and prefectures of Hubei Province, and uses a mathematical model to calculate its fairness. Finally, excel is used to draw a chart to present the results.

2.2.1. Lorentz curve. Lorentz curve was proposed by the American statistician Lorentz in 1907. It was initially used in economics to describe the cumulative percentage of assets from the poorest population to the richest population. Originally used to measure a country's wealth gap, it is now widely used to compare the balance of various resource allocation.

In this paper, Lorentz curve is respectively drawn by the cumulative proportion of population and area corresponding to the cumulative proportion of various types of health human resources. From the perspective of population and area, this paper examines the fairness of four types of health professionals in Hubei Province in 2018. The flatter the radian of Lorentz curve is and the closer it is to the absolute average, the better the equilibrium is.

2.2.2. Gini coefficient. Gini coefficient is an index to judge the distribution uniformity proposed by herschmann according to Lorentz curve.

Generally speaking, the ratio value is between 0 and 1. When the Gini coefficient is less than 0.2, the distribution of social resources is very fair. When the Gini coefficient is between 0.2 and 0.4, it means that the allocation of resources is relatively fair. If it is higher than 0.4, it indicates that there is an uneven distribution of resources. Gini coefficient of 0.4 is the warning line of uneven distribution of resources [8]. The mathematical model used to calculate Gini coefficient is as follows:

\[ G = \sum_{i=1}^{n} PiYi + 2\sum_{i=1}^{n} Pi(1-Vi) - 1 \]  

(1)

Where: \( Pi \) is the proportion of the population (or geographical area) of each city and state in the population (or geographical area) of the whole province

\( Yi \) the proportion of health human resources in the whole province

\( Vi \) is the cumulative value of Yi sorted from low to high, \( VI = Y1 + Y2 + Y3 +... + Yi \)

Health resource density index (HRDI)

In 1996, Zheng Xiaohua, a scholar, proposed to use HRDI to evaluate the health resources in a certain area from the aspects of population and geography, and calculated the demand and lack of health resources in each area [3]. Health resource density index (HRDI) is an index used to measure the allocation of health human resources in population and geographical area. Its mathematical formula is as follows:

\[ HRDI = \sqrt{\frac{r}{s} * \frac{r}{n}} \]  

(2)

Where: HRDI is the density index of health resources

\( R \) is the number of health human resources
N is the population in thousands
S is the area in square kilometers

In this paper, we calculated the specific health resource density index of each city and state, and also calculated the overall health resource density index of Hubei Province as the standard value of health resource density index. When the health resource density index of a city is greater than the standard value of the health resource density index, it indicates that the health resource allocation level of the region is higher than the local average level [8].

3. Result

3.1. Basic situation of health human resource allocation in Hubei Province

According to the survey of various health human resources in Hubei Province in 2018, there are 346,472 health technicians in Hubei Province.

Among them, the number of licensed doctors was 126,559, accounting for 36.5%; the number of registered nurses was 180,812, accounting for 52.19%; the number of pharmacists was 18,659, accounting for 5.39%; the number of technicians was 20,442, accounting for 5.90%; the proportion of doctors, nurses, pharmacists and technicians was 6.78:9.69:1:1.10.

There are significant differences in the number of health human resources in different cities. The average number of health technicians per thousand people in Hubei Province is 5.83. Wuhan, Huangshi and Yichang were the top three cities with the largest number of health technicians per thousand people in Hubei Province, while Shiyan, Suizhou and Xiantao were the bottom three cities. The specific distribution is shown in Table 1.

Table 1. Distribution of health human resources in cities and prefectures of Hubei Province in 2018.

| City       | Permanent population (ten thousand people) | Area (km²) | Number of licensed doctors | Number of registered nurses | Number of pharmacists | Number of technicians | Subtotal of health technical personnel | Number of health technicians per thousand |
|------------|-------------------------------------------|------------|-----------------------------|------------------------------|-----------------------|----------------------|----------------------------------------|----------------------------------------|
| Wuhan      | 10892.9                                   | 8483       | 36861                       | 54434                        | 4683                  | 5406                 | 101384                                | 9.31                                   |
| Huangshi   | 2470.5                                    | 4576       | 5371                        | 9414                         | 991                   | 1046                 | 16822                                 | 6.81                                   |
| Yichang    | 4135.6                                    | 21081      | 9934                        | 14807                        | 1651                  | 1595                 | 27987                                 | 6.77                                   |
| Enshi      | 3361                                      | 24111      | 6548                        | 10938                        | 1058                  | 1031                 | 19575                                 | 5.82                                   |
| Xiangyang  | 2535.1                                    | 10019      | 5325                        | 7817                         | 776                   | 779                  | 14697                                 | 5.80                                   |
| Jingmen    | 2901.5                                    | 12100      | 5982                        | 8770                         | 688                   | 927                  | 16367                                 | 5.64                                   |
| Xiangyang  | 5654                                      | 19626      | 11200                       | 15887                        | 1336                  | 1778                 | 30201                                 | 5.34                                   |
| Qianjiang  | 966                                       | 2004       | 1836                        | 2624                         | 324                   | 322                  | 5106                                  | 5.29                                   |
| Ezhou      | 1076.9                                    | 1505       | 1891                        | 3063                         | 319                   | 277                  | 5550                                  | 5.15                                   |
| Shennongjia| 76.8                                      | 3253       | 109                         | 186                          | 38                    | 45                   | 378                                   | 4.92                                   |
| Jingzhou   | 5641.7                                    | 14104      | 9809                        | 13961                        | 1525                  | 1645                 | 26940                                 | 4.78                                   |
| Huanggang  | 6341                                      | 17453      | 9156                        | 14279                        | 1998                  | 1531                 | 26964                                 | 4.25                                   |
| Xiaogan    | 4915                                      | 8941       | 7047                        | 11222                        | 961                   | 1527                 | 20757                                 | 4.22                                   |
| Tianmen    | 1283.5                                    | 2622       | 2033                        | 2884                         | 215                   | 270                  | 5402                                  | 4.21                                   |
| Shiyan     | 3418                                      | 23698      | 8445                        | 3096                         | 1264                  | 1241                 | 14046                                 | 4.11                                   |
| Suizhou    | 2210.5                                    | 9636       | 3084                        | 4604                         | 577                   | 701                  | 8966                                  | 4.06                                   |
| Xiantao    | 1544.5                                    | 2538       | 1928                        | 2826                         | 255                   | 321                  | 5330                                  | 3.45                                   |
3.2. Lorenz curve analysis of health human resource allocation in Hubei Province

3.2.1. Analysis on the equity of population distribution of health human resources. According to the quantity of all kinds of health human resources in 17 cities of Hubei Province, the quantity of health human resources per thousand people in each city was calculated and ranked from small to large. Then the proportion of population and health resources in each city and state is calculated, and the cumulative proportion of population is taken as the abscissa, and the cumulative proportion of health resources is taken as the ordinate to simulate the state from poverty to wealth in economics [9]. The Lorentz curve of all kinds of health technical personnel by population distribution is drawn, as shown in Figure 1.

It can be seen that the Lorentz curve is close to the line of perfect equality, which indicates that the fairness of the distribution of the four types of health technical personnel by population is good, and the Lorentz curve of the technician is closest to the line of perfect equality, with the best fairness. The Lorentz curve of registered nurses is the farthest from the line of perfect equality, and the fairness is poor among the four categories.

![Figure 1. Lorentz curve of health human resources distribution by population in Hubei Province.](image)

3.2.2. Equity analysis of geographical distribution of health human resources. According to the quantity of all kinds of health human resources in 17 cities of Hubei Province, the quantity of health human resources per square kilometer in each city was calculated and ranked from small to large. Then calculate the area proportion and health resources proportion of each city and state, and then take the cumulative area proportion as the abscissa and the cumulative health resources proportion as the ordinate to simulate the state from poverty to wealth in economics.

The Lorentz curve of the area distribution of various health technical personnel is drawn, as shown in Figure 1.

It can be seen that the four Lorentz curves are far away from the line of perfect equality, indicating that the distribution of health human resources by geographical area is not well balanced. The Lorentz curve of licensed doctors, pharmacists and technicians is very close, indicating that the degree of equilibrium is consistent.
3.3. Gini coefficient analysis of health human resource allocation
After calculating the cumulative proportion of population and health human resources, the mathematical formula (1) in the analysis method was used to further calculate the values we need, so as to calculate the Gini coefficient of all kinds of health technical personnel in Hubei Province according to the population distribution. In the same way, after calculating the cumulative proportion of area, we also calculate the Gini coefficient of area distribution.

The Gini coefficients of all kinds of health human resources according to population distribution were: Licensed Doctors (g = 0.1722), registered nurses (g = 0.2003), pharmacists (g = 0.1504), technicians (g = 0.1363), which were consistent with the results of Lorentz curve. According to the evaluation of population distribution, the fairness of technician distribution is the best, followed by pharmacists and medical practitioners. The Gini coefficient of registered nurses is slightly greater than 0.2, and the fairness of registered nurses is relatively fair. Compared with the first three types of health human resources, the distribution fairness of registered nurses is slightly worse.

The Gini coefficients of different types of health human resources by area distribution were: Licensed doctors (g = 0.3935), registered nurses (g = 0.5007), pharmacists (g = 0.3727), technicians (g = 0.3890), which were consistent with the results of Lorenz curve. According to the area distribution, the distribution of pharmacists is the most fair, followed by technicians and practitioners. The distribution is relatively fair, close to the warning value. The Gini coefficient of registered nurses is far greater than 0.4, even more than 0.5, indicating that the registered nurses are in an unfair state by area distribution. It shows that the fairness of registered nurses needs to be improved. On the whole, the fairness of geographical area is far worse than that of population distribution. The specific Gini coefficient is shown in Figure 3.
3.4. Analysis of health human resource allocation density index (HRDI) in Hubei Province

Using the second mathematical model of the analysis method, we calculated the health human resource density index of 17 cities and prefectures in Hubei Province and the overall health human resource density index of Hubei Province. The results showed that the standard value of health human resource density index is 3.30. Wuhan, Huangshi, Ezhou and Qianjiang were the cities whose health human resource density index was higher than the standard density index, accounting for 23.5%, 76.5% of the cities and states were lower than the standard index, indicating that most of the health human resources were concentrated in a few developed cities.

Wuhan, Huangshi and Ezhou are the top three cities in health resource density, while Suizhou, Shiyan and Shennongjia are the bottom three cities in health resource density. The density of health human resources in Wuhan is 13.88 times of that in Shennongjia. The health human resources in Shennongjia are very scarce, which is far lower than the density of the first health human resources in Wuhan. It should be fully supplemented. See Table 2 for the specific density of health resources.

Table 2. Density index of health human resources in cities of Hubei Province

| City       | Permanent population (thousand) | Area (km2) | Health resource density index | Is it higher than the standard HRDI? |
|------------|---------------------------------|------------|-------------------------------|-------------------------------------|
| Wuhan      | 10892.9                         | 8483       | 10.55                         | Yes                                 |
| Huangshi   | 2470.5                          | 4576       | 5.00                          | Yes                                 |
| Shiyan     | 3418                            | 23698      | 1.56                          | No                                  |
| Yichang    | 4135.6                          | 21081      | 3.00                          | No                                  |
| Xiangyang  | 5654                            | 19626      | 2.87                          | No                                  |
| Ezhou      | 1076.9                          | 1505       | 4.36                          | Yes                                 |
| Jingmen    | 2901.5                          | 12100      | 2.76                          | No                                  |
| Xiaogang   | 4915                            | 8941       | 3.13                          | No                                  |
| Jingzhou   | 5641.7                          | 14104      | 3.02                          | No                                  |
| Huaggang   | 6341                            | 17453      | 2.56                          | No                                  |
| Xianning   | 2535.1                          | 10019      | 2.92                          | No                                  |
| Suizhou    | 2210.5                          | 9636       | 1.94                          | No                                  |
| Enshi      | 3361                            | 24111      | 2.17                          | No                                  |
| Xiantao    | 1544.5                          | 2538       | 2.69                          | No                                  |
| Qianjiang  | 966                             | 2004       | 3.67                          | Yes                                 |
| Tianmen    | 1283.5                          | 2622       | 2.94                          | No                                  |
4. Discussion

4.1. The population distribution of the four types of health technical personnel in Hubei Province is generally fair

According to the statistical results of the data, from the perspective of population distribution, the Lorentz curve and Gini coefficient show that the distribution fairness is good. The four Lorentz curves are close to the average absolute line. The Gini coefficients of medical practitioners, registered nurses, pharmacists and technicians are all below 0.2 or close to 0.2, which indicates that the distribution of all kinds of health professionals in Hubei Province is in a highly fair state.

In other words, in terms of population, the distribution of health resources in Hubei Province is commendable. However, the Gini coefficient of the four types of health professionals is not less than 0.1, and the fairness still has the possibility of further improvement.

4.2. The equity of health technical personnel allocation by area in Hubei Province needs to be improved

According to the statistical results, from the geographical area distribution, the calculation results of Lorentz curve and Gini coefficient show that the distribution is not enough balanced. The four Lorentz curves were far away from the absolute average. The Gini coefficient of the four types of health technical personnel was close to the warning value in three, and the Gini coefficient of registered nurses was far higher than the warning value.

The Gini coefficient is close to the warning value, even greater than the warning value, indicating that the geographical distribution is very unfair. Combined with the results of health resource density index, there are great differences between different cities. The cities with the highest resource density are 13.88 times of the cities with the lowest resource density. Due to the vast land and sparse population in some cities, the balance of area distribution is very poor, such as Shennongjia. In order to achieve the accessibility of health resources, the area factor should be properly considered when allocating health human resources.

4.3. There is a big gap in the density of health human resources between different cities

According to the calculation results of health resource density index, the density of health resources in different cities varies greatly. A small number of developed cities occupy a large number of health resources, most other cities are insufficient, and their health resources do not reach the standard density of health resources. It shows that the balance of health resources allocation in each city and state of Hubei Province is poor, and there is a big gap between different cities.

Medical college graduates should be encouraged to work in less developed cities, such as Shennongjia, Shiyan, Suizhou and other cities with low density of health resources[10]. At the same time, cities with developed health resources should be encouraged to provide medical assistance to less developed cities, and actively build medical consortia with less developed cities, so as to ensure the health capacity of the cities with insufficient health human resources and promote the distribution balance of health resources in Hubei Province as a whole.

5. Conclusions

This paper analyzed the distribution of four types of health professionals in 17 cities and states in Hubei Province in 2018, drew the Lorenz curve according to the richness of health resources, and calculated the Gini coefficient and health resource density index of various health human resources by using mathematical model.
It was found that the equity of population distribution of health professionals in Hubei Province was good, and the equity of geographical distribution needed to be improved. The population distribution of health human resources was in a relatively fair state, and the geographical distribution was close to the alert state.

Firstly, when proposing the allocation of health human resources to allocate health personnel, it is to consider geographical factors, and to promote the development of health capacity in less developed areas with small population and large area.

Secondly, the state should set up incentive policies to encourage medical college graduates to work in cities with small population, promote the balanced distribution of health resources, and ensure the balanced development of Hubei Province.

Finally, it was necessary to encourage the developed cities and states are close to each other to provide medical assistance to the less developed cities and states, and actively build medical consortia with the less developed cities and states, so as to ensure the health capacity of the less developed cities and states with health resources, and ensure the balanced development of health in Hubei Province.

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