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# TEMPORAL AND SPATIAL CHANGES AND EQUITY OF NURSING HUMAN RESOURCES CONFIGURATION IN SICHUAN PROVINCE, CHINA

Huan Yang[1] , Yayun Song[2]

**Abstract:** This research aims to analyze the configuration, distribution, and equity of nursing human resources in Sichuan Province, China, providing a reference for the future development of nursing care in the region. A descriptive analysis was conducted to describe the configuration of nursing human resources in 2010, 2015, and 2020. The Lorenz curve, Gini coefficient, health resource density index, and distribution density maps were used as resources and methodology to evaluate the changes and equity in the configuration of nursing human resources. The result of this research determined that the nurse-to-population ratio was 1.17, 2.09, and 3.42 in 2010, 2015, and 2020, and nursing staff accounted for 24%, 49%, and 35% of technical health personnel. The nurse-to-physician ratio was 1:0.72, 1:1.05, and 1:1.22 in the three years. The Gini coefficients of nursing resource allocation for permanent population and area were 0.24, 0.20, and 0.12 and 0.74, 0.72, and 0.72, respectively. The nursing resource density index was 0.50, 0.91, and 1.42, respectively. In conclusion, the study shows that the equity of nursing resources based on population increased, while the equity based on region still showed disparity, with a sustained increase in nursing human resource density from 2010 to 2020. However, it is necessary to continue increasing the number of nurses and improving the geographical accessibility of nursing care.

**Keywords:** nursing resources, equity analysis, distributional density

**Cambios temporales y espaciales y equidad en la configuración de los recursos humanos de enfermería en la provincia de Sichuan, China**

**Resumen:** Esta investigación tiene como objetivo analizar la configuración, distribución y equidad de los recursos humanos de enfermería en la provincia de Sichuan, China, proporcionando una referencia para el desarrollo futuro de la atención de enfermería en la región. Se realizó un análisis descriptivo para detallar la configuración de los recursos humanos de enfermería durante 2010, 2015 y 2020. Para evaluar los cambios y la equidad en la configuración de los recursos humanos de enfermería se utilizó como recurso metodológico la curva de Lorenz, el coeficiente de Gini, el índice de densidad de recursos de salud y los mapas de densidad de distribución. El resultado de esta investigación determinó que la relación enfermera-población fue de 1,17, 2,09 y 3,42 en 2010, 2015 y 2020, y el personal de enfermería representó el 24%, 49% y 35% del personal técnico de salud. La relación enfermera-médico fue de 1:0,72, 1:1,05 y 1:1,22 en los tres años. Los coeficientes de Gini de asignación de recursos de enfermería para población permanente y área fueron 0,24, 0,20 y 0,12 y 0,74, 0,72 y 0,72, respectivamente. El índice de densidad de recursos de enfermería fue 0,50, 0,91 y 1,42, respectivamente. En conclusión, el estudio muestra que la equidad de los recursos de enfermería en función de la población aumentó, mientras que la equidad en función de la región mostró disparidad, con un aumento sostenido en la densidad de recursos humanos de enfermería desde 2010 a 2020. Sin embargo, es necesario seguir aumentando el número de enfermeras y mejorando la accesibilidad geográfica de la atención de enfermería.

**Palabras clave:** recursos de enfermería, análisis de equidad, densidad distributiva

**Mudanças temporais e espaciais, e equidade na configuração de recursos humanos de enfermagem na Província de Sichuan, China**

**Resumo**: Objetivos: Analisar a configuração, distribuição e equidade de recursos humanos de enfermagem na Província de Sichuan, China, fornecendo uma referência para o futuro desenvolvimento de cuidados de enfermagem na região. Materiais e Métodos: Foi realizada uma análise descritiva da situação atual de configuração de recursos humanos de enfermagem na Província de Sichuan em 2010, 2015 e 2020. Curva Lorenz, coeficiente Gini, índice de densidade de recursos de saúde e mapas de densidade da distribuição foram utilizados para avaliar as mudanças e equidade na configuração de recursos humanos de enfermagem. Resultados: A proporção enfermeiro-população foi 1,17, 2,09 e 3,42 em 2010, 2015 e 2020, respectivamente, com a equipe de enfermagem representando 24%, 49% e 35% do pessoal técnico de cuidados à saúde. A proporção enfermeiro-médico foi 1:0,72, 1:1,05 e 1:1,22 nos três anos, respectivamente. Os coeficientes de alocação de recursos de enfermagem para a população permanente e área foram 0,24, 0,20 e 0,12 e 0,74, 0,72 e 0,72, respectivamente. O índice de densidade de recursos de enfermagem foi 0,50, 0,91 e 1,42, respectivamente. Conclusão: O estudo mostra que a equidade de recursos de enfermagem com base na população aumentou enquanto a equidade com base na região ainda apresentava disparidade, com um contínuo aumento na densidade de recursos humanos de enfermagem ao longo dos anos de 2010 a 2020. Todavia, há necessidade de continuar aumentando o número de enfermeiros e melhorar a acessibilidade a cuidados de enfermagem.

**Palavras-chave**: recursos de enfermagem, análise de equidade, densidade distributiva

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## Introduction

The provision of quality health care is dependent on an adequate number of well-equipped health workers. Such provision is integral to achieving the health-related Sustainable Development Goals*(1)*. The World Health Assembly addressed a significant challenge - the projected need for an additional 18 million health workers, primarily in low- and middle-income countries in 2030*(2)*. Overcoming this challenge is paramount to achieving the health-related Sustainable Development Goals. Hence, the Global Strategy prioritizes universal availability, accessibility, and acceptability of the health workforce to improve health equity globally. Health equity is a key objective for human health, which can be defined as equal in healthcare access or utilization. Inequalities in health and healthcare are caused by different factors, such as those associated with healthcare human resource allocation, socioeconomic status, or geographical region*(3)*.

Nursing is a crucial element of the healthcare human resource, playing a pivotal role in promoting health, preventing diseases, as well as providing treatment and rehabilitation. However, the global nursing shortage, a pre-existing problem, has been exacerbated by the COVID-19 pandemic*(4)*. Nurses are experiencing trauma and exhaustion, leading to a considerable reduction in the numbers within their profession. In the new report released by the International Council of Nurses (ICN), it has been estimated that in light of the current shortage, the increasing average age of nurses, and the cumulative impact of COVID-19, as many as 13 million new nurses will be required in the future to compensate for this global shortage*(5)*.

The equity of nursing resource allocation affects the utilization of resources in the entire healthcare system, which in turn influences the health status of residents. Therefore, improving the fairness and accessibility of nursing resources are of great significance in meeting the growing health needs of people and in promoting the sustainable development of nursing care.

Sichuan Province, as the province with the fastest economic development and the largest population in western China, significantly influences other provinces in the region. At the end of 2020, the province had a permanent resident population of 83.675 million and administered 21 municipalities (prefectures) (see Figure 1) with an area of 486,000 square kilometers. Currently, there is no literature on the allocation of nursing human resources in Sichuan province for research and analysis. Then, this study aims to assess and analyze the configuration, distribution, and equity of nursing human resources in Sichuan Province during the years 2010, 2015, and 2020.

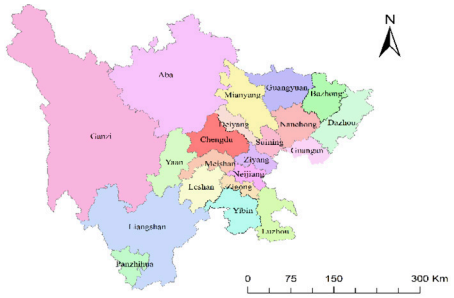



Figure 1: Administrative map of Sichuan province, China.

## Materials

### Data sources

The data for nursing resources in this study were obtained from the Sichuan Health and Health Statistics Yearbook in 2010, 2015, and 2020, while administrative division, area, and population data were extracted from the Sichuan Statistical Yearbook published in 2011, 2016, and 2020. Geographic data for Sichuan Province was obtained from the website of the National Basic Geographic Information Center.

### General descriptive analysis

This study calculated the number of registered nurses per 1,000 population, the number of practicing physicians per 1,000 population, the number of beds per 1,000 population, and the annual average growth rate of the number of registered nurses per 1,000 population for each city (prefecture) in Sichuan Province from 2010 to 2020. These metrics were used to evaluate the allocation of nursing human resources

in Sichuan Province. The calculation formula for the annual average growth rate was as follows: Annual average growth rate =

$$\sqrt[n]{\frac{\text{The value of a certain indicator in the reporting period}}{\text{The value of this indicator in the base period}}}-1$$

## Lorenz curve and Gini coefficient

To study the distribution of nursing resources, this study employed the Gini coefficient and Lorenz curve proposed by the World Health Organization to describe the fairness of healthcare personnel*(6)*. The Gini coefficient is an index that measures the degree of inequality in the overall level based on the Lorenz curve. This study utilized the cumulative percentage of the population as the abscissa and the cumulative percentage of registered nurses as the ordinate to draw the Lorenz curve of the distribution of registered nurses by population in Sichuan Province. Similarly, the cumulative percentage of the area was used as the abscissa and the cumulative percentage of registered nurses was used as the ordinate to draw the Lorenz curved distribution of registered nurses by geographic area in Sichuan Province. The greater the curvature of the Lorenz curve, the greater the degree of inequality in resource utilization; the opposite is true for fairness in resource utilization.

The Gini coefficient is an index that further quantifies the fairness of resource allocation based on the Lorenz curve and can effectively evaluate the differences in resource allocation. The calculation formula was as follows:

$$G = 1 - \sum_{i=1}^{n} [(Xi - Xi\text{-}1)(Yi + Yi\text{-}1)]$$

Where n is the number of cities or prefectures surveyed, Xi is the cumulative percentage of population in each city or prefecture, Yi is the cumulative percentage of health resources in each city or prefecture, and n is the total number of cities or prefectures. The Gini coefficient ranges from 0 to 1, with smaller values indicating more equitable resource distribution*(6)*.

## Health Resource Density Index (HRDI)

The HRDI is a resource allocation model based on the balanced distribution of health resources by population and geographic area. It was used to analyze the accessibility of health resources in this study. The calculation formula for HRDI was as follows:

$$HRDI = \sqrt{\text{The health resources/1000} \times \text{Quantity of health resources/Km}^2}$$

## Statistical methods

Excel 2013 was used to input, integrate, and clean the data and to perform statistical descriptions of registered nurses, unit nursing resource ownership, the percentage of registered nurses in the total healthcare technical personnel, and the doctor-nurse ratio in Sichuan Province from 2010 to 2020. Excel 2013 was also used to calculate the Lorenz curve, Gini coefficient, and HRDI. The density distribution map was created using ArcGIS 10.2.

## Results

The number of registered nurses in Sichuan Province has experienced year-on-year growth from 2010 to 2020, with the total number of registered nurses increasing from 104,900 to 286,000, respectively. The number of registered nurses per 1,000 population has also been on the rise, increasing from 1.17 in 2010 to 3.42 in 2020. The distribution of registered nurse density increased, too (Figures 2, 3, and 4). Furthermore, the average annual growth rate of registered nurses per 1,000 population between 2010 and 2015 was 17.16%. Among all cities (prefectures) in Sichuan Province, Luzhou displayed the fastest average annual growth rate, reaching 83.15%. The average annual growth rate from 2015 to 2020 was 10.73%, with Guangan City exhibiting the fastest average growth rate of 70.60% (Table 1).

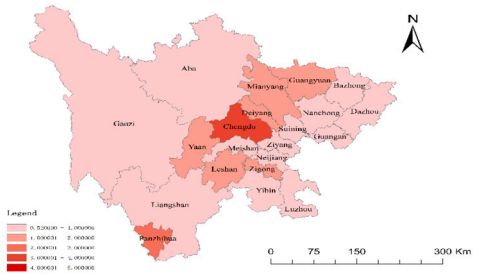



Figure 2: Distribution of RN density per thousand population in Sichuan Province in 2010.

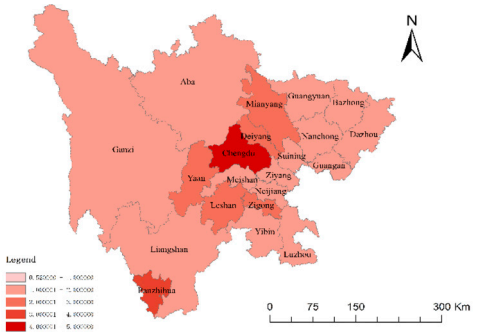



Figure 3: Distribution of RN density per thousand population in Sichuan Province in 2015.

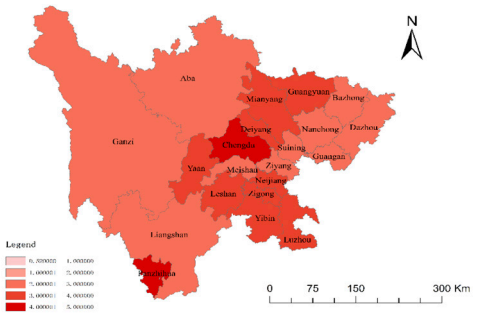



Figure 4: Distribution of RN density per thousand population in Sichuan Province in 2020.

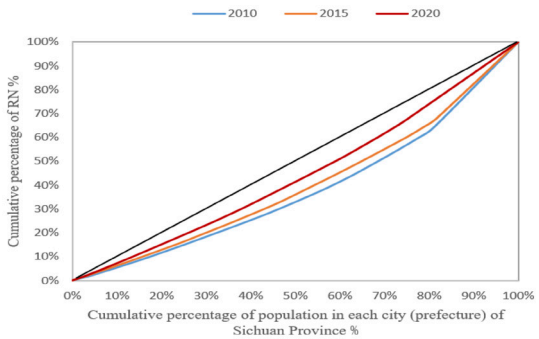



Figure 5: Lorenz curve graph of RN according to land area allocation in Sichuan Province in 2010, 2015 and 2020.

The Lorenz curve for nursing human resources allocated to the resident population was approaching the equity line (Figure 5). The Gini coefficient for the allocation of nursing human resources to the resident population in 2010, 2015, and 2020 decreased from 0.24 to 0.20 and then to 0.12, respectively, revealing an overall downward trend (Table 2).

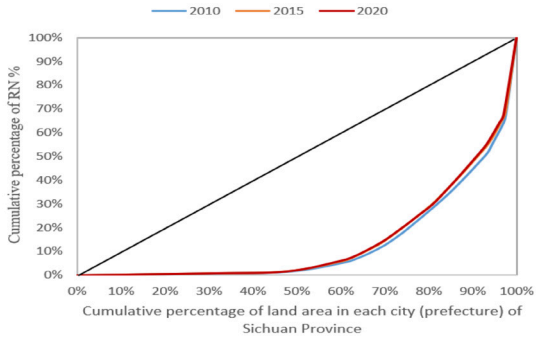



Figure 6: Lorenz curve graph of RN according to land area allocation in Sichuan Province in 2010, 2015 and 2020.

Table 2 The Gini coefficient of nursing human resources in Sichuan Province in 2010, 2015, 2020.

| Year | According to population distribution | According to land area |
|---|---|---|
| 2010 | 0.24 | 0.74 |
| 2015 | 0.20 | 0.72 |
| 2020 | 0.12 | 0.72 |

The allocation of nursing human resources according to geographical area was visualized by sorting them from small to large based on the area of each city (prefecture), and the Lorenz curves for nursing human resources in Sichuan Province from 2010 to 2020 were plotted (Figure 6), which were further away from the equity line than those based on the resident population. The Gini coefficients for the allocation of nursing human resources to Sichuan Province's geographical area in 2010, 2015, and 2020 were 0.74, 0.72, and 0.72, respectively, indicating a significant gap and disparity in the allocation of registered nurses based on geographical area (Table 2).

From 2010 to 2020, the HRDI of nursing per-

Table 1 Overall allocation of nursing human resources in Sichuan Province

| City | Total NO. of RN | | | RN/1000 people | | | RN/1000 people AGR（%） | | RN/technical personnel | | | Doctor/ RN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2010 | 2015 | 2020 | 2010-2015 | 2015-2020 | 2010 | 2015 | 2020 | 2010 | 2015 | 2020 |
| Chendu | 34647 | 59636 | 92968 | 3.02 | 4.86 | 4.44 | 9.79 | -0.36 | 28% | 46% | 35% | 1：0.96 | 1：0.95 | 1：1.28 |
| Zigong | 4404 | 7241 | 9217 | 1.35 | 2.21 | 3.70 | 10.76 | 12.15 | 28% | 52% | 33% | 1：0.82 | 1：1.15 | 1：1.21 |
| Panzhihua | 3011 | 4362 | 5127 | 2.7 | 3.94 | 4.23 | 5.62 | 0.43 | 27% | 47% | 34% | 1：0.88 | 1：1.00 | 1：1.28 |
| Luzhou | 3744 | 9224 | 15548 | 0.75 | 1.82 | 3.65 | 83.15 | 31.44 | 21% | 53% | 36% | 1：0.60 | 1：1.11 | 1：1.31 |
| Deyang | 4440 | 7935 | 10928 | 1.14 | 2.03 | 3.16 | 16.90 | 8.14 | 23% | 49% | 32% | 1：0.65 | 1：1.00 | 1：1.12 |
| Mianyang | 6660 | 11184 | 16066 | 1.23 | 2.05 | 3.30 | 11.86 | 9.81 | 24% | 49% | 33% | 1：0.74 | 1：1.04 | 1：1.14 |
| Guangyuan | 3315 | 5796 | 8811 | 1.07 | 1.9 | 3.82 | 16.65 | 31.85 | 21% | 48% | 33% | 1：0.59 | 1：1.07 | 1：1.23 |
| Suining | 3677 | 5632 | 8433 | 0.96 | 1.49 | 3.00 | 8.01 | 32.09 | 24% | 51% | 30% | 1：0.71 | 1：1.09 | 1：1.01 |
| Neijiang | 3772 | 6714 | 10151 | 0.89 | 1.6 | 3.23 | 17.78 | 32.53 | 23% | 49% | 33% | 1：0.63 | 1：1.07 | 1：1.08 |
| Leshan | 4433 | 7507 | 10572 | 1.25 | 2.12 | 3.35 | 13.03 | 8.85 | 24% | 55% | 34% | 1：0.70 | 1：1.19 | 1：1.23 |
| Nanchong | 5342 | 10037 | 15407 | 0.71 | 1.35 | 2.75 | 23.85 | 34.07 | 20% | 45% | 31% | 1：0.60 | 1：1.02 | 1：1.06 |
| Meishan | 2814 | 5839 | 8328 | 0.81 | 1.67 | 2.82 | 36.25 | 12.73 | 20% | 55% | 33% | 1：0.55 | 1：1.21 | 1：1.18 |
| Yibin | 4740 | 9633 | 14839 | 0.88 | 1.74 | 3.23 | 29.22 | 21.04 | 24% | 51% | 36% | 1：0.71 | 1：1.16 | 1：1.33 |
| Guangan | 2415 | 4792 | 7892 | 0.52 | 1.03 | 2.42 | 29.49 | 70.60 | 20% | 49% | 33% | 1：0.60 | 1：1.08 | 1：1.21 |
| Dazhou | 4328 | 8460 | 14038 | 0.63 | 1.24 | 2.61 | 28.54 | 40.31 | 21% | 56% | 35% | 1：0.62 | 1：1.26 | 1：1.26 |
| Yaan | 2037 | 4052 | 5637 | 1.32 | 2.62 | 3.93 | 29.81 | 6.59 | 22% | 47% | 32% | 1：0.65 | 1：1.12 | 1：1.16 |
| Bazhong | 2060 | 4810 | 7472 | 0.53 | 1.27 | 2.75 | 78.00 | 46.60 | 16% | 54% | 31% | 1：0.41 | 1：1.17 | 1：1.05 |
| Ziyang | 3372 | 6534 | 6781 | 0.67 | 1.30 | 2.94 | 26.50 | 58.16 | 20% | 53% | 32% | 1：0.56 | 1：1.22 | 1：1.14 |
| Aba * | 826 | 1603 | 2329 | 0.92 | 1.75 | 2.83 | 23.90 | 10.06 | 18% | 40% | 25% | 1：0.60 | 1：0.82 | 1：0.92 |
| Ganzi * | 841 | 1577 | 2349 | 0.79 | 1.44 | 2.12 | 19.12 | 5.92 | 15% | 45% | 26% | 1：0.50 | 1：1.10 | 1：1.06 |
| Liangshan * | 4052 | 8075 | 13117 | 0.85 | 1.60 | 2.70 | 22.63 | 12.68 | 24% | 52% | 35% | 1：0.69 | 1：1.20 | 1：1.45 |
| Total | 104930 | 190643 | 286010 | 1.17 | 2.09 | 3.42 | 17.19 | 10.73 | 24% | 49% | 35% | 1：0.72 | 1：1.05 | 1：1.22 |

Table 3 HRDI of RN in Sichuan province in

| City | Density index of registered nurses | | |
|---|---|---|---|
| | 2010 | 2015 | 2020 |
| Chendu | 2.95 | 4.89 | 5.37 |
| Zigong | 1.22 | 1.91 | 2.79 |
| Panzhihua | 1.08 | 1.52 | 1.71 |

sonnel in Sichuan Province increased from 0.50 to 1.42. But certain regions, such as Aba, Ganzi, and Liangshan Prefecture, appeared to have lower HRDI values compared to the provincial average across 2010, 2015, and 2020. Specifically, the HRDI of these regions was below the mean HRDI of the province even as of 2020 (Table 3).

**Discussion**

Our study shows that from 2010 to 2020, the Gini coefficients of nursing by population distribution dropped from 0.24 to 0.12. This indicated that the allocation of nursing was becoming more equitable among the population. However, Gini coefficients based on regional area distribution were still over 0.72 in 2020, indicating an extreme inequity disparity between regions. This reveals that the nursing resource equity distribution based on population was superior to that based on geography, which is consistent with the overall status of nursing human resources in China*(7,8).* The disparity may be attributed to the government setting the number of registered nurses per thousand population, rather than the number of registered nurses per 10,000 square km, as the allocation criterion. Consequently, it is sensible to recommend that the government should prioritize geographical equity when making regional health planning. Enhancing the allocation mechanism for nurse and directing additional resources to remote and economically underdeveloped provinces would contribute to advancing the equitable distribution of health resources.

The distribution density of registered nurses per 1,000 people showed that Chengdu had the highest density, in contrast, remote cities (prefectures) such as Aba Autonomous Prefecture, Ganzi Prefecture, and Liangshan Prefecture had relatively low registered nurse densities. Also, in Chengdu, the nursing human resource density index value was 3.78 times the provincial average, however, in 7 cities (prefectures) in Sichuan Province in 2020, the nursing human resource density was lower than the provincial average. This was along with the study conducted by Sun et al.*(9)* that the capital city of one province has the highest density of registered nurses. A potential explanation for this disparity is variations in income levels among the different regions. The density of nursing is a crucial factor in the quality and accessibility of healthcare services*(10)*. To address the imbalance in nursing human resources allocation caused by varying levels of economic development across regions, it is imperative to focus on spatially distributing nursing resources, particularly in economically underdeveloped areas.

The result showed that the number of registered nurses increased from 10.49 thousand in 2010 to 28.60 thousand in 2020, with an increase of 172.57%. The number of registered nurses per 1,000 people reached 3.42 in 2020, exceeding the Western region average of 0.72 and national average of 3.34(7). By 2020, only one prefecture posed registered nurses less than WHO minimum standard with 2.5 registered nurses per 1,000 people*(11).* Despite these gains, only three cities in the province had more than 3.8 registered nurses per 1,000 people, while 85.71% of cities (prefectures) in the province had substantial room for improvement, according to the National Nursing Development Plan (2021-2025)*(12).* Compared to OECD member countries and developed countries such as the United States, which have an average density of 9 and 11.1 registered nurses per 1,000 people, respectively*(13).* The doctor-nurse ratio in Sichuan province is relatively reasonable and ranks at the forefront of the country, 52% of cities (prefectures) in the province had a doctor-nurse ratio lower than the target of 1:1.20 set by the National Nursing Development Plan (2021-2025)(5). But still lower than the WHO's suggested guidelines that doctor-nurse ratio should be 1:3. The human resources significantly impact the delivery of medical and health services*(14,15).* Therefore, Sichuan Province's nursing development requires continuous efforts, including increasing the number of nurses and improving the geographic accessibility of nursing care. To achieve this, investment mechanisms should be accelerated to construct healthcare human resources teams mainly with government input.

## Conclusion

The study shows that the equity of nursing resources based on population was increased while equity based on regional still showed disparity, with a sustained increase in the density of nursing human resources from 2010 to 2020. Nonetheless, there is a need to continue to increase the number of nurses and improve the geographic accessibility of nursing care. Effective policies and programs should be adopted for optimal distribution of nursing human resources and to enhance the overall quality of nursing care services in Sichuan.

## Authors Contributions

Huan Yang design the study, interpreted the data and write the manuscript. Yayun Song collected the data and revised the manuscript.

## Funding

Not applicable.

## Institutional Review Board Statement

This study was conducted in accordance with the Declaration of Helsinki.

## Informed Consent Statement

Not applicable.

## Conflict of interest

The authors declare that they have no competing interests in this section.

## Data Availability Statement

*The data presented in this study are available on request from the corresponding author.*

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