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Trends, Composition, and Distribution of Nurse Workforce in China: An Analysis from 2003 to 2018

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ABSTRACT

Objectives Given the increased aging population and frequent epidemic challenges, it is vital to have the nurse workforce of sufficient quantity and quality in achieving population health. The objective of this study was to demonstrate the composition, distribution, and trends of the nurse workforce in China, from 2003 to 2018.

Design Secondary analysis using national public datasets in China from 2003 to 2018.

Setting/Participants National population, nurse workforce, and physician workforce.

Primary and secondary outcome measures Frequency and proportion were used to demonstrate 1) the longitudinal growth of nurse workforce; 2) the diversity of nurse workforce in gender, age, work experience, and education level; 3) the distribution of nurse workforce among provinces, rural-urban areas, and hospital/community settings. The Gini coefficient and Theil L index were chosen to calculate the inequality of nurse distribution.

Results The total number of nurses increased from 1.3 million to 4.1 million (2.2 times) and the density increased from 1 to 2.94 per 1000 population (1.9 times) during the past 15 years in China. The nurses to physician ratio changed from 0.65:1 to 1.14:1 over 2003-2018. The majority of the nurse workforce was female, under 35 years old, with less than 30 years of work experience and with an associate's degree. Nurse distribution inequality across Chinese provinces was decreasing, whereas the proportion of nurses employed in the primary care settings and rural areas remained low relatively.

Conclusion These significant changes in China's nurse workforce might be associated with policy reformations. Our study suggests current features in the nurse workforce and can be used to strengthen health services.

Strengths and limitations of this study

1. This study presents the supply, trends, the demographic composition, the distribution across urban-rural regions and working settings, and the distribution equality of the Chinese nurse workforce over the past 15 years.
2. Data are derived from the national reports of China.
3. Findings could be used for providing robust policy prescriptions, healthcare administration, education, and further research to strengthen the nurse workforce.
4. Some nurse composition data are inadequately updated before 2005, and the data collection methods have been constantly modified and updated in the national surveys.

INTRODUCTION

Nursing is the largest profession in the current health care workforce and healthcare service systems in China and worldwide. Nursing has been playing a central role in the health delivery system and providing a full range of responsibilities in health promotion, prevention, treatment, and rehabilitation. It is vital to have the nurse workforce of sufficient capacity, capability, and quality in achieving population health and universal health coverage. A higher proportion of nurses, especially nurses with a higher education level in the health workforce is associated with better health outcomes.[2-5] As the aging population grows heavily globally, as well as the frequent public health emergencies in the past decades, there is an increasing need for safe and quality health care and nurse labor.[6-8]

World Health Organization (WHO) evidenced that despite significant progress, there is a growing mismatch between supply, need, and demand of the nurse workforce, resulting in staff shortages.[9] And WHO projected a significant growth (55%) of nurse workforce demand, leading to an aggregate number of 32.3 million nurses/midwives by 2030 based on current trends.[10] Even in the US, the nursing labor market continues to tighten with 45% of hospitals projecting to increase the number of nurse staff.[11]

As a middle-income country, China has 1.4 billion people, with the aging population accounts 17.9%.[12] People with chronic unfatal diseases keep growing, resulting in a heavy healthcare burden. Also, the distribution inequality of health resources across China cannot be ignored owing to the vast territory.[13] As a result, China has been facing big challenges regarding the nurse workforce.[14] Over the past two decades, the systems of medical education and health care have undergone unprecedented reform in China. In essence, the educational composition is the reflection of economic structure on the demand for human resources. In 2001, China joined the World Trade Organization, boosting the development of finance. Under that circumstance, with the development of medical science and reform of the healthcare system, the composition of nursing education should make corresponding changes. In 2003, the Ministry of Education combined with the other 5 Ministries defined nurses as a badly needed profession.[15] To achieve a higher nurse workforce supply, the government took this as a priority in healthcare management. In 2016, the main goals of Nursing development during the 13th Five-Year plan (2016-2020) are to achieve 4.45 million registered nurses and 3.14 nurses per thousand population by 2020.[16] As a result of that Five-Year, there were almost 4.43 million nurses in China in 2019, which increased by nearly one million from 2016.[17]

To date, the nurse workforce has improved a lot through the healthcare system and education reform in China. To our knowledge, the research is lacking to demonstrate the trends of the Chinese nurse workforce from a national perspective. This study analyzed the public data from the *China Health and Family Planning Statistical Yearbooks (CHFPSY)* and *China Statistical Yearbooks (CSY)*, illustrating the current nurse workforce and trends of over 2003 to 2018 in China. Specifically, we examined: 1) the growth of the nurse workforce, 2) the compositions of nurse workforce, including diversity in gender, age, work experience, education level, and 3) the distribution of nurse workforce across provinces, rural-urban and settings.

METHODS

Study design

A secondary analysis design was used in the study. Data was retrieved from the *CHFPSY* and *CSY*. The two databases are national annual survey reports reflecting the statistics of the healthcare workforce, population health status, and economic and social aspects of 31 provinces, autonomous regions, and municipalities in China (except for Hongkong, Macao, and Taiwan). The annual data from 2003 to 2018 from the *CHFPSY* (yearbooks of 2004-2019) were used to analyze the trends, composition and distribution of the nurse workforce over the past 15 years in China. We also used the *CSY* dataset to retrieve the population data of the national and province levels and calculated the equality/inequality of the distribution of nursing resources over 2003-2018 in China.

Variables and Definitions

The primary variables and definitions included in the data analysis are described as the following, which are corresponding to the national survey datasets:

1) Nurses are those who have passed the nurse qualification examination and obtained a nursing qualification.
2) Physicians are those who pass a licensing examination and are registered at a healthy authority, including licensed physicians and licensed physician assistants.
3) Hospitals include general hospitals, affiliated hospitals of medical college, hospitals specialized in traditional Chinese medicine, hospitals of integrated traditional Chinese with western medicine, national hospitals, specialized hospitals, and nursing homes.
4) Primary care institutions include community health service centers, community health service stations, urban health centers, township health centers, village clinics, and outpatient departments and health centers.
5) The urban areas include municipalities and prefecture-level municipalities.
6) The rural areas include counties and county-level cities, townships, and villages.
7) The density of nurses is defined as the number of nurses per 1000 population.

Data analysis

We downloaded the data from each of the yearbook datasets from 2004 to 2019, which correspond to the nurse and population data of 2003-2018. Excel software was used to merge, manage, and analyze the data. We used frequency and proportion to describe the composition and distributions of the nurse workforce throughout 2003-2018. The growth rate of nurses was calculated as the annual increased number of nurses divided by the total number of nurses of the previous year.

The Gini coefficient and Theil L index were identified by WHO to measure inequalities in the health workforce.[18] The Gini coefficient, an indicator for judging the degree of equality of distribution according to the Lorenz curve, is the most well-known indicator to measure the aggregate level of inequality and cannot explain the sources of inequality. We sorted the number of nurses per 1000 population in each province from small to large, using the cumulative population percentage as the abscissa and using the cumulative percentage of nurses as the ordinate to draw the Lorenz curve of the distribution of nurses across the country by population. The Gini coefficient is twice the area enclosed by the Lorenz curve and the perfect equality line.[19] If b_i= number of nurses in province unit *i* and c_i= number of people in province unit *i*, then the total number of nurses in the country is $B=b_1+b_2+...+b_n$ and the total number of people in the country is $C=c_1+c_2+...+c_n$. If we value $B_i=b_i/B$, $C_i=c_i/C$, then the

Gini coefficient $G = 1 - \sum_{i=1}^{I} C_i (2\sum_{i=1}^{I} B_i - B_i)$. For further analysis, the Theil L index is the most attractive decomposition indicator, as it can be decomposed into two parts, between-groups (T_{1L}) and within-groups (T_{2L}), respectively. If j means urban or rural, then B_{ij} means the proportion of urban or rural nurses in province unit i in the total nurses, and C_{ij} means the proportion of the urban or rural population in province unit i in the total population. The decomposition of Thiel L index is as follows:

$$\text{Theil L} = T_{1L} + T_{2L} = \sum_{i=1}^{I} C_i \log\frac{C_i}{B_i} + \sum_{I=1}^{I} C_i \sum_{j=1}^{J} C_{ij} \log\frac{C_{ij}}{B_{ij}}$$

This study calculated the Gini coefficient and Theil L index to estimate the level of equality among nurse distribution and they were all weighted by the proportion of the population in each province in the total population as we explained in the formula. Besides, we calculated the ratio of the provincial Theil index to the total Theil index to represent the contribution rate of urban-rural differences to total differences.[20] The Gini coefficient and Theil L value from 0 to 1. The smaller value means fairer nurse distribution. We use Microsoft Excel 2013 to perform the above analyses.

Patient and Public Involvement

A few nurses were involved in the reporting of our research and gave suggestions on the content and presentation of our research.

RESULTS

Growth of Nurse Workforce

Over 15 years, the nurse workforce has grown dramatically in China. At the end of 2018, the number of nurses reached over four million, which is 2.2 times more than that in 2003. The density of nurses increased by 1.9 times in the same period to reach about 2.94 nurses per 1000 population in 2018 (Table 1 and Figure 1). In Figure 2, the growth rates of the nurse workforce reveal three segments: an initial period of growth (2003-2006), a rapid growth period (2007-2013), and a period of stable growth (2014-2018). In the initial growth period, the growth rate dramatically increased from 1.6 percent in 2003 to 5.7 percent in 2006. The rapid growth period began in 2007 (9.3%), declined slightly in 2008 and 2011, then rose and reached the highest growth rate (11.5%) in 2013. Since 2014, there was a stable growth rate ranged from 7.7 percent to 8.5 percent.

Meanwhile, we also compared nurses vs. physician workforce in China (Table 1). In a long period of history before 2014, China had been with more physicians than nurses (Figure 1). With the rapid expansion of the nursing staff, the imbalance of nurses and physicians has been changed, and the ratio of nurses to physicians changed from 0.65:1 in 2003 to 1.14:1 in 2018.

Table 1. Change of nurse and physician workforce from 2003 to 2018

	Nurses		Physicians	
Year	Number	Density*	Number	Density*
2003	1265959	1.00	1942364	1.54
2004	1308433	1.03	1999457	1.57
2005	1349589	1.03	2042135	1.56
2006	1426339	1.09	2099064	1.60
2007	1558822	1.18	2122925	1.61
2008	1678091	1.2	2201904	1.66
2009	1854818	1.39	2329206	1.75
2010	2048071	1.53	2413259	1.80
2011	2244020	1.66	2466094	1.82
2012	2496599	1.85	2616064	1.94
2013	2783121	2.04	2794754	2.04
2014	3004144	2.20	2892518	2.12
2015	3241469	2.37	3039135	2.22
2016	3507166	2.54	3191005	2.31
2017	3804021	2.74	3390034	2.44
2018	4098630	2.94	3607156	2.59

Note: *Per 1000 population.

Nurse Demographics and Characteristics

Table 2 presents nurse demographics and characteristics in overall health institutions, hospitals, and primary care institutions in China between 2005 and 2018 (no data available before 2005). The nurse workforce in China has been always predominately female, with the proportion of male nurses slightly increased from 1.7% in 2005 to 2.3% in 2018. Figure 3 shows the different composition of male nurses in hospitals vs. primary care institutions. From 2005 to 2018, male nurses working in primary care institutions dropped to 1.3%, while the proportion in hospitals steadily rose from 1.6 to 2.7%.

Table 2. Demographics and characteristics of nurses from 2005 to 2018

	Overall health institutions				Hospitals				Primary care institutions*			
Year	2005	2010	2015	2018	2005	2010	2015	2018	2005	2010	2015	2018
Gender												
Male	1.7	1.7	2.0	2.3	1.6	1.8	2.2	2.7	2.3	1.5	1.3	1.3
Female	98.3	98.3	98.0	97.7	98.4	98.2	97.8	97.3	97.7	98.5	98.7	98.7
Age												
under 25	10.1	14.1	14.1	9.7	10.2	14.7	15.0	9.7	9.1	12.3	12.0	9.0
25～34	40.3	39.6	46.8	50.6	38.2	39.0	48.8	53.1	52.6	42.5	39.9	42.7
35～44	31.6	26.9	22.0	22.1	32.7	26.6	19.9	20.6	25.6	30.1	31.6	28.7
45～54	17.3	16.9	14.0	12.7	18.1	17.6	13.7	12.1	12.1	13.4	14.7	16.3
55～59	0.6	2.2	2.0	3.4	0.6	2.0	1.9	3.4	0.5	1.5	1.4	2.7
60 or above	0.1	0.4	1.1	1.5	0.1	0.2	0.7	1.1	0.1	0.2	0.4	0.6
Work Experience(years)												
under 5	14.1	23.6	29.7	21.3	14.0	24.3	31.4	21.7	14.3	21.1	25.8	19.5
5～9	19.4	16.2	24.1	31.2	17.5	16.5	24.8	32.5	30.2	13.8	21.0	27.2
10～19	35.9	29.1	20.6	23.9	36.3	27.2	19.1	23.7	35.0	39.0	25.8	23.6
20～29	22.7	21.8	16.7	14.3	23.8	22.8	16.1	13.1	16.6	18.9	20.5	21.4
30 or above	7.7	9.3	8.8	9.3	8.3	9.3	8.5	9.1	3.9	7.2	6.9	8.3
Education												
Master's or above	0.0	0.1	0.1	0.2	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0
Bachelor's	2.7	8.7	14.5	20.8	3.2	10.5	16.7	23.5	0.4	2.6	6.9	13.4
Associate's	28.9	42.5	47.9	48.9	31.8	45.5	50.3	50.4	14.1	32.8	39.9	44.4
Vocational education	60.4	46.0	36.3	29.6	57.7	41.5	31.9	25.5	73.9	60.4	51.2	41.1
High school or below	7.9	2.7	1.1	0.6	7.3	2.5	1.0	0.5	11.6	4.2	2.0	1.1

Note: *Estimated by authors based on demographics data of community health service stations and township health centers.

Young nurses are the main force of the nurse workforce in China. Employees under 35-year-old were accounted for 60.3% of the total nurses in 2018. In table 2, the proportion of nurses between the age of 25 and 34 and those over 55-year-old increased during 2005-2018, whereas the proportion of nurses between 35 and 54 declined slightly. Moreover, the proportion of nurses between 25-34 years old grew gradually in hospital settings but decreased in the primary care institutions across the 15 years. In 2018, there were more young nurses (under 35) in hospitals than primary care institutions.

The nurses' educational levels have changed over time with an increased proportion of the higher level of degrees. The percentage of nurses with a vocational education degree or below dropped year by year, from 74.4% in 2002 to 30.2% in 2018. Associate's degree nurses have become the main force of registered nurses in China, accounting for 48.9% in 2018. The growth of nurses with bachelor's, master's, or Ph.D. degree was fast over the period. By the end of 2018, the proportion of nurses with a

bachelor's degree or above have reached 21.0%. Compared with primary care settings, hospitals had more nurses with higher education levels.

The proportion of experienced nurses who were serving more than 30 years was relatively small in China nurse workforce. The proportion of nurses with 10-29 years' work experience has decreased continually (58.6% in 2005 to 38.2% in 2018), while the percentage of nurses with less than 10 years' experience increased (33.5% in 2005 to 52.5% in 2018). A similar trend was shown overtimes for the distribution of nurse working experience in the hospital and primary care settings, but more hospital nurses had less than 10 years' work experience, and more primary care nurses were with more than 20 years' work experience.

Distribution across Provinces, Rural-Urban Areas, and Settings

We adopted the latest data of 2018 to analyze the nurse distribution among different provinces in China. The density of nurses in each of the provinces and areas ranged from approximately a high of 5.0 nurses in Beijing to a low of 1.6 nurses per 1000 population in Tibet. Figure 4 shows that the provinces in the Northeastern and Western regions had a relatively low density of the nurse workforce, whereas provinces in the Central and Eastern regions tended to have a high nurse per capital supply.

As for the urban-rural distribution of nurses in China, the criteria used in the datasets for dividing urban and rural areas before 2010 were different from those for the recent years, therefore we used the data from 2010 to 2018 for analysis. The data shows that there were huge differences between urban and rural areas. In 2010, there were more than three nurses per 1000 population in urban areas, while there was less than one nurse per 1000 population among rural areas. Over the past decade, the number and density of nurses in both urban and rural areas have greatly increased, but the gap between urban and rural areas has not been narrowed. By 2018, there were 5.08 nurses per 1000 population in urban areas, while the number of that in rural areas was still less than two (Supplementary file).

In 2018, the majority of nurses (73.70%) were employed within hospital settings, and only about 20% of nurses worked in primary care institutions (see Figure 5). Over the past ten years, there was a tendency that more patients went to hospitals rather than primary care institutions (Supplementary file). Hospitals received more than 70% of inpatients and 40% of overall outpatient visits, and primary health care institutions were responsible for over 50% of the visits and 20% of inpatients. During the last decade, although the number of nurses working in all institutions has increased significantly, the distribution of nurses across settings had no significant changes.

To further examine the distribution of equality of the nurse workforce, we calculated the Gini coefficient and Theil L index. Although the analyses were based on the provincial data, due to the lack of valid individual residential data, the results demonstrated significance for understanding the distribution across provinces and between the urban and rural areas over the country. The Gini coefficient of nurses fell from 0.167 in 2010 to 0.119 in 2018. Between-provincial Theil index had similar trends to the corresponding Gini index, dropped from 0.010 in 2010 to 0.004 in 2018. Overall and within-provincial Theil index experienced a decline from 2010 to 2015 and has risen again in the past three years. Within-province inequality accounted for overall inter-provincial inequality has risen consistently, with a peak in 2018 (Theil L: from 52.38% in 2010 to 71.43% in 2018) (Supplementary file).

DISSCUSSION

Understanding the nurse trends, composition, and distribution of supply is crucial for building an effective health care system. This article presents national data with longitudinal and recent status on the nurse workforce in China from 2003 to 2018. To the best of our knowledge, this is the first article to report trends of the nurse workforce on such a large scale and over the past 15 years of period. As in many ways, the nursing human resources and education, and health and family policy all impact each other,[21] the results of the analysis in this article could be used for policymaking, healthcare administration, education, and further research to strengthen nurse workforce.

The number of Chinese nurse workforce in 2017 (3.8 million) accounted for 18 percent of the nurse workforce in the world (20.7 million), and the number of nurses increased to 4.1 million in 2018.[22] The Chinese nurses per 1000 population were 2.94 in 2018, exceeding the minimum standard set by WHO (two nurses per 1000 populations) and some developing countries (e.g. India and South Africa), yet this density is still relatively below the average density of Organization for Economic Co-operation and Development (OECD) member countries (nine nurses per 1000 populations and 50% of WHO Member States in 2017.[22, 23] The ratio of nurses to physicians is another widely used indicator to show nurse supply. The trends in the number of physicians and nurses in Figure 1 indicate intuitive changes in the ratio of nurses to physicians in the past 15 years. The size of physicians over nurses had been consistently large in China until the changes occurred in 2014, for the first time, the problem of an inverted ratio of doctors to nurses was reversed. The larger size of physicians over nurses during a long period of history in China is associated with many factors and one of the reasons may be related to the duties and responsibilities of nurses and physicians different from other countries.[24] Physicians in China have been responsible for some patient care, which may be taken charge of by nurses in other countries.

Besides, we found that changes in growth rates of the nurse workforce were highly associated with policy shifts. In 2003, The Chinese Ministry of Education and the Ministry of Health issued the policies highlighting the nursing shortage, encouraging higher nursing education, and addressing the development of community health services,[15] as such, our data shows a milestone for the growth of nurse workforce at that period. In 2008, the healthcare system reform began in China, aimed to strengthen the nurse workforce, which was another significant impact on nursing growth.[25] In 2011, the Ministry of Education of the People's Republic of China issued a document to set nursing as a first-level discipline independent of clinical medicine admissions.[26] The number of nursing colleges and nursing programs has increased steadily, ensuring a rapid increase in the number of nurses.[27] Although the initial implementation of health care reform policy and the global financial crisis may affect the growth rate slightly in 2008, nurses' numbers were in a period of rapid growth, which brings about the number of nurses surpassed the number of physicians for the first time in 2014. In recent years, the support of national policies, and the increase in specialist nurses' training programs and bases increased the social recognition and attractiveness of nursing positions. Accordingly, a certain number of outstanding talents for Chinese nursing were attracted. However, the ratio of nurses to physicians is still not adequately balanced compared with many developed and developing countries worldwide.[1] Given that, along with an increasingly severe aging population and frequent epidemic challenges, it is vital to adopt effective policies attracting more talents to enter nursing practice.

The demographic composition of the nurse workforce consists of gender, age, education, and working experience. Gender diversity is still lacking in the nursing profession in China. Gender distribution shows that along with the increased proportion of male nurses, the nurse workforce in China is slowly becoming more diverse over time. There is a high demand for male nurses in China, especially after China implemented the universal two-child policy in 2016. Moreover, male nurses show great advantages in physical strength, mental toughness, and mechanics sensitivity. Accordingly, Chinese male nurses have better career prospects and promotion chances compared with female nurses.[28] The occupational cognition of male nurses is also improving in China in recent years.[29] However, the proportion of male nurses is relatively low compared to the US and the UK.[30, 31] Notably, China nurse workforce has been dominated by young aged nurses. In 2018, the proportion of nurses aged 55 or above was 4.9 percent in China that is largely lower than that in the UK (19%) and US (46%).[30, 31] And the proportion of nurses with more than 30 years of experience consistently below 10%. This could be mainly explained by the continuous nurse shortage 30 years ago. In 1990, China had 1.14 billion people but fewer than one million nurses. The severe shortage of nurses in the past has led to a shortage of aged and clinically experienced nurses today. In another respect, the young nurse workforce is an invaluable asset of the health care system in China in addressing the shortage of nursing and dealing with social health issues. In the period of fighting the COVID-19 epidemic in Wuhan, nurses aged 40 or under accounted for more than 90%, playing a vital role in fighting the virus. When the policymakers are seeking solutions to overcome the nurse shortage, it is crucial to consider and develop strategies to retain the young nurses in the workforce and extend their working years.

As for the educational level of nurses, our results confirmed that it was not until 2010 the educational composition of nurses shifted from the main body of vocational education and blow to associate's degree and above. Although there is a gradual increase in the proportion of nurses with an Associate degree and Bachelor's degree or above, there is still a gap between China and developed countries.[30, 31] There was only 2.7% of nurses who have got a bachelor's degree in 2005. The main reason for the low percentage was that undergraduate nursing education wasn't re-start until 1983 with over twenty years of break in China.[32] However, as of 2006, a total of 192 colleges and universities across the country enrolled nursing undergraduates, with more than 20,000 students enrolled.[32] By 2018, there were over 260 colleges and universities that cultivated nursing undergraduates, while 21% of nurses got a bachelor's degree and above. The evidence that nurses with higher education contribute greatly to producing high-quality care is strong. Studies report a significant association between educational level and patient outcomes, including mortality rates.[4, 33, 34] It is urgent to advance the education level of nurses in China through changes in policy, administration, and curricula, including financial advising, academic advising, and easier access to programs (e.g. flexible hours, and/or online courses).[35, 36] Also, a higher education expectation, supportive approaches from the employer could encourage nurses to continue their education.[35, 37]

The nurse workforce is not distributed equally across China. The results demonstrated a substantial variation of nursing resources across geographic and/or economic areas: a high concentration of nurses/providers within urban and/or affluent areas, versus a relative undersupply in rural and/or low-income areas. Such imbalance in the nurse workforce is neither unique to China nor to global nurse providers, which is a worldwide problem for all healthcare professionals.[38, 39] By calculating the Gini coefficient and Theil L index, we found that the differences in the distribution of

nurses in China are mainly reflected in urban and rural areas, while distribution inequality across provinces was decreasing in recent years. Considering that there are more elderly and children in need of health care reside in rural areas of China, it suggests that in the future, more attention should be paid to the urban-rural gap when focusing on health equity between provinces. In terms of distribution in different settings, the majority of nurses are still employed within the hospitals, despite policies that have aimed to strengthen primary care and shift health services towards the community.[15, 40] The proportion of nurses employed in hospitals in China is higher compared with high-income countries (e.g., England, Japan, and the US). To address the imbalanced distribution of healthcare professionals, evidence-based interventions/strategies are suggested, including focused recruitment and training, improved living and working environment, and financial and professional incentives.[41, 42]

Limitations

This study is the first to report trends, composition, and distribution of the Chinese nurse workforce over 2003-2018. However, there are some limitations to the study. Firstly, there is no nurse composition data available before 2005 from CHFPSY/CSY, and we haven't found any related data or survey. Despite some data gaps, we used the largest available data which was meant to reflect the latest trends. Secondly, as the data collection methods have been constantly modified and updated in the national surveys, it would have a certain impact on our analysis. A new criterion of urban and rural classification was adopted in 2010, which brought the incomparability of urban-rural distribution over time. In this case, we conduct analysis using data that adopt the latest standards to enhance the comparability of the results across times.

CONCLUSION

Significant changes in China's nurse workforce were found over time, such as a great increase in the number of nurses, improvement in education, and decreasing nurse workforce inequality. These changes might be highly associated with policy reformations and social and economic needs at national and global levels. Our study also suggests current features in the nurse workforce. Nurses in China are featured with less gender diversity, tend to be younger, and have lower education compared to developed countries. Findings in our study provide evidence to inform nurse workforce policy in the future.

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Figures

Figure 1. Trends in the supply of nurses and physicians from 2003 to 2018

Figure 2. The growth rates in the supply of nurses and physicians from 2003 to 2018

Figure 3. Change of the proportion of male nurses from 2005 to 2018

Figure 4. Distribution of nurses across provinces in China, 2018

Figure 5. Change of nurse distribution across settings in China from 2010 to 2018

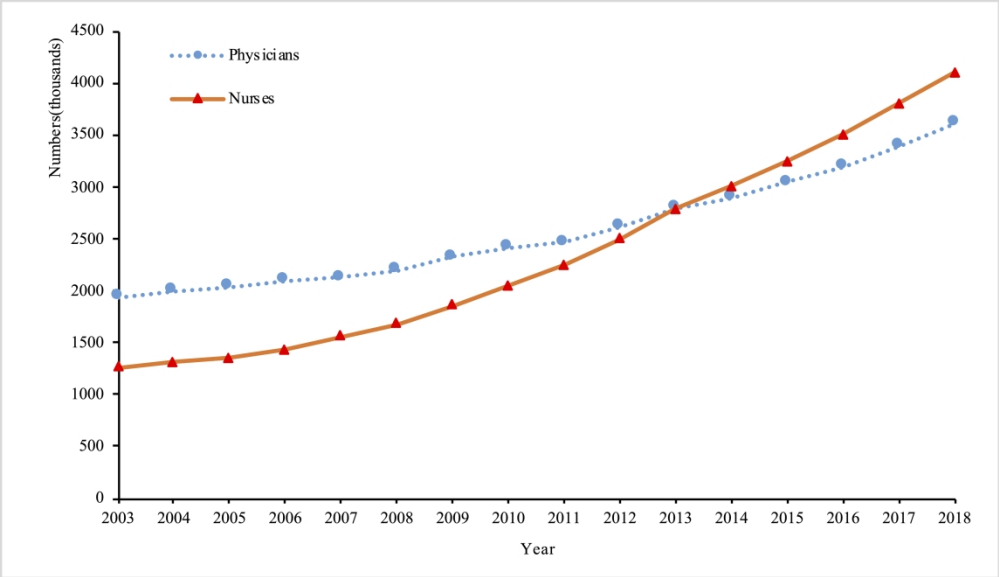

Figure 1. Trends in the supply of nurses and physicians from 2003 to 2018

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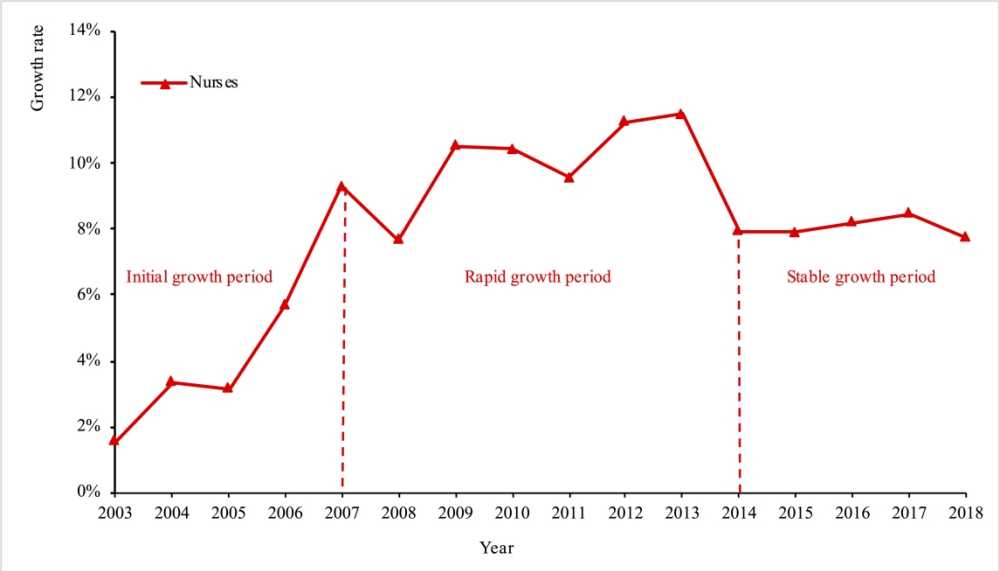

Figure 2. The growth rates in the supply of nurses and physicians from 2003 to 2018

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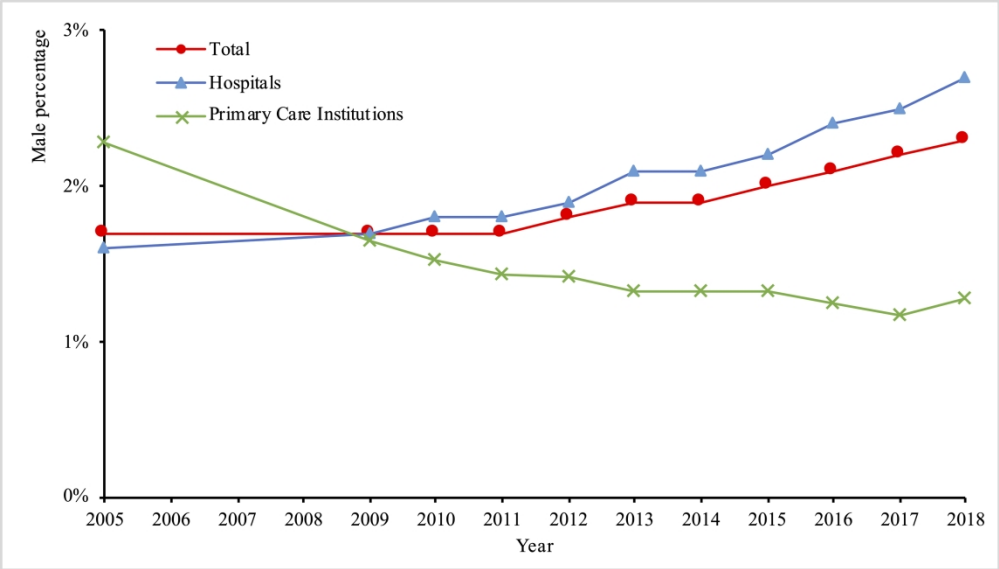

Figure 3. Change of the proportion of male nurses from 2005 to 2018

147x83mm (600 x 600 DPI)

Figure 4. Distribution of nurses across provinces in China, 2018

126x130mm (600 x 600 DPI)

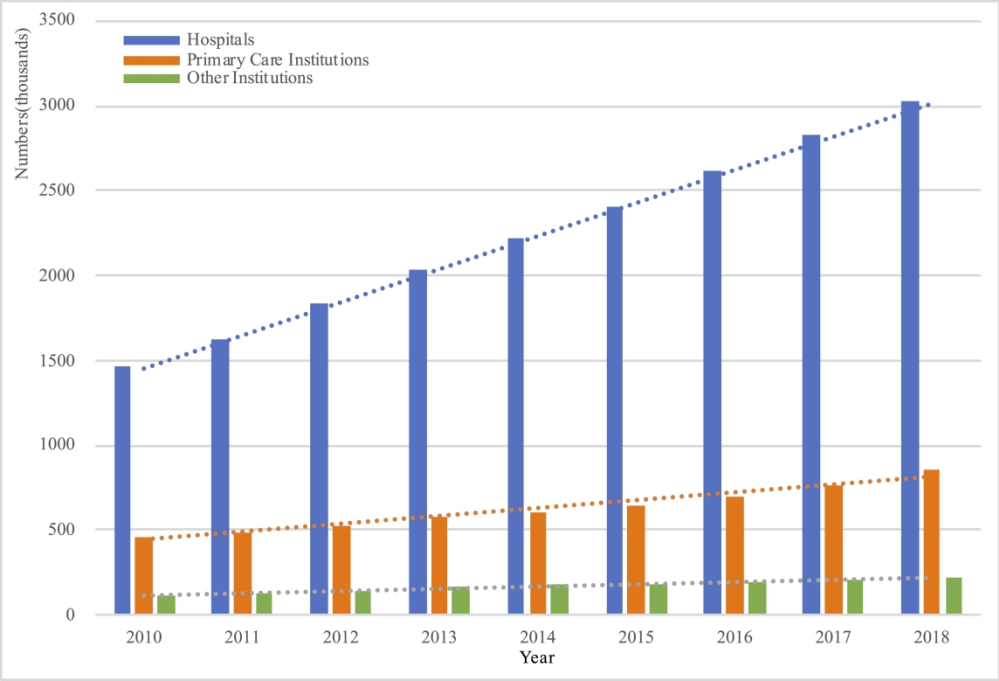

Figure 5. Change of nurse distribution across settings in China from 2010 to 2018

156x106mm (600 x 600 DPI)

Supplemental files:

Table A. Urban-rural distribution of nurse workforce from 2010 to 2018

	Urban		Rural	
Year	Number	Density*	Number	Density*
2010	1200343	3.09	847728	0.89
2011	1304202	3.29	939818	0.98
2012	1449513	3.65	1047086	1.09
2013	1603913	4.00	1179208	1.22
2014	1737367	4.30	1266777	1.31
2015	1892835	4.58	1348634	1.39
2016	2063019	4.75	1444147	1.50
2017	2244366	5.01	1559655	1.62
2018	2417653	5.08	1680977	1.80

Note: *Per 1000 population.

Table B. The amount of visits, inpatients and nurses distribution across settings in China from 2010 to 2018

	Hospitals						Primary Care Institutions*						Other Institutions*					
	Outpatient Visits (10000 person-times)		Inpatients (10000 person)		Nurses		Outpatient Visits (10000 person-times)		Inpatients (10000 person)		Nurses		Outpatient Visits (10000 person-times)		Inpatients (10000 person)		Nurses	
Year	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent
2010	203963.3	34.9%	9524	67.2%	1468754	71.7%	361155.6	61.9%	3950	27.9%	466503	22.8%	18642.7	3.2%	700	4.9%	112814	5.5%
2011	225883.7	36.0%	10755	70.3%	1627761	72.5%	380559.8	60.7%	3775	24.7%	492554	21.9%	20679.1	3.3%	768	5.0%	123705	5.5%
2012	254161.6	36.9%	12727	71.3%	1830202	73.3%	410920.6	59.7%	4254	23.8%	528178	21.2%	23750.7	3.4%	876	4.9%	138219	5.5%
2013	274177.7	37.5%	14007	72.9%	2041367	73.3%	432431	59.1%	4300	22.4%	576630	20.7%	24792.3	3.4%	908	4.7%	165124	5.9%
2014	297207	39.1%	15375	75.2%	2222293	74.0%	436394.9	57.4%	4094	20.0%	603900	20.1%	26584.7	3.5%	972	4.8%	177951	5.9%
2015	308364.1	40.1%	16087	76.4%	2407632	74.3%	434192.7	56.4%	4036	19.2%	646607	19.9%	26785.7	3.5%	930	4.4%	187230	5.8%
2016	326955.9	41.2%	17528	77.1%	2613367	74.5%	436663.3	55.1%	4165	18.3%	695781	19.8%	29550.8	3.7%	1035	4.6%	198018	5.6%
2017	343892.1	42.0%	18915	77.4%	2822446	74.2%	442891.6	54.1%	4450	18.2%	769206	20.2%	31527.3	3.9%	1071	4.4%	212369	5.6%
2018	357737.5	43.1%	20017	78.6%	3020813	73.7%	440632	53.0%	4376	17.2%	852377	20.8%	32432.2	3.9%	1060	4.2%	225440	5.5%

Note: No data available for primary care institutions before 2010, so we used the data from 2010 to 2018 for analysis. *Include specialized public health institutions, sanatoriums, clinical laboratory centers, medicinal scientific research institutions, on-job training institutions, health supervision institutions, medical examination centers, rural water improvement centers, talent exchange centers, and statistical information centers, etc.

Table C. Gini coefficient and Theil index of nurse workforce from 2010 to 2018

	Overall inter-provincial		Between-provincial	Within-provincial	Within provincial /overall
	Gini	Theil L	Theil L	Theil L	Theil L
2010	0.167	0.021	0.010	0.011	52.38%
2011	0.150	0.016	0.008	0.008	50.00%
2012	0.139	0.015	0.008	0.007	46.67%
2013	0.133	0.013	0.007	0.006	46.15%
2014	0.125	0.012	0.006	0.006	50.00%
2015	0.123	0.012	0.006	0.006	50.00%
2016	0.121	0.015	0.005	0.010	66.67%
2017	0.120	0.015	0.005	0.010	66.67%
2018	0.119	0.014	0.004	0.010	71.43%

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Trends, Composition, and Distribution of Nurse Workforce in China: A Secondary Analysis of National Data from 2003 to 2018

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Trends, Composition, and Distribution of Nurse Workforce in China: A Secondary Analysis of National Data from 2003 to 2018

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Trends, Composition, and Distribution of Nurse Workforce in China: A Secondary Analysis of National Data from 2003 to 2018

ABSTRACT

Objectives Given the increased aging population and frequent epidemic challenges, it is vital to have the nurse workforce of sufficient quantity and quality. This study aimed to demonstrate the trends, composition, and distribution of nurse workforce in China.

Design Secondary analysis using national public datasets in China from 2003 to 2018.

Setting/Participants National population, nurse workforce, and physician workforce.

Primary and secondary outcome measures Frequency and proportion were used to demonstrate 1) the longitudinal growth of nurse workforce; 2) the diversity of nurse workforce in gender, age, work experience, and education level; and 3) the distribution of nurse workforce among provinces, rural-urban areas, and hospital/community settings. The Gini coefficient and Theil L index were used to measure the inequality trends of nurse workforce.

Results The total number of nurses increased from 1.3 million to 4.1 million and the density increased from 1 to 2.94 per 1000 population over 2003-2018. The nurses to physician ratio changed from 0.65:1 to 1.14:1. The majority of the nurse workforce was female, under 35 years old, with less than 30 years of work experience, with an associate's degree, and employed within hospitals. Central and Eastern regions had more nurses and there were 5.08 nurses per 1000 population in urban areas while less than two in rural areas in 2018. The Gini coefficient and between-provincial Theil index experienced a consistent decline. Within-province inequality accounted for overall inequality has risen from 52.38% in 2010 to 71.43% in 2018 suggested that the differences of distribution are mainly reflected in urban and rural areas.

Conclusion Chinese nurse workforce has been changed significantly in the past 15 years that may be associated with the reformations of policy, nursing education in China. Our study suggests current features in the nurse workforce and can be used to strengthen future health services.

Strengths and limitations of this study

1. This study shows the longitudinal growth, the demographic composition, the distribution across urban-rural regions and working settings, and the distribution inequality of the Chinese nurse workforce using the national data over 2003 - 2018.
2. As the effective inequality scales, the Gini coefficient and Theil index were calculated to measure the inequality of nurse workforce distribution in China.
3.This study will provide epidemiologic evidence for policy making, healthcare administration, education, and further research to strengthen the nurse workforce.
4. Limitations based on secondary data analysis also apply to this study.
5. Some nurse composition data are inadequately updated before 2005, and the data collection methods have been constantly modified and updated in the national surveys.

INTRODUCTION

Nursing is the largest profession in the current health care workforce and healthcare service systems in China and worldwide. Nursing profession has been playing a central role in the health delivery system and providing a full range of responsibilities in health promotion, prevention, treatment, and rehabilitation. There is a large variation of the growth of nursing workforce among different global regions and countries, and nursing shortage as well as other nursing workforce issues have always been a world-wide health service challenge.[1] It is vital to have the nurse workforce of sufficient capacity, capability, and quality in achieving population health and universal health coverage. A higher proportion of nurses, especially nurses with a higher education level in the health workforce is associated with better health outcomes.[2-5] As the aging population grows heavily globally, as well as the frequent public health emergencies in the past decades, there is an increasing need for safe and quality health care and nurse labor.[6-8]

World Health Organization (WHO) evidenced that despite significant progress, there is a growing mismatch between supply, need, and demand of the nurse workforce, resulting in staff shortages.[9] And WHO projected a significant growth (55%) of nurse workforce demand, leading to an aggregate number of 32.3 million nurses/midwives by 2030 based on current trends.[10] Even in the US, the nursing labor market continues to tighten with 45% of hospitals projecting to increase the number of nurse staff.[11]

As a middle-income country, China has been experiencing a very fast pace of the population aging process and has the largest older population: more people are going to need more care for longer. In particular, the degree of aging is showing an unbalanced trend. The proportion of people over 60 years old in rural areas (20.6%) is higher than that in urban areas (16.4%), while rural health resources have been largely underinvested and remain in deficit.[12] These disparities lead to heavy healthcare burden in rural areas. Also, the inequality in the distribution of health resources between provinces cannot be ignored owing to the vast territory.[13] As a result, China has been facing tremendous challenges regarding the nurse workforce.[14]

Over the past two decades, the systems of medical education and health care have undergone unprecedented reform in China. In essence, the educational composition is the reflection of economic structure on the demand for human resources. In 2001, China joined the World Trade Organization, boosting the development of finance. Under that circumstance, with the development of medical science and reform of the healthcare system, the composition of nursing education has made corresponding changes. In 2003, the Ministry of Education in China combined with the other 5 Ministries defined nurses as a critically needed profession.[15] To achieve a highly qualified nurse workforce, the government has taken this as a priority in healthcare management. During the 13th Five-Year plan (2016-2020) of China, the main goals of the nursing development have been established to prepare 4.45 million registered nurses or 3.14 nurses per thousand population by 2020.[16] As a result of that Five-Year strategic plan, there were almost 4.43 million nurses in China in 2019, which increased by nearly one million from 2016.[17]

To date, the nurse workforce has improved significantly through the reform of healthcare system and health education in China. To our knowledge, the research is still lacking to demonstrate the trends of the Chinese nurse workforce from a national perspective. This study analyzed the public data from the *China Health and Family Planning Statistical Yearbooks (CHFPSY)* and *China Statistical*

Yearbooks (CSY), illustrating the current nurse workforce and trends of over 2003 to 2018 in China. Specifically, we examined: 1) the growth of the nurse workforce, 2) the compositions of nurse workforce, including the diversity in gender, age, work experience, and education level, and 3) the distribution of nurse workforce across provinces, rural-urban areas, and healthcare settings.

METHODS

Study design

A secondary analysis design was used in the study. Data was retrieved from the *CHFPSY* and *CSY*. The two databases are national annual survey reports reflecting the statistics of the healthcare workforce, population health status, and economic and social aspects of 31 provinces, autonomous regions, and municipalities in China (except for Hongkong, Macao, and Taiwan areas). The annual data from 2003 to 2018 from the *CHFPSY* (yearbooks of 2004-2019) were used in analyzing the trends, composition and distribution of the nurse workforce over the past 15 years. We also used the *CSY* dataset to retrieve the population data of the national and province levels and calculated the equality/inequality of the distribution of nursing resources over 2003-2018 in China.

Variables and Definitions

The primary variables and definitions included in the data analysis are described as the following, which are corresponding to the national survey datasets:

1) Nurses are those who have passed the nurse qualification examination and obtained a nursing qualification.
2) Physicians are those who pass a licensing examination and are registered at a healthy authority, including licensed physicians and licensed physician assistants.
3) Hospitals include general hospitals, affiliated hospitals of medical college, hospitals specialized in traditional Chinese medicine, hospitals of integrated traditional Chinese with western medicine, national hospitals, specialized hospitals, and nursing homes.
4) Primary care institutions include community health service centers, community health service stations, urban health centers, township health centers, village clinics, and outpatient departments and health centers.
5) The urban areas include municipalities and prefecture-level municipalities.
6) The rural areas include counties and county-level cities, townships, and villages.
7) The density of nurses is defined as the number of nurses per 1000 population.

Data analysis

We downloaded the data from each of the yearbook datasets from 2004 to 2019, which correspond to the nurse and population data of 2003-2018. Excel software was used to merge, manage, and analyze the data. We used frequency and proportion to describe the composition and distributions of the nurse workforce throughout 2003-2018. The growth rate of nurses was calculated as the annual increased number of nurses divided by the total number of nurses of the previous year.

As for the inequality of nursing distribution, we adopted the Gini coefficient and Theil L index, which have been proposed by the WHO to describe the inequality of the health workforce and applied in measuring the health workforce in China and India. [18] The Gini coefficient, an indicator for judging the degree of equality of distribution according to the Lorenz curve, though not decomposable, is the most well-known indicator to measure the aggregate level of inequality. We sorted the number of

nurses per 1000 population in each province from small to large, using the cumulative population percentage as the abscissa and using the cumulative percentage of nurses as the ordinate to draw the Lorenz curve of the distribution of nurses across the country by population. The Gini coefficient is twice the area enclosed by the Lorenz curve and the perfect equality line.[19] If b_i= number of nurses in province unit *i* and c_i= number of people in province unit *i*, then the total number of nurses in the country is $B=b_1+b_2+...+b_n$ and the total number of people in the country is $C=c_1+c_2+...+c_n$. If we value $B_i=b_i/B$, $C_i=c_i/C$, then the Gini coefficient $G = 1 - \sum_{i=1}^{I} C_i(2\sum_{i=1}^{I} B_i - B_i)$. For further analysis, the Theil L index is the most attractive decomposition indicator, as it can be decomposed into two parts, between-groups (T_{1L}) and within-groups (T_{2L}), respectively. If *j* means urban or rural, then B_{ij} means the proportion of urban or rural nurses in province unit *i* in the total nurses, and C_{ij} means the proportion of the urban or rural population in province unit *i* in the total population. The decomposition of Thiel L index is as follows:

$$\text{Theil L} = T_{1L} + T_{2L} = \sum_{i=1}^{I} C_i \log\frac{C_i}{B_i} + \sum_{i=1}^{I} C_i \sum_{j=1}^{J} C_{ij} \log\frac{C_{ij}}{B_{ij}}$$

This study calculated the Gini coefficient and Theil L index to estimate the level of equality among nurse distribution and they were all weighted by the proportion of the population in each province in the total population as we explained in the formula. Besides, we calculated the ratio of the provincial Theil index to the total Theil index to represent the contribution rate of urban-rural differences to total differences.[20] The Gini coefficient and Theil L value from 0 to 1. The smaller value means fairer nurse distribution. We use Microsoft Excel 2013 to perform the above analyses.

Patient and Public Involvement

A few nurses were involved in the reporting of our research and gave suggestions on the content and presentation of our research.

RESULTS

Growth of Nurse Workforce

Over 15 years, the nurse workforce has grown dramatically in China. At the end of 2018, the number of nurses reached over four million, which is 2.2 times more than that in 2003. The density of nurses increased by 1.9 times in the same period to reach about 2.94 nurses per 1000 population in 2018 (Table 1 and Figure 1). In Figure 2, the growth rates of the nurse workforce reveal three segments: an initial period of growth (2003-2006), a rapid growth period (2007-2013), and a period of stable growth (2014-2018). In the initial growth period, the growth rate dramatically increased from 1.6 percent in 2003 to 5.7 percent in 2006. The rapid growth period began in 2007 (9.3%), declined slightly in 2008 and 2011, then rose and reached the highest growth rate (11.5%) in 2013. Since 2014, there was a stable growth rate ranged from 7.7 percent to 8.5 percent.

Meanwhile, we also compared nurses vs. physician workforce in China (Table 1). In a long period of history before 2014, China had been with more physicians than nurses (Figure 1). With the rapid expansion of the nursing staff, the imbalance of nurses and physicians has been changed, and the ratio of nurses to physicians changed from 0.65:1 in 2003 to 1.14:1 in 2018.

Table 1. Change of nurse and physician workforce from 2003 to 2018

	Nurses		Physicians	
Year	Number	Density*	Number	Density*
2003	1265959	1.00	1942364	1.54
2004	1308433	1.03	1999457	1.57
2005	1349589	1.03	2042135	1.56
2006	1426339	1.09	2099064	1.60
2007	1558822	1.18	2122925	1.61
2008	1678091	1.2	2201904	1.66
2009	1854818	1.39	2329206	1.75
2010	2048071	1.53	2413259	1.80
2011	2244020	1.66	2466094	1.82
2012	2496599	1.85	2616064	1.94
2013	2783121	2.04	2794754	2.04
2014	3004144	2.20	2892518	2.12
2015	3241469	2.37	3039135	2.22
2016	3507166	2.54	3191005	2.31
2017	3804021	2.74	3390034	2.44
2018	4098630	2.94	3607156	2.59

Note: *Per 1000 population.

Nurse Demographics and Characteristics

Table 2 presents nurse demographics and characteristics in overall health institutions, hospitals, and primary care institutions in China between 2005 and 2018 (no data available before 2005). The nurse workforce in China has been always predominately female, with the proportion of male nurses slightly increased from 1.7% in 2005 to 2.3% in 2018. Figure 3 shows the different composition of male nurses in hospitals vs. primary care institutions. From 2005 to 2018, male nurses working in primary care institutions dropped to 1.3%, while the proportion in hospitals steadily rose from 1.6 to 2.7%.

Table 2. Demographics and characteristics of nurses from 2005 to 2018

	Overall health institutions				Hospitals				Primary care institutions*			
Year	2005	2010	2015	2018	2005	2010	2015	2018	2005	2010	2015	2018
Gender												
Male	1.7	1.7	2.0	2.3	1.6	1.8	2.2	2.7	2.3	1.5	1.3	1.3
Female	98.3	98.3	98.0	97.7	98.4	98.2	97.8	97.3	97.7	98.5	98.7	98.7
Age												
under 25	10.1	14.1	14.1	9.7	10.2	14.7	15.0	9.7	9.1	12.3	12.0	9.0
25～34	40.3	39.6	46.8	50.6	38.2	39.0	48.8	53.1	52.6	42.5	39.9	42.7
35～44	31.6	26.9	22.0	22.1	32.7	26.6	19.9	20.6	25.6	30.1	31.6	28.7
45～54	17.3	16.9	14.0	12.7	18.1	17.6	13.7	12.1	12.1	13.4	14.7	16.3
55～59	0.6	2.2	2.0	3.4	0.6	2.0	1.9	3.4	0.5	1.5	1.4	2.7
60 or above	0.1	0.4	1.1	1.5	0.1	0.2	0.7	1.1	0.1	0.2	0.4	0.6
Work Experience(years)												
under 5	14.1	23.6	29.7	21.3	14.0	24.3	31.4	21.7	14.3	21.1	25.8	19.5
5～9	19.4	16.2	24.1	31.2	17.5	16.5	24.8	32.5	30.2	13.8	21.0	27.2
10～19	35.9	29.1	20.6	23.9	36.3	27.2	19.1	23.7	35.0	39.0	25.8	23.6
20～29	22.7	21.8	16.7	14.3	23.8	22.8	16.1	13.1	16.6	18.9	20.5	21.4
30 or above	7.7	9.3	8.8	9.3	8.3	9.3	8.5	9.1	3.9	7.2	6.9	8.3
Education												
Master's or above	0.0	0.1	0.1	0.2	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0
Bachelor's	2.7	8.7	14.5	20.8	3.2	10.5	16.7	23.5	0.4	2.6	6.9	13.4
Associate's	28.9	42.5	47.9	48.9	31.8	45.5	50.3	50.4	14.1	32.8	39.9	44.4
Vocational education	60.4	46.0	36.3	29.6	57.7	41.5	31.9	25.5	73.9	60.4	51.2	41.1
High school or below	7.9	2.7	1.1	0.6	7.3	2.5	1.0	0.5	11.6	4.2	2.0	1.1

Note: *Estimated by authors based on demographics data of community health service stations and township health centers.

Young nurses are the main force of the nurse workforce in China. Employees under 35-year-old were accounted for 60.3% of the total nurses in 2018. In table 2, the proportion of nurses between the age of 25 and 34 and those over 55-year-old increased during 2005-2018, whereas the proportion of nurses between 35 and 54 declined slightly. Moreover, the proportion of nurses between 25-34 years old grew gradually in hospital settings but decreased in the primary care institutions across the 15 years. In 2018, there were more young nurses (under 35) in hospitals than primary care institutions.

The nurses' educational levels have changed over time with an increased proportion of the higher level of degrees. The percentage of nurses with a vocational education degree or below dropped year by year, from 74.4% in 2002 to 30.2% in 2018. Associate's degree nurses have become the main force of registered nurses in China, accounting for 48.9% in 2018. The growth of nurses with bachelor's, master's, or Ph.D. degree was fast over the period. By the end of 2018, the proportion of nurses with a

bachelor's degree or above have reached 21.0%. Compared with primary care settings, hospitals had more nurses with higher education levels.

The proportion of experienced nurses who were serving more than 30 years was relatively small in China nurse workforce. The proportion of nurses with 10-29 years' work experience has decreased continually (58.6% in 2005 to 38.2% in 2018), while the percentage of nurses with less than 10 years' experience increased (33.5% in 2005 to 52.5% in 2018). A similar trend was shown overtimes for the distribution of nurse working experience in the hospital and primary care settings, but more hospital nurses had less than 10 years' work experience, and more primary care nurses were with more than 20 years' work experience.

Distribution across Provinces, Rural-Urban Areas, and Settings

We adopted the latest data of 2018 to analyze the nurse distribution among different provinces in China. The density of nurses in each of the provinces and areas ranged from approximately a high of 5.0 nurses in Beijing to a low of 1.6 nurses per 1000 population in Tibet. Figure 4 shows that the provinces in the Northeastern and Western regions had a relatively low density of the nurse workforce, whereas provinces in the Central and Eastern regions tended to have a high nurse per capital supply.

As for the urban-rural distribution of nurses in China, the criteria used in the datasets for dividing urban and rural areas before 2010 were different from those for the recent years, therefore we used the data from 2010 to 2018 for analysis. The data shows that there were large differences between urban and rural areas. In 2010, there were more than three nurses per 1000 population in urban areas, while there was less than one nurse per 1000 population among rural areas. Over the past decade, the number and density of nurses in both urban and rural areas have greatly increased, but the gap between urban and rural areas has not been narrowed. By 2018, there were 5.08 nurses per 1000 population in urban areas, while the number of that in rural areas was still less than two (Supplementary file).

In 2018, the majority of nurses (73.70%) were employed within hospital settings, and only about 20% of nurses worked in primary care institutions (see Figure 5). Over the past ten years, there was a tendency that more patients went to hospitals rather than primary care institutions (Supplementary file). Hospitals received more than 70% of inpatients and 40% of overall outpatient visits, and primary health care institutions were responsible for over 50% of the visits and 20% of inpatients. During the last decade, although the number of nurses working in all institutions has increased significantly, the distribution of nurses across settings had no significant changes.

To further examine the distribution of equality of the nurse workforce, we calculated the Gini coefficient and Theil L index. Although the analyses were based on the provincial data, due to the lack of valid individual residential data, the results demonstrated significance for understanding the distribution across provinces and between the urban and rural areas over the country. The Gini coefficient of nurses fell from 0.167 in 2010 to 0.119 in 2018. Between-provincial Theil index had similar trends to the corresponding Gini index, dropped from 0.010 in 2010 to 0.004 in 2018. Overall and within-provincial Theil index experienced a decline from 2010 to 2015 and has risen again in the past three years. Within-province inequality accounted for overall inter-provincial inequality has risen consistently, with a peak in 2018 (Theil L: from 52.38% in 2010 to 71.43% in 2018) (Supplementary file).

DISSCUSSION

Understanding the nurse workforce trends, composition, and distribution of supply is crucial for building an effective health care system. The current study presents national data with longitudinal and recent status on the nurse workforce in China from 2003 to 2018. To the best of our knowledge, this is the first study to report trends of the nurse workforce on a large scale, national level, and over the past 15 years of period. As in many ways, the nursing human resources and education, and health and family policy all impact each other,[21] the results of the analysis in this article can be used for policy making, health care administration, education, and further research to strengthen nurse workforce.

The number of Chinese nurse workforce in 2017 (3.8 million) accounted for 18 percent of the nurse workforce in the world (20.7 million), and this number increased to 4.1 million in 2018.[22] The Chinese nurses per 1000 population were 2.94 in 2018, exceeding the minimum standard set by WHO (two nurses per 1000 populations) and some developing countries (e.g. India and South Africa), yet this density is still relatively below the average density of Organization for Economic Co-operation and Development (OECD) member countries (nine nurses per 1000 populations and 50% of WHO Member States in 2017.[22, 23] The ratio of nurses to physicians is another widely used indicator to show nurse supply. The trends in the number of physicians and nurses in Figure 1 indicate intuitive changes in the ratio of nurses to physicians in the past 15 years. The size of physicians over nurses had been consistently large in China until the changes occurred in 2014, for the first time, the problem of an inverted ratio of doctors to nurses was reversed. The larger size of physicians over nurses during a long period of history in China is associated with many factors and one of the reasons may be related to the duties and responsibilities of nurses and physicians different from other countries.[24] Physicians in China have been responsible for some patient care, which may be taken charge of by nurses in other countries.

Besides, we found that changes in growth rates of the nurse workforce were highly associated with policy shifts. In 2003, The Chinese Ministry of Education and the Ministry of Health issued the policies highlighting the nursing shortage, encouraging higher nursing education, and addressing the development of community health services,[15] as such, our data shows a milestone for the growth of nurse workforce at that period. In 2008, the healthcare system reform began in China, aimed to strengthen the nurse workforce, which was another significant impact on nursing growth.[25] In 2011, the Ministry of Education of the People's Republic of China issued a document to set nursing as a first-level discipline independent of clinical medicine admissions.[26] The number of nursing colleges and nursing programs has increased steadily, ensuring a rapid increase in the number of nurses.[27] Although the initial implementation of health care reform policy and the global financial crisis may affect the growth rate slightly in 2008, nurses' numbers were in a period of rapid growth, which brings about the number of nurses surpassed the number of physicians for the first time in 2014. In recent years, the support of national policies, and the increase in specialist nurses' training programs and bases increased the social recognition and attractiveness of nursing positions. Accordingly, a certain number of outstanding talents for Chinese nursing were attracted. However, the ratio of nurses to physicians is still not adequately balanced compared with many developed and developing countries worldwide.[1] Given that, along with an increasingly severe aging population and frequent epidemic challenges, it is vital to adopt effective policies attracting more talents to enter nursing practice.

Growing and developing a more diverse and sustainable nursing workforce in China is still challenging in achieving the goal of health equity. Female nurses dominate and males (2.3 %) remain largely underrepresented in the nursing profession in China, in comparison with the proportion of male nurses in the US (9.6%) and the UK (10.7%), which may be related to different cultures and efforts to increase the gender diversity in nursing.[28, 29] Meanwhile, our finding shows that along with the increased proportion of male nurses, the nurse workforce in China is slowly becoming more diverse over time. There is a high demand for male nurses in China, especially after China implemented the universal two-child policy in 2016. Moreover, male nurses show great advantages in physical strength, mental toughness, and mechanics sensitivity. Accordingly, Chinese male nurses have better career prospects and promotion chances compared with female nurses.[30] The occupational cognition of male nurses is also improving in China in recent years.[31] Notably, China's nurse workforce has been also dominated by young and middle-aged nurses, with more than 70% of nurses being 22-44 years old but the proportion of nurses with more than 30 years of experience consistently below 10%. This unbalanced composition of age and working experience may result from the continuous nurse shortage in the past 30 years and rapid expansion in the past decades, for instance, in 1990, China had 1.14 billion people but only fewer than one million nurses. The severe shortage of nurses in the past has led to a shortage of senior and clinically experienced nurses today, significantly, the proportion of nurses over 55 years old in China (4.9%) is small, compared to the US (46%) and the UK (19%).[28, 29] This is mainly due to China's retirement policy, where most women retire at the age of 55. In another respect, the young nurse workforce is an invaluable asset of the health care system in China in addressing the shortage of nursing and dealing with social health issues. In the period of fighting the COVID-19 epidemic in Wuhan, nurses aged 40 or under accounted for more than 90%, playing a vital role in fighting the virus. When the policymakers are seeking solutions to overcome the nurse shortage, it is crucial to consider and develop strategies to retain the nurses in the workforce and extend their career. Nursing workforce development and retention strategies need to promote different gender, and age and experience groups of nurses. For instance, research has shown that young nurses are more likely to leave due to the imbalance between effort and reward, high psychological demands, and elevated job strain, which suggests that policymakers need to provide young nurses with sufficient social support and the balance between effort and rewards such as salary, recognition, and career opportunities to attract and retain young nurses.[32, 33]

As for the educational level of nurses, our results confirmed that it was not until 2010 the educational composition of nurses shifted from the main body of vocational education and blow to associate's degree and above. Although there is a gradual increase in the proportion of nurses with an associate degree and bachelor's degree or above, there is still a gap between China and developed countries.[28, 29] There was only 2.7% of nurses who have received a bachelor's degree in 2005. The main reason for the low percentage was that undergraduate nursing education had not re-started until 1983 with over twenty years of break in China.[34] However, as of 2006, a total of 192 colleges and universities across the country enrolled nursing undergraduates, with more than 20,000 students enrolled.[34] By 2018, there were over 260 colleges and universities that cultivated nursing undergraduates, while 21% of nurses obtained a bachelor's degree and above. The evidence that nurses with higher education contribute greatly to producing high-quality care is strong. Studies report a significant association between educational level and patient outcomes, including mortality rates.[4, 35,

36] It is urgent to improve the education level of nurses in China. At the policy level, while encouraging the development of advanced nursing education, it is necessary to consider providing a broader career development path for highly educated nurses, so as to attract nurses to pursue high education and retain highly educated nursing talents. In addition, considering that many nurses in China have only received an associate's and vocational education, continuing education needs to be vigorously developed. Potential strategies include providing financial advising, academic advising, and open access to programs (e.g. flexible schedules, and/or online courses). [37, 38] Also, a higher education expectation and supportive approaches from the employer may motivate nurses to continue their education.[37, 39]

The nurse workforce is lack of diversity and unequally distributed across China. The results demonstrated a substantial variation of nursing resources across geographic and/or economic areas: a high concentration of nurses/providers within urban and/or affluent areas, versus a relative undersupply in rural and/or low-income areas. Such imbalance in the nurse workforce is neither unique to China nor to global nurse providers, which is a worldwide problem for all healthcare professionals.[40, 41] By calculating the Gini coefficient and Theil L index, we found that the differences in the distribution of nurses in China are mainly reflected in urban and rural areas, while distribution inequality across provinces was decreasing in recent years. Considering that there are more elderly and children in need of health care reside in rural areas of China, it suggests that in the future, more attention should be paid to the urban-rural gap when focusing on health equity between provinces. In terms of distribution in different settings, the majority of nurses are still employed within the hospitals, despite policies that have aimed to strengthen primary care and shift health services towards the community.[15, 42] The proportion of nurses employed in hospitals in China is higher compared with developed countries (e.g., England, Japan, and the US). To address the imbalanced distribution of healthcare professionals, evidence-based interventions/strategies are suggested, including focused recruitment and training, improved living and working environment, and financial and professional incentives.[43, 44]

Limitations

This study is the first to report trends, composition, and distribution of the Chinese nurse workforce over 2003-2018. However, there are some limitations to the study. Firstly, there is no nurse composition data available before 2005 from CHFPSY/CSY, and we haven't found any related data or survey. Despite some data gaps, we used the largest available data which was meant to reflect the latest trends. Secondly, as the data collection methods have been constantly modified and updated in the national surveys, it would have a certain impact on our analysis. A new criterion of urban and rural classification was adopted in 2010, which brought the incomparability of urban-rural distribution over time. In this case, we conduct analysis using data that adopt the latest standards to enhance the comparability of the results across times.

CONCLUSION

Significant changes in China's nurse workforce have been found over time, such as a great increase in the total number of nurses, improvement in education, and decreasing nurse workforce inequality. These changes might be highly associated with policy reformations and social and economic needs at the national and global levels. Our study also suggests current features in the nurse workforce. Nurses in China are featured with less gender diversity, tend to be younger, and have lower education level

compared to developed countries. Findings in our study provide evidence to inform nurse workforce policy, education, and healthcare services in the future.

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Patient consent for publication Not required.

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Data sharing: The access policy and procedures are available at https://data.cnki.net/yearbook.

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Figures

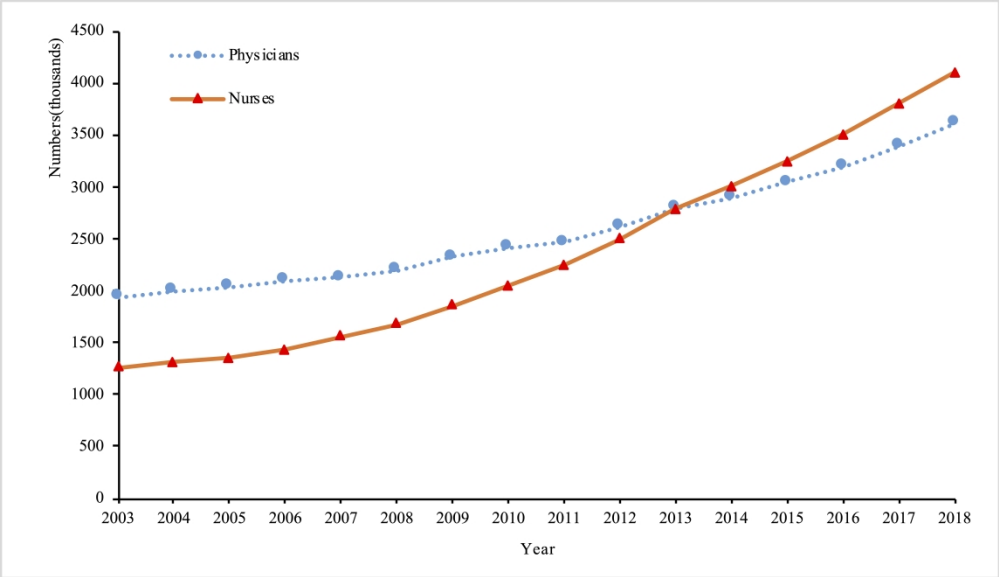

Figure 1. Trends in the supply of nurses and physicians from 2003 to 2018

170x98mm (1200 x 1200 DPI)

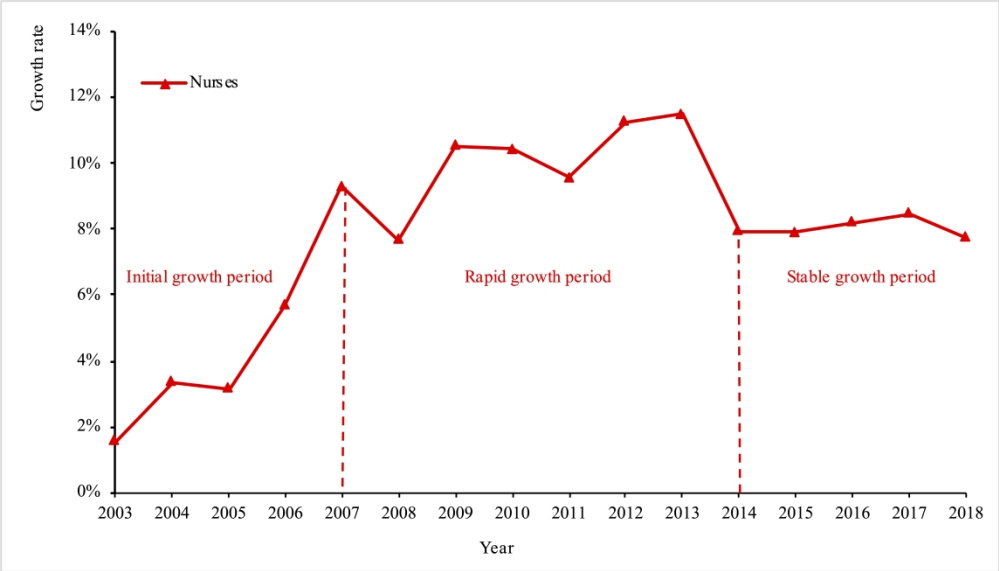

Figure 2. The growth rates in the supply of nurses from 2003 to 2018

161x92mm (1200 x 1200 DPI)

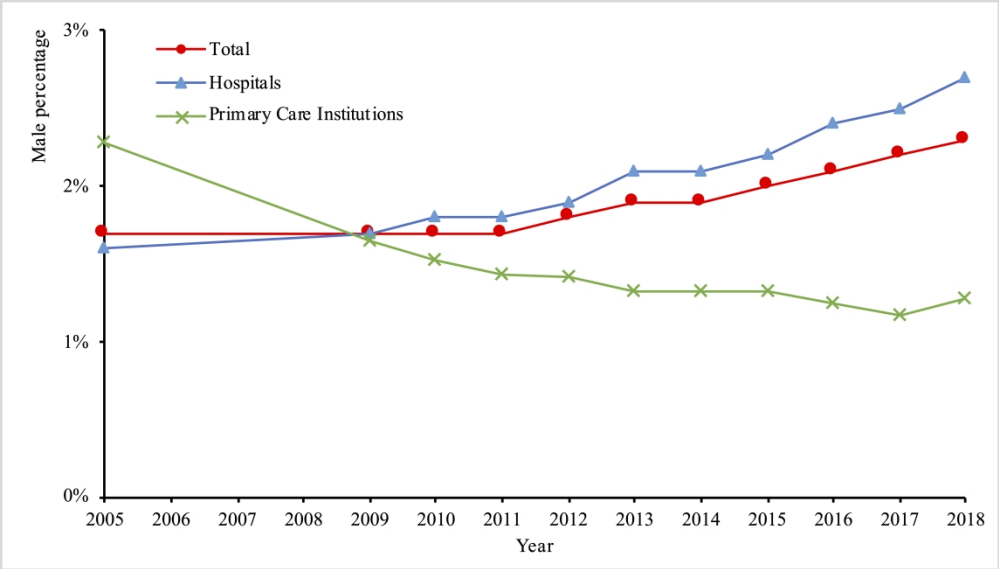

Figure 3. Change of the proportion of male nurses from 2005 to 2018

147x83mm (1200 x 1200 DPI)

Figure 4. Distribution of nurses across provinces in China, 2018

126x130mm (1200 x 1200 DPI)

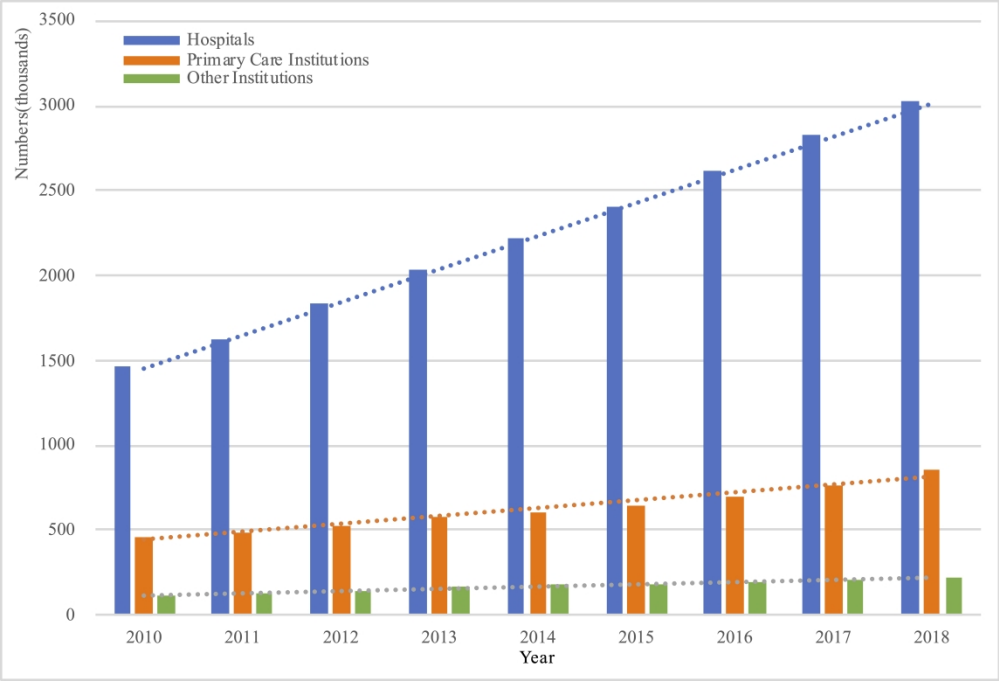

Figure 5. Change of nurse distribution across settings in China from 2010 to 2018

156x106mm (1200 x 1200 DPI)

SUPPLEMENTAL FILE

Table A. Urban-rural distribution of nurse workforce from 2010 to 2018

Year	Urban		Rural	
	Number	Density*	Number	Density*
2010	1200343	3.09	847728	0.89
2011	1304202	3.29	939818	0.98
2012	1449513	3.65	1047086	1.09
2013	1603913	4.00	1179208	1.22
2014	1737367	4.30	1266777	1.31
2015	1892835	4.58	1348634	1.39
2016	2063019	4.75	1444147	1.50
2017	2244366	5.01	1559655	1.62
2018	2417653	5.08	1680977	1.80

Note: *Per 1000 population.

Table B. The number of visits, inpatients and nurses distribution across settings in China from 2010 to 2018

Year	Hospitals						Primary Care Institutions						Other Institutions*					
	Outpatient Visits (10000 person-times)		Inpatients (10000 person)		Nurses		Outpatient Visits (10000 person-times)		Inpatients (10000 person)		Nurses		Outpatient Visits (10000 person-times)		Inpatients (10000 person)		Nurses	
	n	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent	*n*	percent
2010	203963.3	34.9%	9524	67.2%	1468754	71.7%	361155.6	61.9%	3950	27.9%	466503	22.8%	18642.7	3.2%	700	4.9%	112814	5.5%
2011	225883.7	36.0%	10755	70.3%	1627761	72.5%	380559.8	60.7%	3775	24.7%	492554	21.9%	20679.1	3.3%	768	5.0%	123705	5.5%
2012	254161.6	36.9%	12727	71.3%	1830202	73.3%	410920.6	59.7%	4254	23.8%	528178	21.2%	23750.7	3.4%	876	4.9%	138219	5.5%
2013	274177.7	37.5%	14007	72.9%	2041367	73.3%	432431	59.1%	4300	22.4%	576630	20.7%	24792.3	3.4%	908	4.7%	165124	5.9%
2014	297207	39.1%	15375	75.2%	2222293	74.0%	436394.9	57.4%	4094	20.0%	603900	20.1%	26584.7	3.5%	972	4.8%	177951	5.9%
2015	308364.1	40.1%	16087	76.4%	2407632	74.3%	434192.7	56.4%	4036	19.2%	646607	19.9%	26785.7	3.5%	930	4.4%	187230	5.8%
2016	326955.9	41.2%	17528	77.1%	2613367	74.5%	436663.3	55.1%	4165	18.3%	695781	19.8%	29550.8	3.7%	1035	4.6%	198018	5.6%
2017	343892.1	42.0%	18915	77.4%	2822446	74.2%	442891.6	54.1%	4450	18.2%	769206	20.2%	31527.3	3.9%	1071	4.4%	212369	5.6%
2018	357737.5	43.1%	20017	78.6%	3020813	73.7%	440632	53.0%	4376	17.2%	852377	20.8%	32432.2	3.9%	1060	4.2%	225440	5.5%

Note: No data available for primary care institutions before 2010, so we used the data from 2010 to 2018 for analysis. *Include specialized public health institutions, sanatoriums, clinical laboratory centers, medicinal scientific research institutions, on-job training institutions, health supervision institutions, medical examination centers, rural water improvement centers, talent exchange centers, and statistical information centers, etc.

Table C. Gini coefficient and Theil index of nurse workforce from 2010 to 2018

Year	Overall inter-provincial		Between-provincial	Within-provincial	Within provincial /overall
	Gini	Theil L	Theil L	Theil L	Theil L
2010	0.167	0.021	0.010	0.011	52.38%
2011	0.150	0.016	0.008	0.008	50.00%
2012	0.139	0.015	0.008	0.007	46.67%
2013	0.133	0.013	0.007	0.006	46.15%
2014	0.125	0.012	0.006	0.006	50.00%
2015	0.123	0.012	0.006	0.006	50.00%
2016	0.121	0.015	0.005	0.010	66.67%
2017	0.120	0.015	0.005	0.010	66.67%
2018	0.119	0.014	0.004	0.010	71.43%