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A study on equity in the allocation of health human resources in maternal and child health institutions in China (2002–2021) and forecasting the five-year future trends (2022–2026)

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Abstract

Background Strengthening health systems and ensuring equity and access to human resources can significantly reduce maternal and child mortality and improve maternal and child health outcomes. This mixed-methods study aimed at the quantity, quality, and equity of the allocation of human resources for health (HRH) in Chinese maternal and child healthcare institutions from 2002 to 2021 while providing a reference for optimally allocating HRH in the new era.

Methods Relying on health-related data obtained from statistical yearbooks in 2003–2022, the study analysed the allocation status using descriptive statistics, examined the allocation equity with the Gini coefficient and the Health resource agglomeration degree/Health resource population agglomeration degree (HRAD/HRPAD). Finally, the study predicted the future allocation trend by compiling a grey prediction model GM (1,1).

Results HRH quantity in Chinese maternal and child healthcare institutions experienced steady growth. However, the composition of educational background and professional titles was unreasonable. The quality structure needs to be further optimized. The equity of demographic allocation ($Gini < 0.2$) was superior to the geographic allocation ($Gini = 0.631–0.678$), with significant regional differences. The HRAD values of HRH in different regions were as follows: eastern region ($3.50–3.70$) > central region ($1.69–1.92$) > western region ($0.36–0.44$); HRPAD (2021): western region (1.150) > central region (0.991) > eastern region (0.912). The equity of sparsely populated regions was superior to that of densely populated regions. The HRH future allocation trend is positive.

Conclusions Emphasis should be placed on the status quo of unreasonable allocation and unbalanced distribution. Careful consideration must be given to factors like service population, service radius, economic development, and population mobility while considering demographic and geographic equity to promote the reasonable allocation and full utilisation of HRH.

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Keywords Maternal and child healthcare institution, Allocation of human resources for health, Equity, Health resource agglomeration degree

Introduction

Reproductive health and maternal, newborn, and child health (MNCH) are key points and primary goals within the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) of the United Nations (UN) [1, 2]. Due to the proposal of MDGs in 2000–2015 and SDGs in 2015 and the unremitting efforts of all humankind, maternal and child health worldwide has substantially improved. Indicators such as maternal mortality, and child mortality under five years old have improved significantly [3]. However, the improvement in health outcomes has been uneven, which can be attributed to disparities in economic development [4] and issues related to health human resources [5].

According to the World Health Organization (WHO) statistics, the global health workforce totaled 65.1 million professionals in 2020, comprising approximately 29.1 million nurses and 2.2 million midwives [6]. As of 2021, a persistent shortage of 90 million midwives remained unresolved [7]. Systemic stock shortages and uneven distribution patterns constitute primary challenges in maternal-child health human resource allocation. Current global health workforce distribution demonstrates pronounced regional disparities: High-income countries account for most health professionals, while middle- and low-income nations face varying shortages [8]. Africa and low-income countries exhibit the most severe deficits, exemplified by a doctor-nurse-midwife density of only 15.4 per 10,000 population—significantly lower than the SDG-tracking median of 44.5 [9].

China is the largest developing country in the world with an enormous population, significantly influencing the achievement of global goals. China has permanently attached great importance to women's and children's health and all-round development. Over more than 40 years of sustained efforts, China has established a three-tiered maternal-child health system with maternal and child health institutions as the core, primary healthcare facilities as the foundation, and large general hospitals and scientific research institutions as supporting elements. This integrated framework primarily provides comprehensive health management services covering preconception, prenatal, postpartum, and childhood stages while ensuring maternal-infant safety assurance through critical care centers-based services [10]. In recent years, the Chinese government has considerably raised maternal and child health levels by implementing various medical and health system reforms and policies, including the “Health China 2020” initiative, the “Health China 2030” initiative, and the “China Program for the

Development of Women and Children.” By lowering maternal mortality from 1,500/100,000 at the beginning of the founding of the new China to 16.9/100,000 in 2020 and reducing infant mortality from 200 to 5.4%, China has achieved the UN's MDGs on maternal and child health before schedule [11].

In recent years, there has been a gradual increase in studies investigating human resource allocation in China's public health and maternal-child health care systems, with analyses primarily conducted from the perspectives of spatial distribution patterns, equity dimensions, and developmental challenges. The studies demonstrate that the number of healthcare professionals in maternal and child health institutions has continuously increased [12]. However, substantial gaps persist in aspects such as resource allocation disparities compared with peer medical institutions, insufficient competitive advantages in talent team construction, and service capability limitations [12]. Regional differences in maternal-child health human resource allocation remain particularly pronounced [13], exhibiting distinct spatial agglomeration characteristics [14]. Provincial studies reveal hierarchical priority patterns in healthcare resource allocation: population-based allocation demonstrates optimal resource distribution, followed by socioeconomic development considerations, and trailed by geographical accessibility performance [15]. These configurations exhibit notably low allocation efficiency across provinces [16].

However, current research lacks empirical evidence on both long-term temporal perspective and national-level equity analysis of human resource allocation in maternal and child healthcare institutions, as well as predictive studies based on long-term trend projections. There is also insufficient micro-level manifestation analysis of regional disparities and macro-level pattern identification across provinces, which restricts the formulation of evidence-based policy interventions for balanced development. Our research aims to describe trends in quantity and structure, analyse the equity of allocation through the Gini coefficient and aggregation degree, and forecast the number of Chinese maternal and child healthcare institutions' HRH from 2021 to 2025 through the GM (1,1). This study proposes to enrich existing research by systematically analysing long-term human resource allocation trends and equity dimensions in maternal and child healthcare institutions from a national perspective, incorporating demographic and geographic factors as critical variables. Simultaneously, it focuses on addressing regional disparities in the allocation of HRH within Chinese maternal and child healthcare institutions,

proposes policy recommendations to enhance equity in resource distribution, and aims to optimise the HRH configuration.

Methods

Data sources

The data used in this study were derived from the China Health Statistical Yearbook [17, 18], the China Statistical Yearbook (2003–2022) [19], and the Third National Land Resource Survey of the People's Republic of China (Data for Hong Kong, Macao, and Taiwan were missing) [20]. The Chinese government released the data used in this study, which are reliable and authentic. Based on the 2021 China Health Statistical Yearbook, China is divided into three regions, i.e., Eastern, Central, and Western China. Eastern China comprises Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; Central China includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan; Western China is composed of Inner Mongolia, Chongqing, Guangxi, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The indicators selected for analysis and evaluation primarily included year-end population, provincial geographic area, and health workers and health technicians in maternal and child healthcare hospitals.

Human resources for health in Chinese maternal and child healthcare institutions

Chinese maternal and child healthcare institutions' staff consist of health technicians, other technicians, management staff, and logistics staff. Health technicians are a subset and core staff primarily responsible for health-related tasks. The Chinese government requires health technicians to account for 70–72% of the Medical Institutions' staff. Therefore, two categories of indicators were chosen to measure the HRH of Chinese maternal and child healthcare institutions: health workers (the total staff) and health technicians. In addition, the structure of the four types of personnel that make up the HRH are also listed separately in the *China Health Statistical Yearbook*. This study used health technicians to represent the quality of HRH.

Health technicians: medical practitioners, assistant medical practitioners, registered nurses, and other health professionals.

Other technicians: non-health professionals who engage in technical work such as medical device repair, scientific research and teaching.

Management staff: staff with leadership or management responsibilities.

Logistics staff: staff who undertake maintenance and logistical support services.

Lorenz curve and Gini coefficient

The Lorenz curve was proposed by American economist Max Otto Lorenz in 1905 as a graphical representation of income inequality. The greater the curvature of the Lorenz curve, the more unequal the distribution of income, and vice versa [21]. The ratio of the unequal area to the completely unequal area in the Lorenz curve is called the Gini coefficient, a vital indicator determining income equity [22]. In recent years, they have been widely used in health economics as essential tools for evaluating the equity of the allocation of health resources [23]. A Gini coefficient of <0.3 is relatively equitable, a Gini coefficient of 0.3–0.4 is moderately equitable, a Gini coefficient of >0.4 is inequitable, and a Gini coefficient of 0.5–0.7 is highly inequitable. The calculation formula is as follows [24, 25]:

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

where n denotes the number of regions; X_i is the cumulative percentage of the population and geographical area; Y_i is the cumulative percentage of HRH for maternal and child health ($i = 1, 2, \dots, n$).

HRAD/HRPAD

HRAD helped evaluate the equity of the geographic allocation of health resources across different regions [26].

$HRAD = 1$ means that the geographic distribution of health resources is equitable; $HRAD > 1$ depicts that health resources are too concentrated based on geographical area; $HRAD < 1$ indicates that the health resources are insufficient, with inequitable allocation and poor geographic accessibility [27]. The population agglomeration degree (PAD) is an indicator of how concentrated a region's population is relative to the region as a whole. $HRAD/PAD$ (from now on referred to as $HRPAD$) helped evaluate the equity of health resources allocation between different regions by population. $HRPAD = 1$ means that health resources and population are perfectly balanced; $HRPAD > 1$ means that health resources are surplus relative to the population; $HRPAD < 1$ means that health resources are insufficient relative to the population, and the demographic allocation is inequitable [28]. The calculation formula is [29, 30]:

$$HRAD_i = \left(\frac{HR_i}{HR_n} \right) / \left(\frac{A_i}{A_n} \right); PAD_i = \left(\frac{P_i}{P_n} \right) / \left(\frac{A_i}{A_n} \right)$$

Where HR_i and HR_n denote the total amount of health resources in region i and all regions, respectively; A_i and A_n denote the land area of region i and all regions,

respectively; P_i and P_n denote the population of region i and all regions, respectively.

Predictive analysis using the model GM (1,1)

Depending on the raw data of HRH in Chinese maternal and child healthcare institutions between 2009 and 2021, the current study compiled a model GM (1,1) using MATLAB (R2021a) to predict the numbers of HRH in 2022–2026. The accuracy of the model predictions was tested through the posterior error ratio (C) and small error probability (P) [31].

Results

Overall status and trend of HRH in Chinese maternal and child healthcare institutions in 2002–2021

Overall, the numbers of health workers, health technicians, and other technicians in Chinese maternal and child healthcare institutions from 2002 to 2021 indicated an upward trend (Table 1). The number of health workers increased by 365,427 by the end of 2021, with an average annual growth rate of 6.07% based on 2002. Since the implementation of the universal two-child policy in 2016, the number of health workers in maternal and child healthcare institutions has increased, with an average annual growth of 30,818 people at a rate of 6.91% from 2016 to 2021. The average annual growth rate in these five years was significantly higher than in 2002–2015 (with an average annual growth rate of 5.02%). Specifically, health technicians accounted for the most significant

proportion (81.15–83.75%), which increased yearly, with an average annual growth rate of 6.23%. The number of HRH allocated for every 10,000 persons (with the population at the end of 2021 as the denominator) in maternal and child healthcare institutions increased yearly, reaching 3.84 by the end of 2021.

Quality structure and changes of HRH in Chinese maternal and child healthcare institutions in 2002–2021

Health technicians and other technicians in Chinese maternal and child healthcare institutions were relatively young, with those aged below 45 accounting for 70% above in 2021. The educational background of health workers in maternal and child healthcare institutions improved significantly in 2021 compared to 2012 and 2002. Technical secondary school degree holders dominated the composition of educational background but later shifted to junior college degrees and then Bachelor's degree holders. Regarding the structure of professional titles, the ratio of health technicians with senior, sub-senior, middle, primary, and low professional titles in Chinese maternal and child healthcare institutions was approximately 1:4:12:15:13. Quality structure and changes of HRH are illustrated in Table 2.

Equity of the allocation of HRH in Chinese maternal and child healthcare institutions in 2002–2021

In 2002–2021, the Gini coefficients of the health workers and health technicians allocated from the demographic

Table 1 The general situation of health human resources allocation of maternal and child health hospitals in China from 2002 to 2021

Year	Health workers		Health technicians		Other technicians		Management staff		Logistics staff	
	number	proportional allocation(1/10.000)	number	proportion(%)	number	proportion(%)	number	proportion(%)	number	proportion(%)
2002	176,905	1.39	143,933	81.36	6683	4.64	12,508	7.07	13,781	7.79
2003	177,820	1.39	145,610	81.89	7060	4.85	11,865	6.67	13,285	7.47
2004	178,703	1.39	146,657	82.07	7442	5.07	11,754	6.58	12,850	7.19
2005	187,633	1.46	153,153	81.62	8533	5.57	12,372	6.59	13,575	7.23
2006	192,142	1.48	157,017	81.72	8654	5.51	12,704	6.61	13,767	7.17
2007	206,529	1.58	167,605	81.15	8352	4.98	14,273	6.91	16,299	7.89
2008	219,892	1.67	179,918	81.82	9104	5.06	13,986	6.36	16,884	7.68
2009	232,782	1.76	191,801	82.40	9470	4.94	13,597	5.84	17,914	7.70
2010	245,102	1.84	202,365	82.56	10,334	5.11	13,622	5.56	18,781	7.66
2011	261,861	1.95	216,149	82.54	11,478	5.31	13,606	5.20	20,628	7.88
2012	285,180	2.12	235,741	82.66	12,598	5.34	14,251	5.00	22,590	7.92
2013	308,199	2.26	254,911	82.71	13,652	5.36	14,781	4.80	24,855	8.06
2014	326,732	2.38	270,674	82.84	14,366	5.31	15,265	4.67	26,427	8.09
2015	351,257	2.54	291,361	82.95	15,987	5.49	15,898	4.53	28,011	7.97
2016	388,238	2.79	320,748	82.62	18,139	5.66	18,290	4.71	31,061	8.00
2017	426,881	3.05	353,168	82.73	20,416	5.78	19,657	4.60	33,640	7.88
2018	454,985	3.24	376,982	82.86	22,344	5.93	20,747	4.56	34,912	7.67
2019	486,856	3.46	405,060	83.20	23,290	5.75	21,819	4.48	36,687	7.54
2020	514,734	3.65	428,809	83.31	25,410	5.93	22,655	4.40	37,860	7.36
2021	542,332	3.84	454,195	83.75	28,849	6.35	19,259	3.55	40,029	7.38

Table 2 Quality structure of health human resources in maternal and child health institutions nationwide in 2002, 2012 and 2021(%)

Year and Personnel Categories	2002			2012			2021		
	Health technicians	Other technicians	Management staff	Health technicians	Other technicians	Management staff	Health technicians	Other technicians	Management staff
age									
< 25	11.2	11.8	5.7	8.6	6.9	2.5	7.1	4.5	2.2
25–34	38.8	35.8	26.1	37.7	36.2	21.5	40.6	38.4	24.4
35–44	28.1	31.3	34.3	30.7	32.0	32.8	26.8	28.8	28.1
45–54	20.4	19.9	30.5	18.0	20.2	32.8	17.8	20.3	29.9
55–59	1.3	1.2	3.0	3.8	3.9	8.9	4.8	4.6	10.2
≥ 60	0.1	0.1	0.4	1.2	0.9	1.5	2.8	3.3	5.3
educational background									
master or above	0.3	0.1	0.3	1.9	0.8	2.0	3.9	3.2	4.9
bachelor	10.4	5.3	10.1	24.0	20.7	28.6	41.8	43.6	46.4
junior college	30.3	25.6	37.1	42.1	41.9	42.2	39.9	36.6	34.5
vocational school	51.6	31.0	29.1	30.4	24.9	17.6	13.9	11.9	9.6
High school and below	7.4	38.0	23.4	1.6	11.7	9.6	0.5	4.7	4.6
professional title									
senior	0.5	0.0	0.5	1.1	0.2	2.2	2.1	0.2	1.8
sub-senior	4.6	0.5	6.0	5.6	1.8	8.6	8.8	3.2	7.2
middle	30.9	10.6	24.4	25.9	13.7	22.0	24.8	18.1	15.1
primary	39.6	25.1	25.5	30.8	24.9	19.2	32.1	24.1	13.5
low	20.0	27.0	17.9	27.6	33.5	15.7	27.9	33.8	13.6
unknown	4.5	36.7	25.7	9.0	25.9	32.2	4.2	20.6	48.8

Table 3 Gini coefficient of HRH in maternal and child health institutions in China from 2002 to 2021

Year	Dimension of population		Dimension of geography	
	Health workers(total)	Health technicians	Health workers(total)	Health technicians
2002	0.143	0.145	0.633	0.631
2003	0.148	0.148	0.637	0.635
2004	0.158	0.159	0.639	0.637
2005	0.146	0.146	0.647	0.643
2006	0.160	0.161	0.652	0.650
2007	0.159	0.157	0.654	0.652
2008	0.160	0.158	0.661	0.660
2009	0.167	0.166	0.660	0.659
2010	0.168	0.167	0.663	0.662
2011	0.172	0.167	0.668	0.667
2012	0.178	0.179	0.673	0.673
2013	0.178	0.179	0.677	0.676
2014	0.183	0.186	0.677	0.677
2015	0.176	0.181	0.677	0.678
2016	0.169	0.177	0.673	0.675
2017	0.170	0.178	0.672	0.674
2018	0.169	0.177	0.673	0.675
2019	0.174	0.183	0.675	0.677
2020	0.176	0.184	0.671	0.674
2021	0.162	0.169	0.670	0.671

dimension in Chinese maternal and child healthcare institutions were less than 0.2, indicating a highly equitable overall allocation. In contrast, the Gini coefficients from the geographic dimension were between 0.6 and 0.7 (Table 3), indicating an excessive HRH allocation gap and a high degree of inequity. The overall equity of the demographic allocation of HRH for maternal and child health was superior to the geographic allocation. This difference can be better observed in the Lorenz curves, taking 2021 as an example (Fig. 1a and b).

Agglomeration degrees and change trends of HRH in Chinese maternal and child healthcare institutions in 2002–2021 by regions

From 2002 to 2021, the HRAD ranges of health workers in maternal and child healthcare institutions in Eastern, Central, and Western China were 3.50–3.70, 1.69–1.92, and 0.36–0.44, respectively. The HRAD ranges of health technicians in Eastern, Central, and Western China were 3.51–3.71, 1.68–1.92, and 0.37–0.44, respectively (Table 4). The geographic allocation of HRH in maternal and child healthcare institutions was over-concentrated in eastern and central China (Fig. 2a and c). Although the geographic allocation in Western China saw a slight equity improvement but remained relatively inequitable.

As opposed to geographical allocation, from 2002 to 2021, the HRPADs of HRH in maternal and child healthcare institutions in Eastern China gradually decreased,

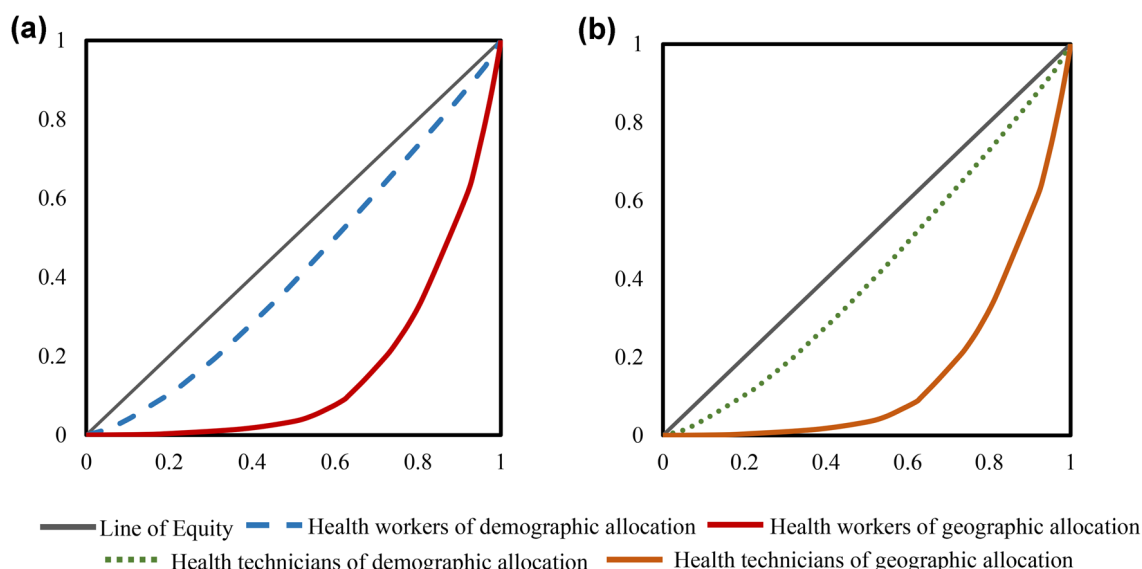


Fig. 1 (a) Lorenz curve of health workers, 2021. (b) Lorenz curve of health technicians, 2021

indicating a trend of demographic inequity. Overall, the HRPADs of HRH in Western China's maternal and child healthcare institutions gradually increased (Table 4), depicting a trend of gradually increased equity (Fig. 2b and d). Among the three regions, the western region has the best equity of HRH population allocation.

Agglomeration degrees and change trends of HRH in Chinese maternal and child healthcare institutions in 2002–2021 by provinces

In 2021, the HRADs of health workers and health technicians in maternal and child healthcare institutions were less than 1 across eight provinces (i.e., Jilin, Liaoning, Gansu, Heilongjiang, Inner Mongolia, Xinjiang, Qinghai, and Tibet), five of which are in Western China. Shanghai, Beijing, Guangdong, Shandong, and Zhejiang were the top five, with HRAD values far above the national average (8.218 for Shanghai and 7.468 for Beijing). The gap between Shanghai and Tibet in the HRADs of health workers and health technicians was about 8. The allocation of maternal and child HRH by geographical region is unbalanced, with significant regional differences (Table 5; Fig. 2a and c [32]).

The HRPADs were less than 1 in 15 regions. Notably, Tianjin had the smallest HRPAD values, with poor equity of HRH demographic allocation. The top five regarding the equity level were Guangxi, Ningxia, Jiangxi, Yunnan, and Guizhou, primarily distributed in Western China, indicating that the demographic allocation of HRH was relatively equitable, with high accessibility of health services (Table 5; Fig. 2b and d).

Prediction of the allocation of HRH in Chinese maternal and child healthcare institutions in 2022–2026

The raw data were suitable for modelling (all class ratio test values within the standard range of [0.867, 1.154]), and possessed high fitting precision ($C=0.004$, $p=1.00$) and good robustness (with a maximum relative error of $0.026 < 0.1$). The prediction results depicted that the number of HRH in Chinese maternal and child healthcare institutions would increase steadily to 598,187, 643,885, 693,073, 746,020, and 803,011 in 2022–2026 (Fig. 3). Based on the *Statistical Bulletin on Health Development in China 2022*, the total number of employees in maternal and child healthcare institutions was 561,000.

Discussions

The quantity of HRH in Chinese maternal and child healthcare institutions has grown steadily, but the quality structure needs further optimization

From 2002 to 2021, HRH quantity in Chinese maternal and child healthcare institutions experienced steady growth, with a continued rise in allocation density. This could be related to China's socioeconomic development and the comprehensive medical and health system reform since 2009 [33]. Among various employees, technicians grew most rapidly. Health workers in maternal and child healthcare institutions depicted a benign development trend in all aspects [34].

Structurally, the HRH structure of educational background and professional titles in China's maternal and child healthcare institutions is unreasonable, and the allocation structure needs further optimization. In recent years, the academic qualifications of health technicians in Chinese maternal and child healthcare institutions have been improving. However, health technicians with a

Table 4 HRAD and HRPAD in maternal and child health institutions in different regions of China from 2002 to 2021

Year	Health workers		Health technicians									
	Eastern China		Central China		Western China		Eastern China		Central China		Western China	
	HRAD	HRPAD	HRAD	HRPAD	HRAD	HRPAD	HRAD	HRPAD	HRAD	HRPAD	HRAD	HRPAD
2002	3.562	1.017	1.865	0.989	0.389	0.988	3.549	1.014	1.869	0.991	0.390	0.991
2003	3.588	1.022	1.885	1.003	0.380	0.966	3.568	1.017	1.887	1.004	0.383	0.973
2004	3.559	1.010	1.919	1.022	0.376	0.960	3.545	1.006	1.919	1.022	0.379	0.966
2005	3.682	1.031	1.884	1.018	0.366	0.935	3.663	1.026	1.874	1.013	0.371	0.948
2006	3.684	1.024	1.895	1.030	0.363	0.931	3.678	1.022	1.881	1.022	0.367	0.943
2007	3.635	1.003	1.890	1.033	0.372	0.958	3.649	1.006	1.873	1.023	0.374	0.964
2008	3.683	1.010	1.860	1.020	0.372	0.962	3.710	1.018	1.834	1.006	0.374	0.967
2009	3.598	0.981	1.873	1.032	0.382	0.991	3.609	0.984	1.862	1.025	0.383	0.994
2010	3.577	0.962	1.862	1.030	0.388	1.023	3.588	0.965	1.859	1.028	0.387	1.021
2011	3.624	0.972	1.843	1.022	0.385	1.017	3.642	0.977	1.831	1.016	0.385	1.017
2012	3.661	0.980	1.820	1.012	0.385	1.016	3.687	0.987	1.811	1.007	0.383	1.011
2013	3.697	0.975	1.791	1.014	0.386	1.024	3.708	0.978	1.783	1.009	0.386	1.024
2014	3.639	0.957	1.793	1.020	0.395	1.045	3.651	0.960	1.794	1.020	0.393	1.040
2015	3.635	0.952	1.791	1.025	0.396	1.048	3.644	0.954	1.791	1.025	0.395	1.044
2016	3.570	0.931	1.789	1.030	0.406	1.074	3.575	0.933	1.789	1.029	0.406	1.073
2017	3.565	0.928	1.759	1.018	0.415	1.094	3.569	0.929	1.754	1.015	0.415	1.096
2018	3.538	0.918	1.773	1.031	0.415	1.095	3.550	0.921	1.763	1.025	0.416	1.097
2019	3.544	0.918	1.727	1.009	0.426	1.121	3.556	0.921	1.722	1.006	0.425	1.119
2020	3.499	0.902	1.703	1.002	0.439	1.152	3.506	0.904	1.700	1.001	0.438	1.151
2021	3.545	0.912	1.680	0.991	0.437	1.150	3.550	0.913	1.675	0.988	0.438	1.151

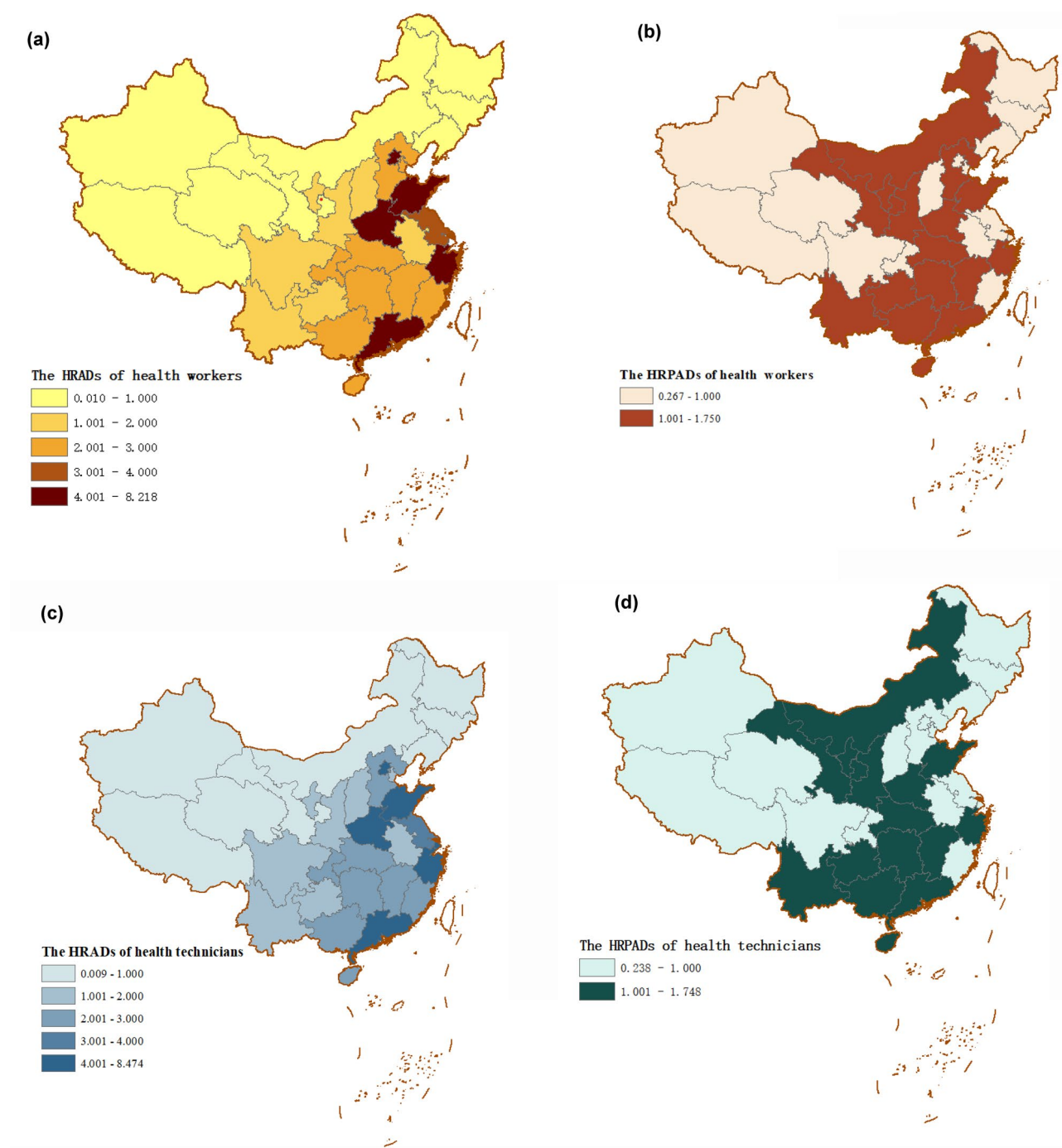


Fig. 2 (a) HRADs of health workers in maternal and child healthcare institutions of China, 2021. (b) HRPADs of health workers in maternal and child healthcare institutions of China, 2021. (c) HRADs of health technicians in maternal and child healthcare institutions of China, 2021. (d) HRADs of health technicians in maternal and child healthcare institutions of China, 2021 (a, b, c, and d were created using the China Standard Map (GS(2020)4619), supervised by the Ministry of Natural Resources of the People's Republic of China, and visualized via ArcMap 10.8)

postgraduate degree were relatively low and grew slowly, showing a more significant gap than in general hospitals [35]. Regarding professional title structure, the proportion of primary, middle, and senior health technicians follow a 5.6:2.4:1 ratio, manifesting a pyramidal distribution pattern rather than the “small at both ends and large

in the middle” olive-shaped distribution. This structurally imbalanced configuration is characterized by a disproportionately high proportion of lower-tier professionals, which stymies career advancement pathways and creates systemic vulnerabilities [36].

Table 5 HRAD and HRPAD of maternal and child health institutions in each Province of China in 2021

Regions	Health workers		Health technicians	
	HRAD	HRPAD	HRAD	HRPAD
Beijing	7.468	0.849	7.541	0.857
Tianjin	2.091	0.267	1.860	0.238
Hebei	2.688	1.004	2.620	0.978
Shanxi	1.323	0.890	1.237	0.832
Nei Mongol	0.152	1.091	0.150	1.083
Liaoning	0.553	0.287	0.515	0.267
Jilin	0.641	0.751	0.571	0.669
Heilongjiang	0.308	0.663	0.285	0.615
Shanghai	8.218	0.306	8.474	0.316
Jiangsu	3.760	0.647	3.760	0.647
Zhejiang	4.609	1.031	4.738	1.060
Anhui	1.619	0.543	1.672	0.560
Fujian	2.013	0.844	2.026	0.850
Jiangxi	2.345	1.292	2.418	1.332
Shandong	5.013	1.154	5.045	1.162
Henan	4.470	1.125	4.315	1.086
Hubei	2.462	1.174	2.574	1.228
Hunan	2.434	1.130	2.503	1.162
Guangdong	5.713	1.187	5.729	1.190
Guangxi	2.509	1.750	2.506	1.748
Hainan	2.479	1.209	2.527	1.233
Chongqing	2.274	0.850	2.212	0.827
Sichuan	1.150	0.985	1.148	0.984
Guizhou	1.800	1.231	1.833	1.253
Yunnan	1.042	1.268	1.068	1.300
Tibet	0.010	0.500	0.009	0.452
Shaanxi	1.525	1.186	1.498	1.164
Gansu	0.487	1.230	0.485	1.226
Qinghai	0.036	0.631	0.035	0.620
Ningxia	1.029	1.371	1.062	1.414
Xinjiang	0.067	0.626	0.067	0.627

Chinese maternal and child health institutions are public welfare organizations providing comprehensive medical care services with safety net functions for women and children throughout their life cycles. According to the 2022–2026 forecast data, although human resource quantities continue to show growth trends, structural impacts stemming from evolving service demands in maternal and child health require sustained attention. Like Japan and other nations, China confronts the challenges of low fertility rates. To counteract this demographic trend, the Chinese government has implemented two-child and three-child policies, thereby theoretically expanding the potential for fertility rate improvement, with observable practical growth in two-child birth rates [37]. Meanwhile, regional disparities persist in China's reproductive health levels, influenced by economic development stages, per capita consumption patterns, and government public investment allocations [38]. The long-term development of maternal and child health human

resources necessitates quantitative preservation and qualitative enhancement.

Nevertheless, due to their specialized service orientations and public welfare attributes, these institutions encounter competitive disadvantages in talent acquisition compared with general hospitals [39]. This circumstance has led to persistent staffing shortages and technological bottlenecks within maternal and child health institutions [40], which fundamentally constrain the implementation of high-quality healthcare programs and jeopardize the sustainable development of maternal and child health initiatives. Thus, to enhance the comprehensive quality of HRH in maternal and child healthcare institutions across all levels, close attention should be paid to the quality structure of human resources for maternal and child health. The roles of academic qualifications and professional titles in driving and improving professional technical competence could help establish a reasonable talent training and introduction mechanism.

Equitable population-based allocation but persistent geographical inequity in human resource distribution for maternal and child health institutions in China: a structural challenge to equity-driven development

From 2002 to 2021, the demographic allocation of HRH in Chinese maternal and child healthcare institutions achieved a highly equitable level and was relatively equitable, consistent with relevant studies [41–43]. In contrast, the geographic allocation exceeded the warning line of 0.4, indicating the relatively poor equity of geographic allocation. The demographic equity of HRH allocation in Chinese maternal and child healthcare institutions was superior to the geographic equity [44].

This phenomenon stems from China's economic and social development processes and institutional frameworks for resource allocation. For a long time, population has served as a primary criterion for human resource allocation in China's healthcare system, functioning to assess regional health service demands and calculate per capita resource availability [45]. Population agglomeration typically generates resource allocation advantages. The equity in the population-based allocation of healthcare personnel in China's maternal and child health institutions is closely correlated with the “population-proportional allocation” policy. Developing countries have adopted such policies to enhance healthcare accessibility and have demonstrated proven effectiveness, as evidenced by successful cases in Kenya, Vietnam, and Japan [46, 47].

Geographically, the allocation of HRH for maternal and child health institutions in China exhibits significant inequity, with HRH geographic clustering intensity following a pronounced gradient: Eastern region (3.50–3.70) > Central region (1.69–1.92) > Western region

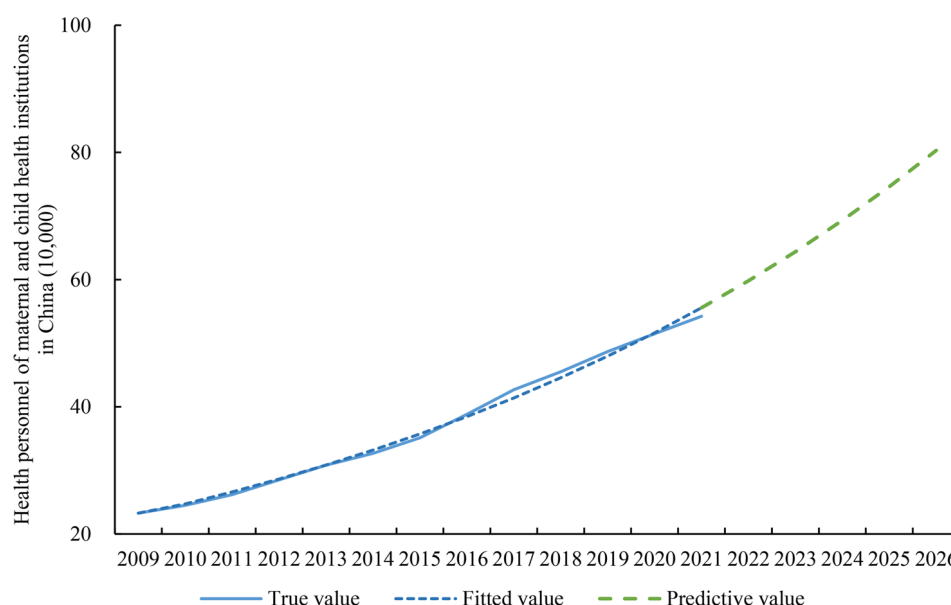


Fig. 3 Forecast of health human resources in Maternal and Infant Health-care Institutions of China

(0.36–0.44). Regions such as Xinjiang, Tibet, and Inner Mongolia exhibit a profound mismatch between HRH allocation and their vast geographical footprints. Studies have indicated that the larger the geographic area served, the lower the service effectiveness because of the density of health workers [48]. These western regions' expansive territories and sparse populations render equitable allocation based on geographic area inherently challenging.

Notably, when accounting for population factors, the disparity in HRH agglomeration across regions undergoes a notable shift: the western region exhibits marginally more significant equity than the central region, surpassing the eastern region. For instance, provinces such as Guangxi, Jiangxi, Yunnan, and Guizhou in west and central China demonstrate relatively balanced HRH distribution. This reversal may stem from economic development-induced mismatches between population distribution patterns and regional land areas. Western China accounts for nearly 71% of the country's geographic area but only feeds 27% of the population. Its vast territory and sparse population make achieving the equity of demographic allocation easier. Furthermore, to address the brain drain driven by economic development disparities between Eastern and Western regions, the Chinese government has implemented policies such as the Western Plan Volunteers program, Paired Assistance Initiatives, and the Three Supports and One Assistance Program (*San Zhi Yi Fu*), aiming to achieve equitable allocation of HRH in western regions.

Eastern China has a significant population agglomeration effect and is distributed with megalopolises and mega-cities like Shanghai and Beijing. This makes it easy for Eastern China to achieve equity in health resources

in the geographic dimension [49]. However, due to the advanced economic and technological development, superior geographic location, and strong population attractiveness, the current allocation level still cannot entirely satisfy Eastern China residents' maternal and child health needs [50]. In addition, it is necessary to pay attention to changes in the degree of agglomeration in central China. Overall, the allocation of health resources in central China is more equitable regarding demographic and geographic dimensions. However, the demographic allocation equity is decreasing with time, dropping to 0.991 in 2021. A gap in HRH has begun to emerge.

Policy recommendations for enhancing maternal and child health human resources in China

The connotation of residents' access to public health services encompasses not only the accessibility of health resources but also their availability, exemplified by metrics such as "reachable within a 15-minute walk". Maternal and child healthcare is essential for basic public health and medical services.

Significant progress in optimising the allocation of maternal and child health (MCH) human resources in China remains attainable. A holistic strategy encompassing four dimensions is critical: First, by conducting comprehensive demand assessments to strengthen evidence-based decision-making, integrating service radius, economic development trajectories, and population mobility patterns, establish region-specific human resource allocation benchmarks aligned with China's heterogeneous development landscape, ensuring accessible health human resources and facilities within defined

service radii. Second, to guarantee universal access to essential healthcare services, policy support and talent reinforcement should target economically underdeveloped regions and areas with weak maternal and child health infrastructure—such as upgrading institutional infrastructure, providing exchange and training opportunities [51], and implementing incentive mechanisms including salary adjustments and enhanced professional recognition for personnel committed to underserved regions [52].

Third, sustained implementation of initiatives like the Western Development Strategy could cultivate endogenous growth drivers in Western regions. By boosting regional economic vitality and career prospects, such efforts may reverse the talent drain, attract skilled maternal and child health professionals, and alleviate pressure on eastern regions' service demands. Fourth, it is imperative to prioritize interregional cooperation frameworks, encompassing east-west pairing assistance programs and digital health innovation networks, to facilitate horizontal mobility of human resources and technical expertise. These collaborative architectures leverage telemedicine platforms [53] and aim to maximize resource utilization, expand service coverage, and ensure equitable access to specialized care across China's vast and geographically diverse territories, thereby promoting rational allocation and efficient utilization of maternal and child health resources.

Conclusions

Fair distribution of HRH is necessary to guarantee equal access to healthcare resources. This study found that the quantity of HRH in Chinese maternal and child healthcare institutions experienced steady growth. The demographic allocation equity of HRH in Chinese maternal and child healthcare institutions was superior to the geographic equity, with significant regional differences. Overall, the equity of sparsely populated regions was superior to that of densely populated regions. Therefore, attention should be paid to adjusting the HRH quality structure and allocation. In particular, introducing sound policies on academic qualifications and professional titles is crucial for sustainable growth in this field. When allocating human resources for maternal and child health, the Chinese government should carefully consider factors such as service population, service radius, economic development, and population mobility while accounting for demographic and geographic equity to promote the reasonable allocation and full utilization of HRH.

Limitations

The current study has three limitations. Firstly, this study identified differences in allocating equity in demographic and geographic dimensions by analysing the equity of

allocation alone but did not delve into the causes of inequity. Secondly, the prediction analysis did not consider the fertility rate and the impact of social policies, such as family planning policy in 2013, 2016, and 2021. Thirdly, this study only focused on the allocation equity but neglected the allocation efficiency. In the future, evaluation can consider equity and efficiency in allocating human resources for maternal and child health to make it more scientific and reasonable.

Abbreviations

HRH	Human resources for health
HRAD	Health resource agglomeration degree
HRPAD	Health resource population agglomeration degree
MNCH	Maternal, newborn, and child health
MDGs	Millennium Development Goals
SDGs	Sustainable Development Goals
PAD	Population agglomeration degree

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Author contributions

LZ, HL, GM, and WL contributed to the study design and data analysis; LZ, WL, and JC contributed to data collection; LZ, WL, contributed to manuscript writing; and LZ, WL, and JC were responsible for manuscript revision.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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