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Title page

A Hierarchical Regional difference and inequality of health resource allocation in Shanghai from 2010 to 2016

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Abstract

Objectives Aiming to analyze the hierarchical distribution of health resource in hospitals and primary health centers (PHCs) in Shanghai over 7 years.

Setting A longitudinal study was conducted to analyze health resource allocation status and time trends in shanghai with the data from the Shanghai Yearbook dataset from 2010-2016.

Participants: Seven-year data from 2010-2016 in Shanghai were taken for analysis and inclusion and exclusion criteria of the study indicators were specified

Outcomes measure 10 health resource indicators were used to measure hospital and PHC health resource from a hierarchical perspective. The Theil index was also calculated to measure the distribution inequality of health resource.

Results The numbers and values of health resource per 1000 population in hospitals and PHCs all increased across all the city and districts, and equipment grew faster than health workforce totally. Of all districts central districts had higher ratios than suburban districts both in doctors and equipment, and grew faster than suburban ones in the former indicator and reversely slower in latter indicator for hospitals and PHCs from 2010 to 2016.The Theil indexes in hospitals had higher values than those in PHCs for the equipment. The Theil indexes of the indicators all showed downward time trends in hospitals and PHCs but for the technicians and doctors in hospitals from 2010 to 2016.

Conclusion: The increase of the health resource and the inequality improvement of the resource allocation during 7 years in Shanghai indicated that measures Shanghai

government had taken to deepen new-round China health care reform was successful since 2009. However, there still existed resource distribution regional difference between urban and rural areas and inequality across different health institutions. It is crucial for shanghai government to make deeper efforts to achieve regional balance and improve the fairness of health resource allocation in the future.

Keywords: Health Resource, Regional Difference, Hospital, PHC

Strengths and limitations of this study

▸▸A longitudinal study was conducted with the data from the Shanghai Yearbook dataset from 2010-2016, analyzing the health resource allocation status, time trends and inequality in hospitals and primary health centers (PHCs) in Shanghai to confirm whether the China's new-round health care reform since 2009 worked. Few previous studies like this paper focus on the changes of health resource allocation over time as well as its association with China's new-round health care reform since 2009.

▸▸ From a hierarchical view, the study investigated the static and dynamic status of the health workforce and equipment in hospitals and PHCs during the 7 years (from 2010 to 2016) with the 10 main indicators, by comparing the amount per 1000 population and growth rate of health resource between the hospitals and PHCs ,center and rural administrative divisions in that period. For the distribution inequality of health resource across the city and 16 districts, the Theil index was also calculated to identify the fairness of health workforce and medical equipment.

▸▸ Although this study was conducted in China, it offers some lessons to other developing countries that are implementing health care reform to ensure their people to

benefit from the balance of health resource allocation and improvement of the distribution inequality of health resource, which is a common issue in the world.

▸▸ This study can only reflect the health resource allocation status in Shanghai at the cut-off (till 2016). A new study on changes of health resource allocation from 2017 until now and comparability of this study with that prospective research can be a future work when data are available.

▸▸ The study chooses indicators for the quality of health resources from hierarchical perspective rather than indicators of the quality of health services, which probably missed some unmeasured indicators influencing the differences observed. Caution needs to be taken when generalising the findings.

Background

Allocating reasonably health resources is essential to achieve health service equity, better population health, and society harmony[1-3]. However, disparities of health resources exist between urban and rural areas, across various types of medical institutions, and these inequalities are being further widened currently in China[4-7]. Even within Shanghai, a city with a largest scale of population in China, the regional difference in the health resource allocation across districts is significant as health resources are mainly allocated in the center areas of the city [8].

Since 2009, when China launched Opinions on Deepening Reform of the Medical and Health care System[9],a number of policies were released, including the Guidelines to Promote the Construction of Graded Diagnosis and Treatment System[10], the "Healthy China 2030" Planning Outline, the National Fitness Program (2016-2020), the 13th Five-Year Plan for Medical and Health Service Development, and the Plan for Deepening Reform of the Medical and Healthcare System During the 13th Five-Year Plan Period (2016-2020). Through optimizing the structures of medical institutions, the Chinese government has put forward a“two-step”goal: a proper reasonable medical procedure will be built, in which the patients can be diagnosed primarily, referred with two ways, linked up or down, divided clearly and treated rapidly; a sound integrated medical and health care system with Chinese characteristics will be established, which is integral, complementary, collaborative and efficient. Accordingly, Shanghai government also implemented corresponding measures to change the imbalance of health resource allocation and public health care system, conforming tightly to the

national health reform strategies and guidelines mentioned above. As a result of these measures, the quantity of health doctors, nurses and medical equipment had increased and the distribution of health resources had been more balanced [8,11-12].

Some studies have explored inequality in health resources and health service within hospitals and the primary health centers (PHCs) in China[6,13-17], and those studies have shown that since 2009, a new-round medical reform in China had reduced health resources inequality across provinces or cities[5,18]. However, other studies have found that China's immense investment in the new health reform since 2009 not to be successful in reducing health resource allocation inequality in PHCs[6,17]. Existing studies examined the quantity and inequality of health resource in China, while they overlooked the changes of health resource allocation over time as well as its association with China's health care reform. Considering the overall goal of china's new healthcare guidelines and plans that promote a more equitable and efficient distribution of healthcare resources, it is essential to study the changes of quantity and equity of health resource allocation in China over time since then.

Therefore, the purpose of this study was 1) to depict hierarchically distribution of health resource in hospitals and PHCs over 7 years (2010–2016) in Shanghai; 2) to provide policy implications to optimize health resource allocation in hospitals and PHCs to improve quality and quantity of health services and achieve an equitable health system for China.

Methods

Data resource

This study used the data from the Shanghai Medical Statistical Yearbook from 2010-2016, and the Shanghai Statistical Yearbook from 2010-2016, respectively published

by the Shanghai Health Commission and the Shanghai Statistics Bureau. since China has pushed the hospitals and primary health centers (PHCs) to set up a hierarchical medical system to improve the health service quality, we measure health resource allocation to evaluate the effect of these policies on the different institutions: hospitals and PHCs. The indicators used included the number of health technicians in hospitals or PHCs, doctors in hospitals or PHCs, total value of medical equipment above ￥10,000 in hospitals or PHCs, number of medical equipment valued above ￥10,000 in hospitals or PHCs, medical equipment above ￥1,000,000 in hospitals and valued ￥500,000-690,000 in PHCs were also taken from the Shanghai Medical Statistical Yearbook from 2010-2016（Table 1）. Per capita measures of the above indicators were calculated after obtaining the annual population in the whole city and in every different administrative district from the Shanghai Statistical Yearbook from 2010-2016. Specially, inclusion and exclusion criteria of these indicators are shown as following.

1) Doctors refer to the professionals who held a physician practicing certificate including the practicing physicians and practicing physician assistants in China. technicians refer to the workforce who assist medical staff complete tasks around their assigned unit or clinic's and accommodate patient needs, including pharmacists, radiologists except of registered nurses. Those who engaged in the management of health workers are not included as health workforce, such as president, vice president, party secretary.

2) Medical equipment refers to durable equipment as it is intended to withstand repeated use by professional and patients, including diagnostic equipment including medical imaging machines, such as ultrasound and MRI machines, PET and CT scanners, and x-ray machines, and treatment equipment including infusion pumps, medical lasers and LASIK surgical machines and other medical equipment in health institutions of China.

Shanghai is one of the four direct-controlled municipalities of People's Republic of China, and is further divided into 16 districts, among which there is 7 urban districts and 9 suburban ones. Urban administrative divisions are as follows: Huangpu, Xuhui, Changingg, Jing'an, Putuo, Hongkou and Yangpu, and rural ones are Minhang, Baoshan, Jiading, Pudong new, Jinshan, Songjiang, Qingpu, Fengxian and Chongming. During seven years from 2010 to 2016, Shanghai city had experienced three administration division merges aiming to facilitate the long-term development of all the districts involved, enhance the administrative efficiency of urban function and resource distribution for the city, as well as reduce administrative costs. Luwan district was merged to neighboring one to form a new Huangpu district in 2011, Zhabei was merged into Jing'an district in 2015, and Chongming county was upgraded to Chongming district in 2016. To maintain data comparability, we analyzed the data of the new 16 administration divisions, and integrated the data of the two merged districts: Luwan and Zhabei into that of Huangpu and Jing'an respectively.

1.2 Data analysis

There are many measures to evaluate the equity of the health resource allocation, such as Lorenz curve, Gini coefficient and the Theil index etc. The Theil index is a

statistic primarily used to measure income inequality or other economic phenomena among different individuals and varied groups. It is a special case of the generalized entropy index and is one of the most widely used measures of the inequality of regional economic development. It was proposed by econometrician Henri Theil at the Erasmus University Rotterdam[19]. The Theil index can be formulated as follows:

$$T = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{\overline{y}}\log(\frac{y_i}{\overline{y}}) \quad (1)$$

In formula (1), T is the Theil index represents the income allocation inequality, y_i and $\overline{y}$ represents the income of individual i and the average income of the population respectively.

The Theil index has another form to measure the inequality between different groups, e.g. the between-region difference. The formula could be defined as follows:

$$T = \sum_{i=1}^{k} w_i \ln(\frac{w_i}{e_i}) \quad (2)$$

In (2) above, w_i represents the proportion of income of group *i* accounting for all the income of total groups. e_i represents the proportion of population in group *i* accounting for overall population of the groups. In this study, we defined w_i as the proportion of health resources in district *i* accounting for the resources of the whole city, e_i as the proportion of the population in district i accounting for overall population of the city.

Results

Time trends in hierarchical health resource allocation of Shanghai from 2010 to 2016

The amount and growth rate of health resource allocation changes in hospitals and PHCs in shanghai were shown in Table 2. As shown in Table 2, the amount of health resource in hospitals and PHCs increased gradually from 2010 to 2016, the numbers and value of health resource per 1000 population all increased and equipment grew faster than health workforce in hospitals and PHCs totally. For example, the number of equipment valued above ¥10,000 per 1000 and above ¥1,000,000 per 1000 in hospitals increased by 73.9% and by 122.7% respectively, and the technicians per 1000 and doctors per 1000 in hospitals increased by 30.6% and by 25.5%,respectively from 2010 to 2016,more than twice the corresponding numbers of technicians and doctors in PHC in the same period .

From an administrative division prospective, from 2010 to 2016, an increasing trend can also be observed in the number of doctors per 1000 population and equipment per 1000 population both in hospitals and PHCs across all districts, except for Chongming division with an unexpected decrease from 0.94 in 2010 to 0.87 in 2016 for the number of equipment valued above ￥10,000 per 1000 population in PHCs. In common, for every district, a similar trend can also be seen that the number of equipment per 1000 population grew faster than that of doctors per 1000 population either in hospital or PHCs from 2010 to 2016. Noticeably, wherever in hospitals and PHCs, central districts had higher ratios than suburban districts both in the number of doctors per 1000 population and equipment per 1000 population, which indicated an unchanged distribution concentration of health resource among central areas other than rural ones in Shanghai. When compared with the number of doctors per 1000 population in

hospitals, central districts grew faster than suburban ones from 2010 to 2016 (Fig.1 (a) and (b). For example, in hospitals, Xuhui district had an increase by 39.47%, Hongkou got 28.57%, and Huangpu district got 28.57% in the ratio of doctors per 1000 from 2010 to 2016, while Songjiang and Qingpu just increased by under 1% in the same period. Even Fengxian, the fastest growing division for ratios of doctors across all the rural districts, just increased by 14.29%, still lower than 15% that was the average growth level for hospitals in central districts during seven years. Meanwhile, in PHCs, neither for central districts or suburban ones had a markable increase-by rate in the number of doctors per 1000 population during this period. Reversely, for the number of equipment per 1000 population (Fig.2 (a) and (b)), there was a different trend that both in hospitals and PHCs central districts grew slower than suburban ones in the same period. For example, from 2010 to 2016, in hospitals, Huangpu, Xuhui, Jing'an and Hongkou district all increase with the growth rates of 22.75%, 76.16%, 157.40%, and 354.23% for the ratios of equipment, respectively, while Songjiang, Qingpu and Fengxian all experienced rapid development more than five-fold times for per capita equipment in this period. Similarly, in PHCs, Changning, Putuo, Jing'an and Hongkou all doubled this number, while Qingpu and Jinshan increased by more than two times for this ratio of equipment from 2010 to 2016.

Time trends of Theil index of hierarchical health resource allocation in shanghai from 2010 to 2016

Seen from Table 3, Fig. 3, both inequality and trends of the Theil indexes of the health resources allocation in hospitals and PHCs were shown over time. For the

inequality, the Theil indexes in hospitals had higher values than those in PHCs for overall health resource, especially for the equipment, indicating a more unfairness of health resource allocation in hospitals than in PHCs in Shanghai during this period. For example, in 2016, the Theil indexes of the numbers of technicians and doctors in hospitals were 0.3344 and 0.3401, respectively, while the corresponding indexes in PHCs were 0.0186 and 0.0178, respectively. The Theil index of the numbers of total value of equipment above ￥10,000, number of equipment above ￥10,000 in hospitals were 0.5282 and 0.4562 respectively, while the corresponding indexes in PHCs were 0.0482 and 0.0570, respectively.

For the trends of the Theil index in health resource in Shanghai from 2010 to 2016, both in hospitals and PHCs the Theil indexes of the indicators showed a decline except for the technicians and doctors in hospitals, demonstrating the inequality improvement in health institutions for most of these health resource indicators of Shanghai over seven years. From 2010 to 2016, the Theil indexes of all the equipment indicators in hospitals ,total value of equipment above ￥10,000 , number of equipment above ￥10,000 , and number of equipment above ￥1,000,000, all showed a decline, despite a bit increase from 2013 to 2014,which indicated that the inequality of hardware construction in hospitals had been improved in those years. Similarly, for the Theil indexes of the healthcare workforce in PHCs, number of technicians, and number of doctors, there all showed consistently a downward trend during the period. Also, those indexes of total value of equipment above ￥10,000, number of equipment above ￥10,000 and number of equipment valued ￥500,000-690,000 in PHCs were shown an

ending decrease after experiencing some fluctuation in this period. However, for the Theil indexes of the healthcare workforce in hospitals, a reverse trend were both observed in the number of technicians and doctors during this period, for example, the Theil index of technicians in hospitals decreased from 0.2712 in 2010 to 0.2479 in 2013, followed by an increase until 0.3344 in 2016, this trend demonstrated that problem of the healthcare workforce allocation inequality in hospitals had not been solved in those years.

Discussion

Summary of principal findings

This study analyzed the time trends and inequality of health resource allocation of shanghai from a hierarchical perspective, finding an increasing, growing trend in amount and equality improvement in health resource allocation from 2010 to 2016. However there still existed situation in which health resource distribution differentiated regionally across different districts, and equipment and health workforce distribution showed serious inequalities between hospitals and PHCs in shanghai.

Implications for policy and practice

Firstly, the study found that the number of technicians, number of doctors, total value of equipment above ￥10,000 , number of equipment above ￥10,000 in hospitals and PHCs, number of equipment valued above ￥1,000,000 in hospitals, and number of equipment valued ￥500,000-690,000 in PHCs were all increasing during seven years. These results showed that achievement of Chinese government ’s efforts to make healthcare system reform operate smoothly to provide a safe, efficient and convenient

health service for the people over past 7 years. To expand and optimize the health resource, on the supply-side, according to "Healthy China 2030" Planning Outline and other health policy plans, China had integrated the health subsystems by investing financially in health institutions to multiple equipment, recruit and cultivate technicians, doctors, and making health institutions function re-oriented, updating healthcare service model based on the population health, to present a collaborative hierarchical medical system meeting people's health care demands [20-23]. It included not only perfecting the plans for geographical distribution of health resource across different regions and districts[24], but also keeping the hierarchical allocation balanced dynamically between hospitals and PHCs. On the demand-side, he also educated the people with "big-health" concept to foster a healthy life style , and re-designed medical insurance to widen coverage among more poorer people[25],making more and more patients have access to health resource reasonably. So, these measures mentioned above China and Shanghai government had resulted in increase of technicians, doctors and equipment across different institutions and districts on one hand, and inequality improvement of these health resource on the other hand in Shanghai from 2010 to 2016. Many previous studies supported the result[17,26-27].

Secondly, this study observed the regional difference in health resource allocation of Shanghai from 2010 to 2016. For example, unbalanced development of health programs between urban and rural areas still existed, resulting in the an abnormal phenomena named "inverted triangle" instead of "equilateral triangle, meaning that more and more technicians and doctors in PHCs were attracted to tertiary public hospitals and specialty

public hospitals, causing a loss of medical human resource in the primary health care. It maybe was because of shortages of primary health care, e.g. lower salary and constrained career advance caused primary health care doctors and nurses have to leave to work at larger hospitals. Another reason is that more lager hospitals were distributed in urban districts than in rural ones, attracting more and more health workforce in hospitals in urban areas. Some previous studies also contributed to these "inverted triangle" results[5,28]. One reason for suburban districts grew faster than urban ones in the numbers of equipment in hospitals and PHCs, was that based on fewer health resource and slower development for health institutions of rural areas ,it was urgent and important to expand equipment in health institutions and easy to achieve this goal than to recruit and educate doctors and nurses in a short time when invested in vastly in Shanghai since 2009. This regional difference result was similar to previous studies finding the rapid growing of equipment in hospitals and PHCs in suburban areas in China[29-30].

Thirdly, the present study confirms the inequality among technicians, doctors, and equipment in health institutions from 2010 to 2016. On one hand, the Theil indexes of health workforce in hospitals, such as technicians and doctors, were increasing during this period, indicating a worsening distribution inequality of health resource though increased during the period. The reason for this is that the elevated provision of human resources does not necessarily indicate a decline in inequity, as has been proven in other countries[31-34]. As mentioned in regional difference above, more and more technicians, doctors would like to flow into larger urban hospitals rather than rural hospitals, new

hospitals or private hospitals for sake of higher salary and more access to their own career development there. Another reason was that hospitals both in urban areas and rural ones would compete for more patients and profits , because of the Matthew effect in medical field , indicating that more and more patients were seeing doctors in famous general or tertiary hospitals in urban areas, and fewer patients would trust doctors in not-famous hospitals, leading to more human resource in health institutions pouring into larger hospitals, further exacerbating the disparities between larger hospitals and small ones. This finding was similar to some previous studies which all confirmed the health workforce distribution gap between urban health institutions and rural ones[35-37]. On the other hand, hospitals had higher Theil indexes than PHCs in all the number of health resource, especially equipment in shanghai at every year, demonstrating another unbalanced distribution of health resource between hospitals and PHCs. The explanation for this is that with rapid development of hospitals, many hospitals had gained high profits, and continuously invested in recruiting and educating doctors and buying more large and advanced medical equipment to meet more and more patients' medical needs unreasonably, resulting in the over-investment of health workforce and equipment in hospitals, meanwhile PHCs had not enough to invest in these health resource because of fewer patients and fewer profits to compete for with hospitals. This result was consistent with findings reported by Zhang T. et al.(2017)[38] and Wang YY. et al.(2017)[26].

The present study had several limitations. First, the data used in this manuscript can only reflect the health resource allocation status in Shanghai at the cut-off, for we can

only gain the data from the Chinese Yellowbooks which are often published officially at least two years later, so it was not possible to provide a complete reflection of the whole picture. A new study on changes of health resource allocation from 2017 until now and comparability of this study with that prospective research can be a future work when data are available. Second, the study did not consider the effect of the population health outcomes on the health resource allocation. According to the (health capacity paradigm, HCP) theory [39], the population health status in a region will have mutual effect on health resource allocation in that area. For the convenience of the study, we do not take account of these factors that may affect the results. Third, in this study, we choose indicators for the quality of health resources from hierarchical perspective rather than indicators of the quality of health services. There might be other unmeasured indicators influencing the differences observed, integrating the indicators of health resource used in this present study with ones of health service quality will get a sounder conclusion in the future.

Conclusion

Based on the analysis above, we can find that the increase of the health resource and the inequality improvement of the resource allocation in Shanghai from 2010 to 2016. This revealed that measures Chinese government had taken to ensure technicians, doctors, and equipment in hospitals and PHCs for the people to deepen China health care reform was successful since 2009. However, there still existed resource distribution regional difference between urban and rural areas and inequality across different health institutions. To achieve the regional balance of health resource

allocation between central and rural areas in Shanghai, a comprehensive solution is to raise wages and improve working conditions of the health workers to prevent them from flowing to urban hospitals is needed to change the situation of "inverted triangle" and eliminate the regional difference between hospitals and PHCs for the government. Some motivational efforts for him to make that cultivating and training more medical students with high degree and encouraging them to work in rural areas are also needed. Lastly, Some policies should not only pay attention to the health workforce distribution imbalance between larger urban hospitals and smaller ones, such as salary raising for doctors and nurses in small-scale suburban hospitals and implementing of job performance evaluation reform in hospitals, but also focus on the eliminate redundant equipment investment in hospitals and health workforce disparity between hospitals and PHCs, such as cost-benefit analysis, the input/output optimization and controlling of the scale of operations in the trial reform of public hospitals, improving the essential drug system, and cultivating and training grass-rooted medical workers, especially general practitioners in primary health care of China.

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Table 1 The Health Resource Allocation Indicators

The Prospective		Indicators
Hierarchical	Hospital	Number of technicians in hospitals
		Number of doctors in hospitals
		Total value of equipment above ￥10,000 in hospitals
		Number of equipment above ￥10,000 in hospitals
		Number of equipment above ￥1,000,000 in hospitals
	PHC	Number of technicians in PHCs
		Number of doctors in PHCs
		Total value of equipment above ￥10,000 in PHCs
		Number of equipment above ￥10,000 in PHCs
		Number of equipment valued ￥500,000-690,000 in PHCs

Table 2 The Amount and GR of Health Resource Allocation (2010 – 2016) (per 1000)

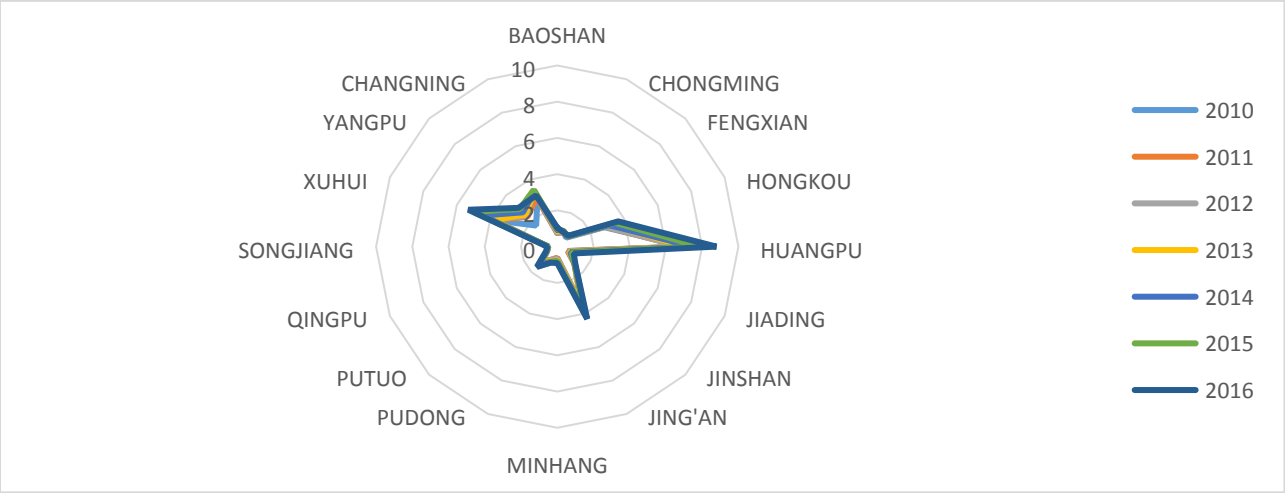
Indicator	2010	2011	2012	2013	2014	2015	2016	GR
Number of technicians in hospitals	4.205	4.331	4.484	4.750	4.970	5.205	5.493	30.6%
Number of doctors in hospitals	1.415	1.437	1.476	1.527	1.613	1.695	1.776	25.5%
Total value of equipment above ￥10,000 in hospitals	62.306	75.231	75.775	79.025	87.995	100.582	108.823	74.7%
Number of equipment above ￥10,000 in hospitals	3.659	4.384	4.758	5.090	6.393	6.199	6.363	73.9%
Number of equipment above ￥1,000,000 in hospitals	0.087	0.108	0.122	0.133	0.154	0.176	0.193	122.7%
Number of technicians in PHCs	1.063	1.081	1.095	1.118	1.153	1.180	1.205	13.4%
Number of doctors in PHCs	0.402	0.414	0.421	0.421	0.439	0.440	0.448	11.6%
Total value of equipment above ￥10,000 in PHCs	4.215	4.420	5.208	5.890	6.525	7.683	8.255	95.8%
Number of equipment above ￥10,000 in PHCs	0.575	0.583	0.695	0.769	0.876	0.989	1.086	89.0%
Number of equipment valued ￥500,000-690,000 in PHCs	0.010	0.012	0.013	0.014	0.016	0.019	0.021	112.4%

GR: Growth Rate

Table 3 Time Trends of the Theil Indexes of Health Resource in Shanghai (2010 - 2016)

Indicators	2010	2011	2012	2013	2014	2015	2016
Number of technicians in hospitals	0.2712	0.2593	0.2570	0.2479	0.2489	0.2544	0.3344
Number of doctors in hospitals	0.3377	0.3308	0.3307	0.3165	0.3266	0.3371	0.3401
Total value of equipment above ￥10,000 in hospitals	0.6213	0.5773	0.6317	0.5212	0.5401	0.5397	0.5282
Number of equipment above ￥10,000 in hospitals	0.5124	0.4797	0.4561	0.3724	0.4829	0.3636	0.4562
Number of equipment above ￥1,000,000 in hospitals	0.6613	0.6136	0.5831	0.4993	0.5037	0.5027	0.4699
Number of technicians in PHCs	0.0354	0.0303	0.0250	0.0227	0.0190	0.0189	0.0186
Number of doctors in PHCs	0.0423	0.0385	0.0325	0.0295	0.0248	0.0197	0.0178
Total value of equipment above ￥10,000 in PHCs	0.0783	0.0799	0.0748	0.0866	0.0729	0.0889	0.0482
Number of equipment above ￥10,000 in PHCs	0.0918	0.0924	0.0962	0.0885	0.0826	0.0611	0.0570
Number of equipment valued ￥500,000-690,000 in PHCs	0.1028	0.1397	0.1314	0.1359	0.0886	0.0630	0.0490

(a)



(b)

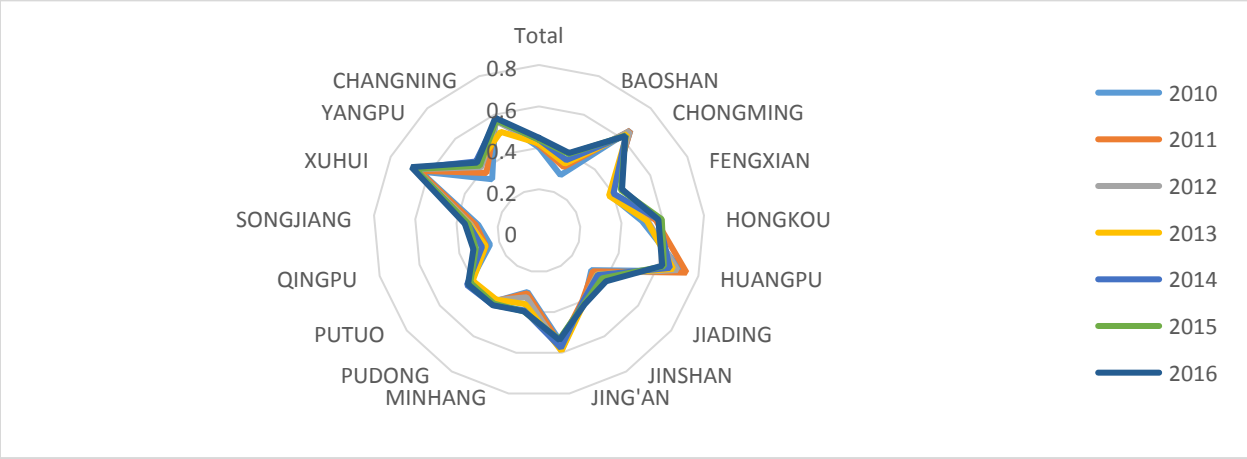
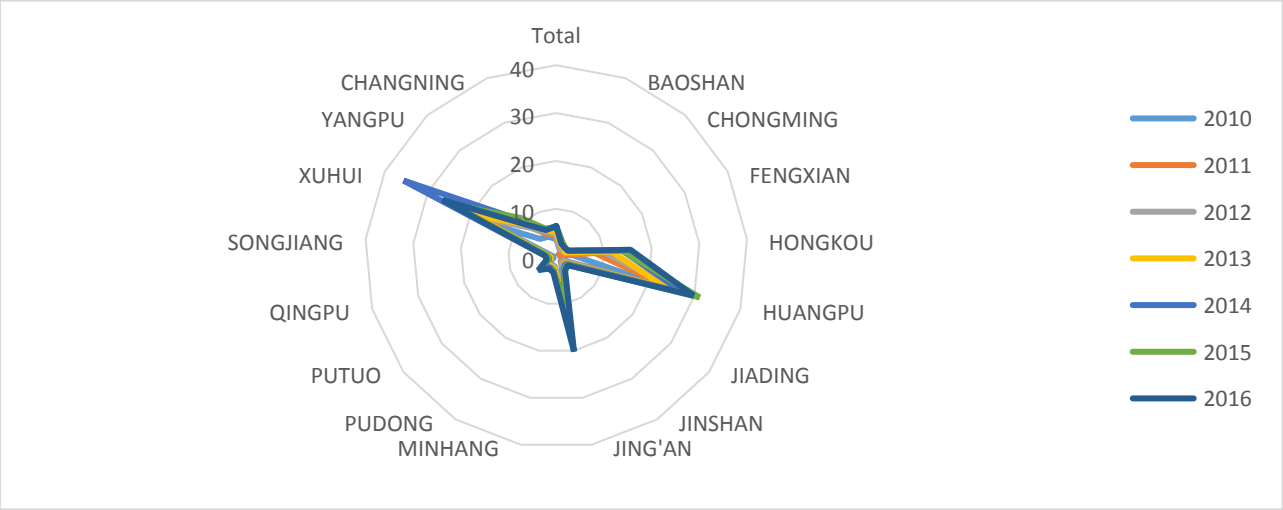


Fig.1 Per 1000 doctors in health institutions across the districts from 2010 to 2016. (a) presents per 1000 doctors in hospitals across the districts from 2010 to 2016;(b) presents per 1000 doctors per 1000 population in PHCs across the districts from 2010 to 2016

(a)



(b)

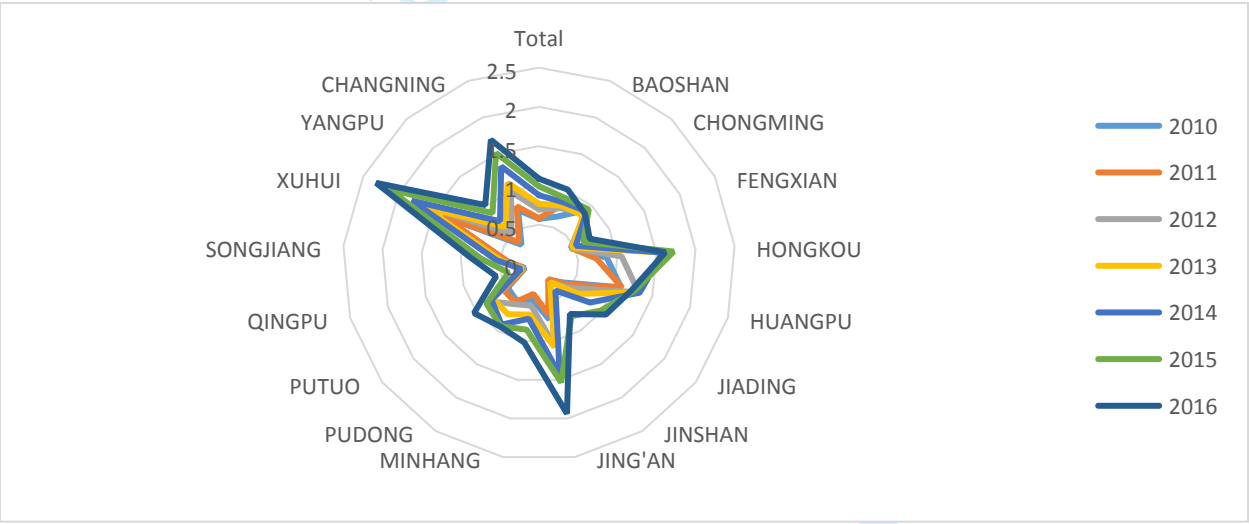
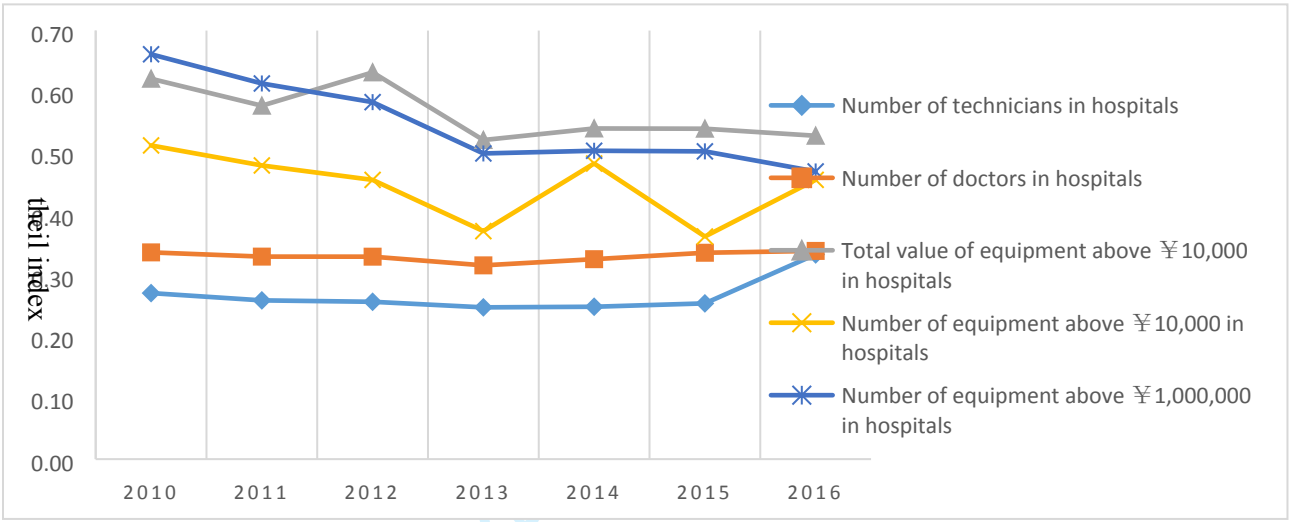


Fig.2 The number of equipment above ￥10,000 per 1000 in health institutions from 2010 to 2016 (a) presents the number of equipment above ￥10,000 per 1000 in hospitals from 2010 to 2016;(b) presents the number of equipment above ￥10,000 per 1000 in PHCs from 2010 to 2016



(b)

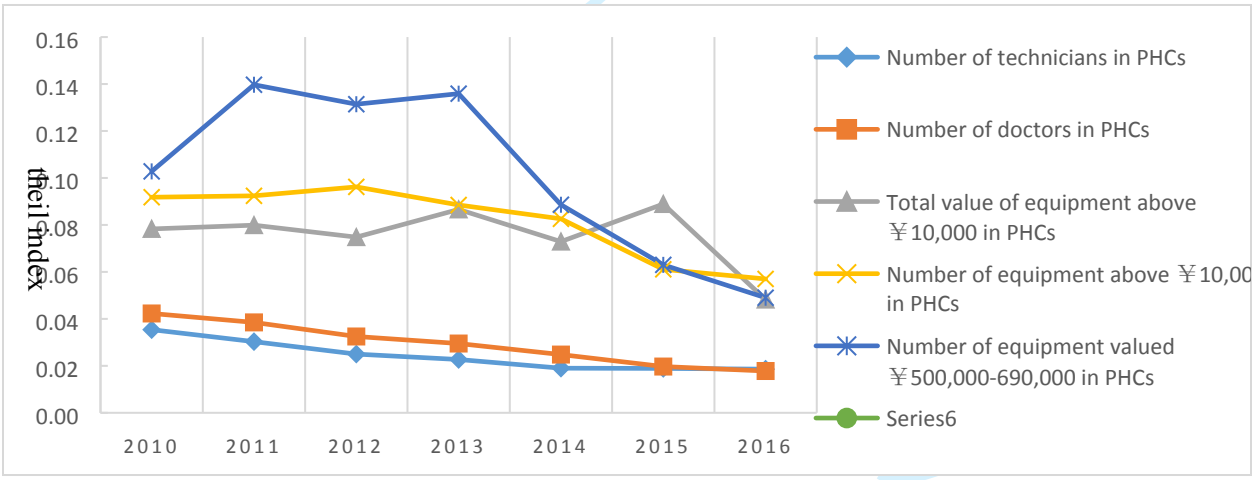


Fig. 3 Trends of the theil indexes for the health resource in health institutions from 2010 to 2016 (a) presents trends of the theil indexes for the health resource in hospitals from 2010 to 2016;(b) presents trends of the theil indexes for the health resource in PHCs from 2010 to 2016

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Differences in regional distribution and inequality in health-resource allocation at hospital and primary health center levels: A longitudinal study in Shanghai

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Abstract

Objectives: To analyze differences in regional distribution and inequality in health-resource allocation at the hospital and primary health center (PHC) levels in Shanghai over 7 years.

Design: A longitudinal survey using 2010–2016 data, which were collected for analysis.

Setting: The study was conducted at the hospital and PHC levels in Shanghai, China.

Outcome measures: Ten health-resource indicators were used to measure health-resource distribution at the hospital and PHC levels. In addition, the Theil index was calculated to measure inequality in health-resource allocation.

Results: All quantities of health-care resources per 1000 people in hospitals and PHCs increased across Shanghai districts from 2010 to 2016. Relative to suburban districts, the central districts had higher ratios, both in terms of doctors and equipment, and had faster growth in the doctor indicator and slower growth in the equipment indicator in hospitals and PHCs. The Theil indices of all health-resource allocation in hospitals had higher values compared with those in PHCs every year from 2010 to 2016; furthermore, the Theil indices of the indicators, except for technicians and doctors in hospitals, all exhibited downward time trends in hospitals and PHCs.

Conclusions: Increased health-care resources and reduced inequality of health-resource allocation in Shanghai during the 7 years indicated that measures taken by the Shanghai government to deepen the new round of healthcare reform in China since 2009 had been successful. Meanwhile there still existed regional difference between urban and rural areas and inequality across different medical institutions. To solve these problems, we prescribe increased wages, improved working conditions, and more open access to career development for doctors and nurses; reduced investments in redundant equipment in hospitals; and other incentives for balancing the health workforce between hospitals and PHCs.

Keywords: Health-care resources, regional difference, inequality, hospital, primary health center (PHC)

Strengths and limitations of this study

►► Few studies have focused on the association between health-resource allocation and healthcare reform, making the findings of the present study generalizable and applicable to countrywide policies and interventions.

►► A future study will be conducted on health-resource distribution and inequality in health-

resource allocation in Shanghai from 2017 until the present, and its findings will be compared with those of the present study, to provide robust policy prescriptions for China and other developing countries.

►► This study did not analyze factors that may have affected the results, such as the mutual effect between the population's health status and health-resource allocation.

►► Because this study chose indicators of the quality of health-care resources rather than of health service, unaccounted-for factors represented by these indicators could have influenced the observed differences. Thus, the study's conclusion should be generalized with caution.

1. Introduction

Reasonable health-resource allocation is essential to achieving health service equity, which contributes to public health and mitigates social conflict [1–3]. In many countries, healthcare reform aims to provide universal and equitable access to health care, which is recognized as a fundamental human right. The distribution of health-care resources is a critical component of health-care access. Furthermore, equity is a basic principle of health-resource allocation, and it is foundational to achieving fairness in the provision of health services. Many studies have demonstrated that wide access to health care can play a crucial role in promoting regional health equity [4–6]. The equitable allocation of health-care resources helps deliver health-care resources to those most in need and ensures accessibility to basic health services as well as fairness for vulnerable populations[7]. Moreover, inequality in health-care resources has adverse consequences, such as the uneven distribution of health-care allocation, which in turn leads to growing inequalities between the rich and poor with respect to health and the economic burden of disease [8]. In 2009, China launched a new round of healthcare reforms with the aim of providing households with secure, efficient, convenient, equitable, and affordable health-care services by reversing the early 1980s move to a market-oriented health system. The reform strengthened the government's role in healthcare, its commitment to equity, and its willingness to experiment with regulated market approaches. The Chinese healthcare system is composed of a health financing system, a health service delivery system, and a health supervision system. Although relatively independent, these subsystems are interrelated, and different actors have their function in them. The health service delivery system consists of the public health system and medical service delivery system; the medical service delivery system includes hospitals at the provincial, city, and county levels, as well as primary

health centers (PHCs). The Chinese Ministry of Health divides medical institutions into three levels by their tasks and functions to form a hierarchical medical system. In this hierarchy, PHCs (the first level), secondary hospitals (the second level), and tertiary hospitals (the third level) provide primary, secondary, and tertiary care, respectively[9]. In this hierarchical medical system in China, patients are channeled toward the appropriate-level institution for treatment and are encouraged to first visit PHCs when they need to see a doctor. Patients are then referred up the hierarchy where necessary, and doctors have the right to decide such referrals. This hierarchical medical system was designed to enable the government to allocate health-care resources efficiently among patients in China.

Accordingly, since 2009, the Shanghai government has implemented corresponding measures to allocate health-care resources between hospitals and PHCs, conforming tightly to national health reform strategies and guidelines. As a result of these measures, the quantity of medical equipment and numbers of doctors and nurses have increased, and the distribution of health-care resources has become more balanced [10–12]. However, many studies have noted widening urban–rural disparities in health-care resources across Chinese medical institutions of various types [13–18], including in Shanghai [12]. Studies have examined variations in the quantity of and inequality in health-resource allocation in China; however, they have overlooked differences over time in health-resource allocation at two institutional levels as well as their association with China's 2009 healthcare reform. Considering the overall goal of China's new health-care guidelines and plans to promote more equitable and efficient health-care resource distribution, it is essential to study the differences in health-resource distribution and inequity of allocation in Shanghai over time since the 2009 reforms.

Therefore, the purpose of this study was first, to investigate regional difference in health-resource distribution and the inequity in their allocation at the hospital and PHC level over 7 years (2010–2016) in Shanghai and second, their association with the new round of health reform in China since 2009.

2. Methods

2.1Patient and public involvement

This study used secondary data from Yearbooks (2010-2016) in Shanghai of China and did not require patient or public involvement.

2.2 Data source

This study used data from the Shanghai Medical Statistical Yearbook from 2010–2016 and the Shanghai Statistical Yearbook from 2010–2016, which are published by the Shanghai Health Commission and Shanghai Statistics Bureau, respectively. Because China has pushed hospitals and PHCs to establish a hierarchical medical system to improve health service quality, we measured health-resource allocation to evaluate the effect of these policies on hospitals and PHCs. The indicators used included the number of health technicians in hospitals or PHCs, the number of doctors in hospitals or PHCs, the total value of medical equipment above RMB 10,000 (US$ 1424) in hospitals or PHCs, the number of medical equipment items valued above RMB 10,000 (US$ 1424) in hospitals or PHCs, and the number of medical equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals and between RMB 500,000 and 690,000 (US$ 71,205 and 98,263) in PHCs. These data were taken from the 2010 to 2016 editions of the Shanghai Medical Statistical Yearbook. Table 1 presents all 10 indicators and their definitions along with how they were measured. Per capita measures of all the indicators were calculated after obtaining the annual population of the whole city and every administrative district from the 2010–2016 editions of the Shanghai Statistical Yearbook

Table 1 Indicators of health-resource allocation, their definitions, and how they were measured

Indicators	Definition	How they were measured
Number of technicians in hospitals	Workforce in hospitals who assist medical staff complete tasks around their assigned unit or clinic and accommodate patient needs, including pharmacists and radiologists; registered nurses were excluded.	Number of technicians in hospitals divided by the population
Number of doctors in hospitals	Physicians in hospitals who hold a practicing physician certificate, including practicing physicians and assistants in China. Those who are engaged in the management of health workers as part of the health workforce, such as presidents, vice presidents, and party secretaries were excluded.	Number of doctors in hospitals divided by the population
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	Total monetary value equal to or more than RMB 10,000 of durable equipment in hospitals that is intended to withstand repeated use by professional and patients. This includes diagnostic equipment, including medical imaging machines, such as ultrasound and MRI machines, PET and CT scanners, and X-ray machines; treatment equipment, including infusion pumps, medical lasers, and LASIK surgical machines; and other medical equipment in Chinese health institutions.	Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals divided by the population
Number of equipment items valued above RMB 10,000	This refers to the number of durable equipment items (as defined above) valued at or more than RMB 10,000 in hospitals.	Number of equipment items valued above RMB 10,000 (US$ 1,424) in

(US$ 1,424) in hospitals		hospitals divided by the population
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	This refers to the number of durable equipment items (as defined above) valued at or more than RMB 1,000,000 in hospitals.	Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals divided by the population
Number of technicians in PHCs	This refers to the workforce in PHCs (the same as defined above for hospitals).	Number of technicians in PHCs divided by the population
Number of doctors in PHCs	This refers to the actual physicians in PHCs (the same as defined above for hospitals).	Number of doctors in PHCs divided by the population
Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	This refers to the total monetary value at or more than RMB 10,000 of durable equipment in PHCs (equipment is the same as defined above for hospitals).	Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs divided by the population
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	This refers to the number of durable equipment items (as defined above) valued at or more than RMB 10,000 in PHCs.	Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs divided by the population
Number of equipment items valued at RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	This refers to the number of durable equipment items (as defined above) valued between RMB 500,000 and 690,000 in PHCs.	Number of equipment items valued at RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs divided by the population

Shanghai is one of four directly controlled municipalities of the People's Republic of China, and it is further divided into 16 districts, among which are seven urban and nine suburban districts. Shanghai's urban administrative divisions are as follows: Huangpu, Xuhui, Changning, Jing'an, Putuo, Hongkou, and Yangpu. Its rural administrative divisions are Minhang, Baoshan, Jiading, Pudong New Area, Jinshan, Songjiang, Qingpu, Fengxian, and Chongming. Over 7 years from 2010 to 2016, Shanghai had three administration division mergers aimed at facilitating the long-term development of all the districts involved; enhance the administrative efficiency of urban function and resource distribution for the city; as well as reduce administrative costs. Specifically, in 2011, Luwan District was merged with a neighboring district to form the new Huangpu District; Zhabei was merged with Jing'an District in 2015; and Chongming County was upgraded to

Chongming District in 2016. To maintain data comparability, we formatted the new data of the 16 administration divisions by integrating the data of the two merged districts of Luwan and Zhabei into those of Huangpu and Jing'an, respectively.

2.3 Data analysis

Many measures exist for evaluating the equity of health-resource allocation, such as the Lorenz curve, Gini coefficient, and Theil index. The Theil index is a statistic primarily used to measure income inequality or other economic phenomena among different individuals or within varied groups. It is a special case of the generalized entropy index and one of the most widely used measures of inequality in regional economic development. The Theil index was proposed by econometrician Henri Theil at Erasmus University Rotterdam [19], and it can be formulated as follows:

$$T = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{\overline{y}}\log(\frac{y_i}{\overline{y}}), \quad (1)$$

where T is the Theil index, which represents income allocation inequality, and y_i and $\overline{y}$ is the income of individual *i* and the average income of the population, respectively.

The Theil index has another form to measure the inequality between different groups, which is known as the between-region difference. This formula can be written as follows:

$$T = \sum_{i=1}^{k} w_i \ln(\frac{w_i}{e_i}), \quad (2)$$

where w_i represents the proportion of the income of group *i* accounting for the total income of all groups and e_i represents the proportion of the people in group *i* accounting for the overall population of all groups. In this study, we defined w_i as the proportion of health-care resources in district *i* accounting for the resources of the whole city, and we defined e_i as the proportion of the people in district *i* accounting for the overall population of the city.

3. Results

3.1 Differences in regional distribution of health-resource allocation at the hospital and PHC levels in Shanghai from 2010 to 2016

Table 2 presents descriptive statistics of indicators of health-resource allocation in Shanghai's hospitals and PHCs. Table 3 presents changes in numbers and growth rates related to health-resource allocation in Shanghai's hospitals and PHCs. Further details of changes for each indicator with whiskers box plot per every year from 2020 to 2016 are presented in appendix (see the additional file). As indicated by the table, the health-care resources in hospitals and PHCs increased gradually from 2010 to 2016, the quantities of health-care resources per 1000 of the population all increased, and the number of equipment items grew faster than did the health workforce in hospitals and PHCs overall. For example, from 2010 to 2016, the number of equipment items valued above RMB 10,000 (US$ 1424) per 1000 people and above RMB 1,000,000 (US$ 142,410) per 1000 people in hospitals increased by 73.9% and 122.7%, respectively; furthermore, the numbers of technicians and doctors per 1000 people in hospitals increased by 30.6% and 25.5%, respectively, more than twice the corresponding numbers of technicians and doctors in PHCs during the same period.

As for administrative divisions, from 2010 to 2016, an increasing trend was observed in the numbers of doctors and equipment items per 1000 people both in hospitals and PHCs across all districts except for Chongming District. Chongming had an unexpected decrease from 0.94 in 2010 to 0.87 in 2016 for the number of equipment items valued above RMB 10,000 (US$ 1424) per 1000 people in PHCs.

In common for every district was a similar trend of the number of equipment per 1000 of the population growing faster than that of doctors, in both hospital and PHCs from 2010 to 2016. Noticeably, whether in hospitals or PHCs, central districts had higher ratios than did

Table 2 Descriptive Statistics of indicators of health-resource allocation in Shanghai's hospitals and PHCs (2010–2016; per 1000)

Indicators	Obs.	Min.	Max.	Mean.	Median
Number of technicians in hospitals	112	1.42	26.14	6.04	3.34
Number of doctors in hospitals	112	0.49	8.79	2.07	1.10
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	112	4.51	516.87	114.33	46.49
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	112	0.36	35.65	6.77	2.95
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	112	0.05	8.24	1.87	0.81
Number of technicians in PHCs	112	0.76	2.06	1.23	1.17
Number of doctors in PHCs	112	0.25	0.74	0.46	0.42

Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	112	1.65	20.61	6.33	5.35
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	112	0.19	2.32	0.86	0.79
Number of equipment items valued above RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	112	0.00	0.21	0.04	0.03

Table 3 Changes in the numbers and growth rates related to health-resource allocation in Shanghai's hospitals and PHCs (2010–2016; per 1000)

Indicator	2010	2011	2012	2013	2014	2015	2016	GR
Number of technicians in hospitals	4.21	4.33	4.48	4.75	4.97	5.21	5.49	30.6%
Number of doctors in hospitals	1.42	1.44	1.48	1.53	1.61	1.70	1.78	25.5%
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	62.31	75.23	75.78	79.03	88.00	100.58	108.82	74.7%
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	3.66	4.38	4.76	5.09	6.39	6.20	6.36	73.9%
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	0.09	0.11	0.12	0.13	0.15	0.18	0.19	122.7%
Number of technicians in PHCs	1.06	1.08	1.10	1.12	1.15	1.18	1.21	13.4%
Number of doctors in PHCs	0.40	0.41	0.42	0.42	0.44	0.44	0.45	11.6%
Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	4.22	4.42	5.21	5.89	6.53	7.68	8.26	95.8%
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	0.58	0.58	0.70	0.77	0.88	0.99	1.09	89.0%
Number of equipment items valued above RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	0.01	0.01	0.01	0.01	0.02	0.02	0.02	112.4%

GR = growth rate.

suburban districts both in the number of doctors and equipment per 1000 of the population. This indicated an unchanged distribution concentration in health-care resource allocation among central areas other than rural ones in Shanghai. Figures 1 (a) and (b) illustrate the numbers of doctors in hospitals and PHCs, respectively, per 1000 of the population across Shanghai's districts from 2010 to 2016. As for the number of doctors per 1000 people in hospitals, central districts grew faster than suburban ones did over this period; for example, in hospitals, Xuhui exhibited an increase of 39.47%, Hongkou of 28.57%, and Huangpu of 28.57%, whereas Songjiang and Qingpu only

exhibited increases of under 1% in the same period. Even Fengxian, the fastest growing division for ratios of doctors across all rural districts, only exhibited an increase of 14.29%, lower than the 15% average growth rate for hospitals in central districts over the 7 years. By contrast, no PHCs in either central or suburban districts exhibited a marked increase in the number of doctors per 1000 of the population.

Figure 2 (a) and (b) illustrate the number of equipment items valued above RMB 10,000 per 1000 people in hospitals and PHCs, respectively, from 2010 to 2016. A different trend was observed between central and suburban districts in that central districts grew slower in terms of hospitals and PHCs in the same period. For example, from 2010 to 2016, in terms of equipment ratios in hospitals, Huangpu, Xuhui, Jing'an, and Hongkou Districts all exhibited increases in growth rates of 22.75, 76.16, 157.40, and 354.23%, respectively, while Songjiang, Qingpu, and Fengxian Districts all experienced rapid development of more than five-fold in per capita equipment. Similarly, in terms of equipment ratios in PHCs, Changning, Putuo, Jing'an, and Hongkou increased by 100%, while Qingpu and Jinshan increased by more than 200%.

3.2 Inequality in health-resource allocation at the hospital and PHC levels in Shanghai from 2010 to 2016

Table 4 and Fig. 3 present the Theil indices of health-resource allocation in Shanghai's hospitals and PHCs from 2010 to 2016. In the same year at different levels of medical institutions, the Theil indices in hospitals were higher than those in PHCs for overall health-care resources, especially for equipment. This indicated greater unfairness of health-care resource allocation in hospitals than in PHCs in Shanghai during this period. For example, in 2016, the Theil indices of the numbers of technicians and doctors in hospitals were 0.33 and 0.34, respectively, whereas the corresponding indices in PHCs were both 0.02. The Theil indices of the total value of equipment above RMB 10,000 (US$ 1424) and the number of equipment items valued above RMB 10,000 (US$ 1424) in hospitals were 0.53 and 0.46, respectively, whereas the corresponding indices in PHCs were 0.05 and 0.06, respectively.

Table 4 Theil indices related to health-resource allocation in hospitals and PHCs in Shanghai (2010–2016)

Indicators	2010	2011	2012	2013	2014	2015	2016
Number of technicians in hospitals	0.27	0.26	0.26	0.25	0.25	0.25	0.33

Indicators	2010	2011	2012	2013	2014	2015	2016
Number of doctors in hospitals	0.34	0.33	0.33	0.32	0.33	0.34	0.34
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	0.62	0.58	0.63	0.52	0.54	0.54	0.53
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	0.51	0.48	0.46	0.37	0.48	0.36	0.46
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	0.66	0.61	0.58	0.50	0.50	0.50	0.47
Number of technicians in PHCs	0.04	0.03	0.03	0.02	0.02	0.02	0.02
Number of doctors in PHCs	0.04	0.04	0.03	0.03	0.02	0.02	0.02
Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	0.08	0.08	0.07	0.09	0.07	0.09	0.05
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	0.09	0.09	0.10	0.09	0.08	0.06	0.06
Number of equipment items valued RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	0.10	0.14	0.13	0.14	0.09	0.06	0.05

As for Theil index trends for health-care resources in Shanghai from 2010 to 2016, the indices of all indicators exhibited a decline for both hospitals and PHCs, except for the numbers of technicians and doctors in hospitals. This indicated a reduction in the inequality in health institutions with respect to most health-care resource indicators in Shanghai over the 7 years. From 2010 to 2016, the Theil indices of all the equipment indicators in hospitals, the total value of equipment above RMB 10,000 (US$ 1424), the number of equipment items valued above RMB 10,000 (US$ 1424), and the number of equipment items valued above RMB 1,000,000 (US$ 142,410) all exhibited declines (despite a slight increase from 2013 to 2014). This indicated a reduction in the inequality of hardware construction in hospitals in that period.

Similarly, regarding the Theil indices of the health-care workforce in PHCs, those for the numbers of technicians and doctors both exhibited consistent downward trends during the period. Furthermore, after experiencing some fluctuations during this period, the indices for the total value of equipment above RMB 10,000 (US$ 1424), number of equipment items valued above RMB

10,000 (US$ 1424), and number of equipment items valued RMB 500,000–690,000 ($71,205–98263) in PHCs exhibited continual decreases. However, for the Theil indices of the health-care workforce in hospitals, reverse trends were observed in both the numbers of technicians and doctors during this period; for example, the index of technicians in hospitals decreased from 0.27 in 2010 to 0.25 in 2013, followed by an increase to 0.33 in 2016; similarly, the index of doctors in hospitals exhibited the same trend, which demonstrated that the problem of inequality in health-care workforce allocation in hospitals had not been solved.

4. Discussion

This study analyzed the temporal trends and inequality of health-resource allocation at the hospital and PHC levels in Shanghai, noting trends of improvements in the quantity and inequality in health-resource allocation from 2010 to 2016. However, various regions have an unbalanced distribution of health-care resources, especially equipment and health workforce in hospitals, which exhibited serious inequalities in either number or temporal trend.

First, this study observed that the number of technicians, number of doctors, total value of equipment above RMB 10,000 (US$ 1424), number of equipment items valued above RMB 10,000 (US$ 1424) in hospitals and PHCs, number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals, and number of equipment items valued RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs all increased over the 7 years. These results indicated that the Chinese government's goals of reforming the healthcare system to operate smoothly and provide a safe, efficient, and convenient health service over past 7 years have been achieved. To expand and optimize health-care resources on the supply side, according to the "Healthy China 2030" planning outline and other health policy plans, China has integrated health subsystems by investing financially in health institutions to purchase various types of equipment; recruit and train technicians and doctors; make health institutions function reoriented; update the health-care service model based on the state of public health; and present a collaborative hierarchical medical system that meets people's health-care demands [20–23]. This included not only perfecting plans for the geographical distribution of health-care resources across different regions and districts [24] but also maintaining a dynamic balance in allocation between hospitals and PHCs. On the demand-side, the government has educated Chinese people about the "big health" concept to foster healthy lifestyles, as well as re-designed medical insurance to widen coverage among poorer people [25],

providing an increasing number of patients with reasonable access to health-care resources. Thus, the aforementioned measures of the Chinese and Shanghai governments have resulted in increased numbers of technicians, doctors, and equipment items across different institutions and varied districts, and also reduced the inequality in health-resource allocation from 2010 to 2016. Numerous studies have supported these results [17,26–27].

Second, this study observed regional differences in health-resource distribution at the hospital and PHC levels from 2010 to 2016. Health programs were unbalanced in their development when hospitals and PHCs were compared, which resulted in an aberrant phenomenon named an "inverted triangle," as opposed to an "equilateral triangle," meaning that increasing numbers of technicians and doctors in PHCs have been attracted to tertiary and specialty public hospitals. This has caused losses in medical human resources in the PHCs. This has happened because of lower salaries and limited career advancement causing PHC doctors and nurses to leave to work at larger hospitals. Some relevant studies have also noted an "inverted triangle" [5,28]. Furthermore, more larger hospitals were distributed in urban districts than in rural ones, which led to increasing numbers of the health workforce being attracted from suburban to central districts. Additionally, suburban districts grew faster than urban ones did in terms of numbers of equipment items in hospitals and PHCs because—due to fewer health-care resources and the slower development of health institutions in rural areas—expanding the equipment in health institutions was urgent. Moreover, this goal was easier to achieve than quickly recruiting and training doctors and nurses was when the government invested significantly in Shanghai from 2009 onward. This result on the regional difference is similar to those of studies that discovered rapidly growing numbers of equipment items in suburban areas in China and an overcentralized health workforce in urban areas [29–30].

Third, this study used the Theil index to analyze inequality in health-resource allocation. The index has some disadvantages, such as being complex to calculate and interpret; a wide variety when distribution varies regardless of the change that occurs in the top, middle, or bottom tier of resources; and the fact that when comparing populations with different sizes, the calculation is dependent on the number of individuals in the population or group. Nonetheless, this measurement method can still be robust when determining inequality within and between group components, with high sensitivity to the efficiency of health-resource allocation. This is because the index is decomposable by groups, can incorporate group-level data, and is particularly effective at paring

effects in hierarchical data sets [31]. This study confirmed the inequality among technicians, doctors, and equipment in hospitals from 2010 to 2016. On the one hand, hospitals had higher Theil indices than did PHCs in numbers of all health-care resources, especially equipment in Shanghai in every year, again demonstrating unbalanced distribution of health-care resources between hospitals and PHCs. This is attributable to the fact that with the rapid development of hospitals, many hospitals have profited and have thus continually invested in the recruitment and education of doctors and have bought large quantities of advanced medical equipment to meet the medical needs of an increasing number of patients. This has resulted in overinvestment in the health workforce and equipment, whereas PHCs have not invested enough in these health-care resources and cannot compete with hospitals because they have fewer patients and are less profitable. This result is consistent with the findings reported by Zhang T. et al. [32]and Wang YY. et al. [26]. On the other hand, the Theil indices of the health workforce in hospitals, such as technicians and doctors, increased during this period, indicating worsening inequality in health-resource allocation. The reason is that the elevated provision of human resources does not necessarily indicate a decline in inequity, as has been noted in other countries [33–36]. As mentioned, increasing numbers of technicians and doctors flow into larger urban hospitals from rural, new, or private hospitals for reasons of salary and career advancement. Another reason is that hospitals will compete for more patients and profit because of the Matthew effect in the medical field, indicating that an increasing number of patients have been seeing doctors in famous tertiary or larger hospitals, and fewer patients trust doctors in nonfamous or small hospitals, leading to more human resources in health institutions pouring into larger hospitals, thereby further exacerbating the disparities between larger and smaller hospitals. This finding is similar to those of some relevant studies, which have confirmed the health workforce distribution gap among hospitals of various sizes[37–39].

The present study has several limitations. First, the data used potentially only reflect the health-resource allocation status in Shanghai at the cut-off because we could only obtain them from the Chinese Yellowbooks, which are often published officially at least 2 years after the year the data were for; therefore, crucial information could have been omitted from our data. In the future, a new study on changes in health-resource allocation from 2017 to the present, along with comparisons with the present study, can be conducted when the data are available. Second, this study did not consider the effect of the population's health outcomes on health-resource allocation. According to the health capacity paradigm theory [40], the population's health status in a region will

have mutual effects on health-resource allocation in that area. Due to time and resource constraints, we did not consider these factors, which may have affected the results. Third, we selected indicators for health-resource allocation at different institutional levels rather than indicators of the quality of health services. Factors represented by other unmeasured indicators may have influenced the results. Thus, integrating the indicators of health-resource allocation used in this study with those of health service quality may yield more robust results in a future study.

5. Conclusion

Health-care resources increased and inequality in resource allocation decreased in Shanghai from 2010 to 2016. This indicates the success of the measures taken by the Chinese government since its 2009 reforms, specifically with respect to technicians, doctors, and equipment in hospitals and PHCs. However, the distribution of health-care resources differed between urban and rural areas and between hospitals and other institutions. To achieve an institutional and regional balance in health-care resource distribution between central and rural areas, a comprehensive solution to raise wages and improve working conditions of health workers in PHCs and rural areas is required, which will prevent their excessive flow to hospitals and urban areas. This will prevent the inverted triangle from occurring and mitigate the institutional burden for the government. In addition, motivational efforts are required to cultivate and train more medical students to a high degree and encourage them to work in rural areas. Policies should not only be focused on the imbalance in the health workforce distribution between larger urban hospitals and smaller ones—such as policies for raising salaries for doctors and nurses in small-scale suburban hospitals and implementing job performance evaluation reform in all hospitals—they should also be focused on reducing redundant equipment investments and health workforce disparity in hospitals—such as implementing cost-benefit analyses and input/output optimization as well as controlling the scale of operations in the trial reform of public hospitals. To more deeply explore health-resource allocation, future studies must be conducted that integrate the indicators used in the present study with indicators of health service quality.

Contributor statement

ED, HW, LC,TW and LZ designed the study together， acquired the data and developed the statistical plan. SL,MC and TX carried out the survey. HW and LC performed the statistical analysis. ED,TW and LZ interpreted the analysis. ED and LZ drafted and revised the manuscript. All authors read and approved the final manuscript.

Competing interests None

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Data sharing statement Data are available upon reasonable request.

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(a)

(b)

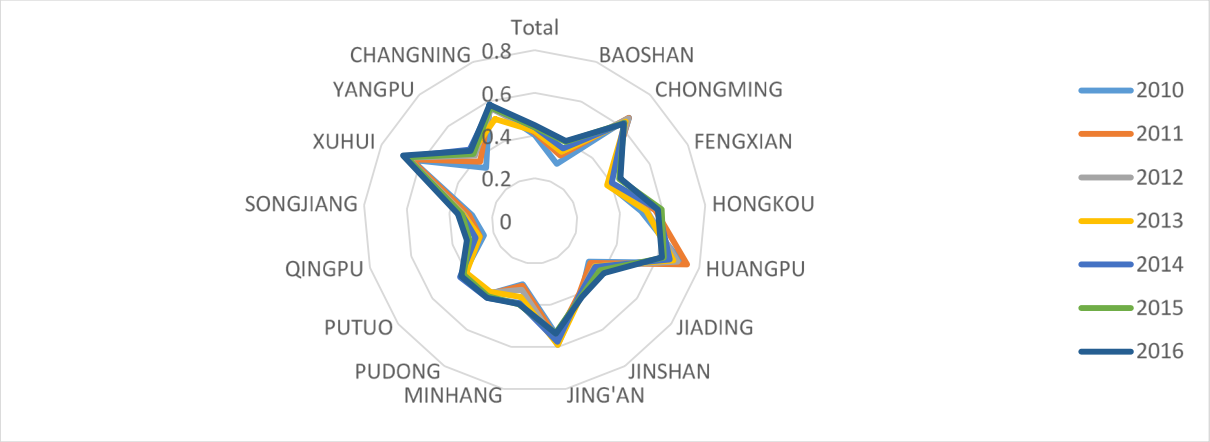
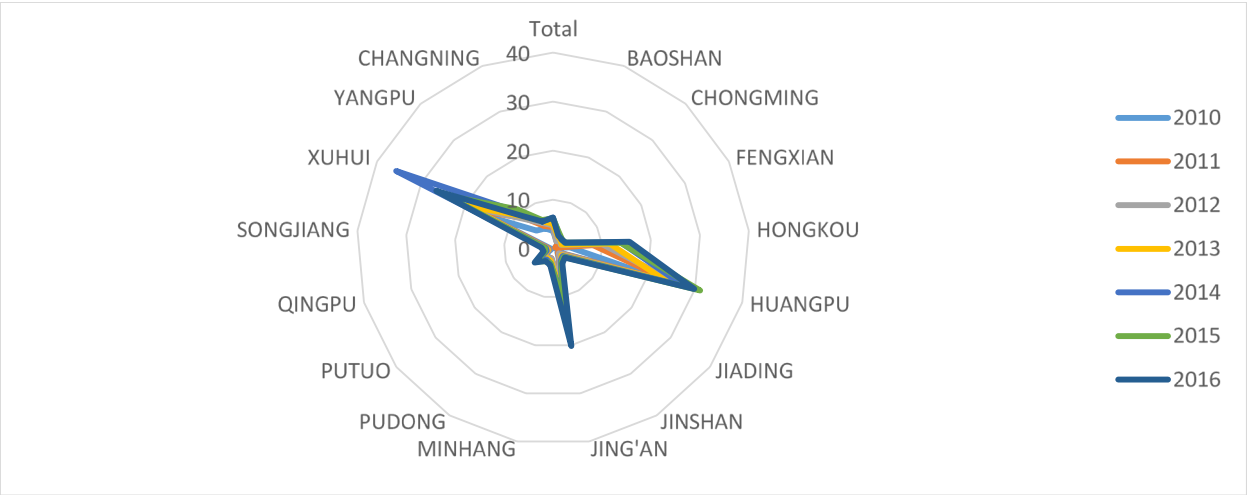


Fig.1 Per 1000 doctors in health institutions across the districts from 2010 to 2016. (a) presents per 1000 doctors in hospitals across the districts from 2010 to 2016;(b) presents per 1000 doctors per 1000 population in PHCs across the districts from 2010 to 2016

(a)



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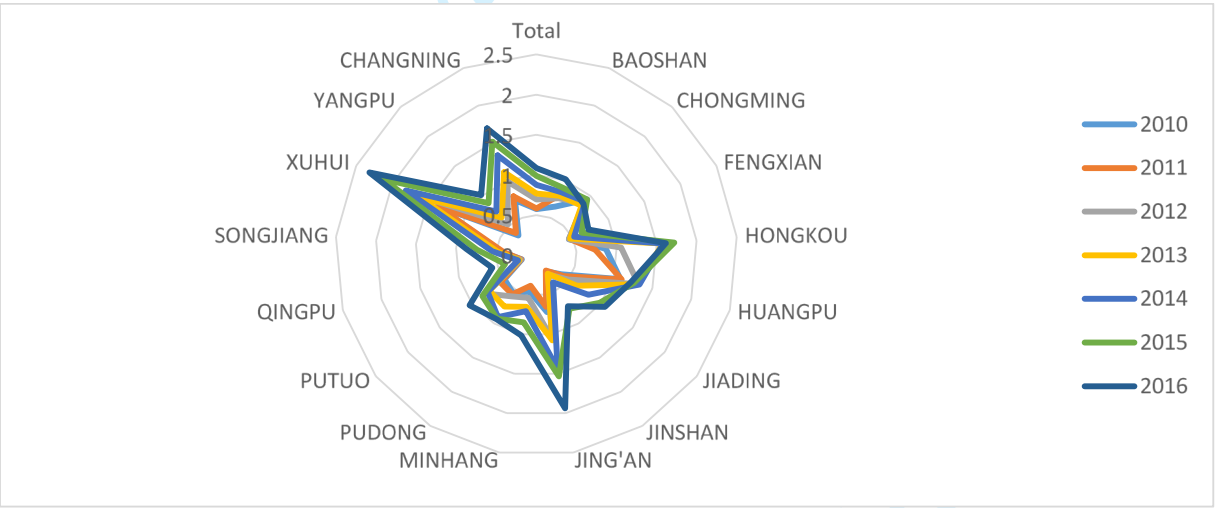
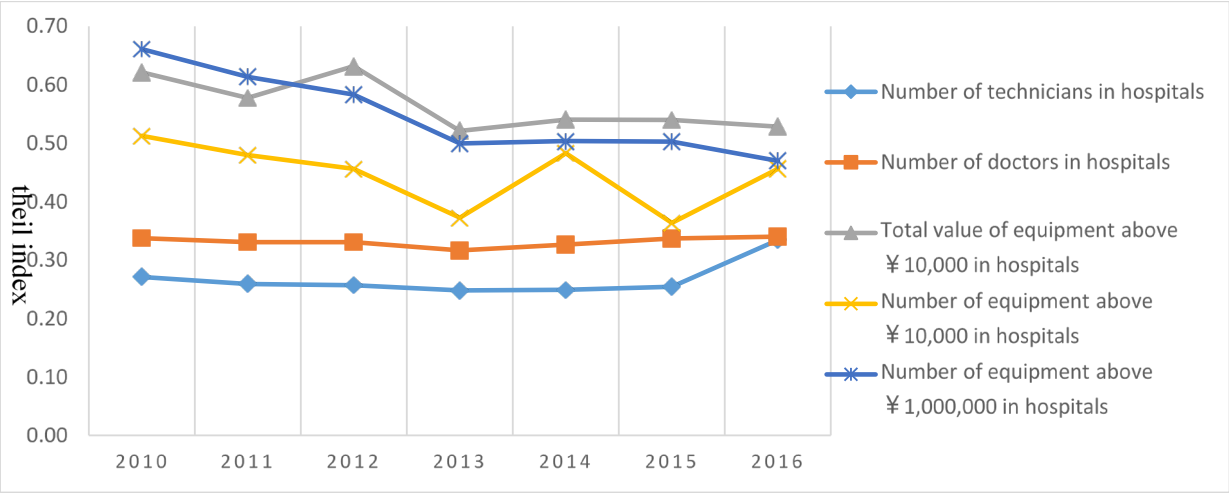


Fig.2 The number of equipment above ￥10,000 per 1000 in health institutions from 2010 to 2016 (a) presents the number of equipment above ￥10,000 per 1000 in hospitals from 2010 to 2016;(b) presents the number of equipment above ￥10,000 per 1000 in PHCs from 2010 to 2016

(a)



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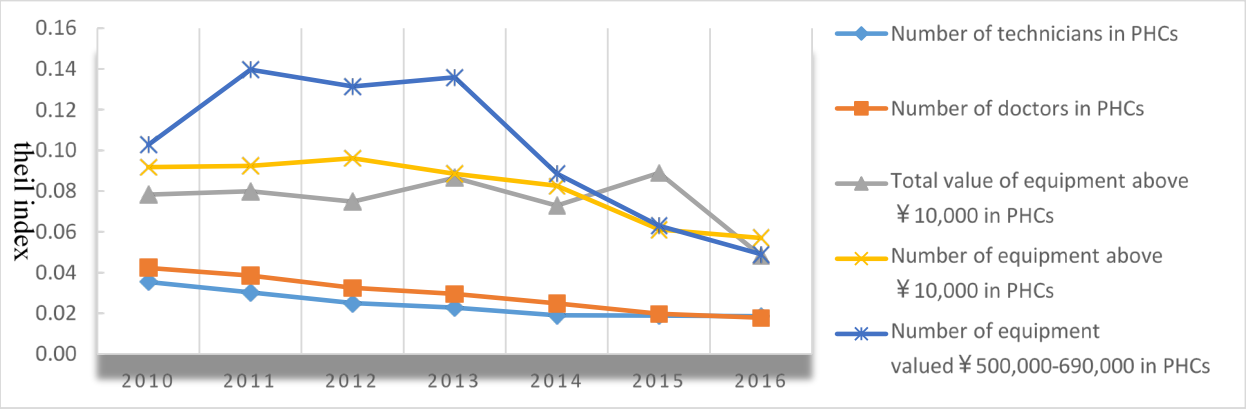
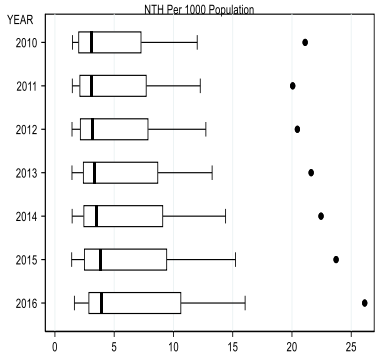


Fig. 3 Trends of the Theil indexes for the health resource in health institutions from 2010 to 2016 (a) presents trends of the Theil indexes for the health resource in hospitals from 2010 to 2016;(b) presents trends of the Theil indexes for the health resource in PHCs from 2010 to 2016

Appendix 1

a)



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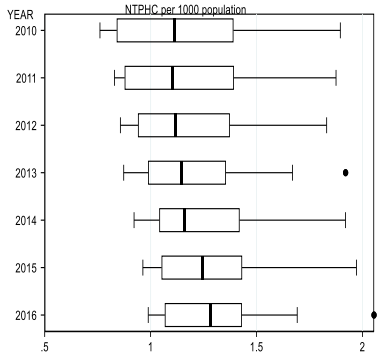

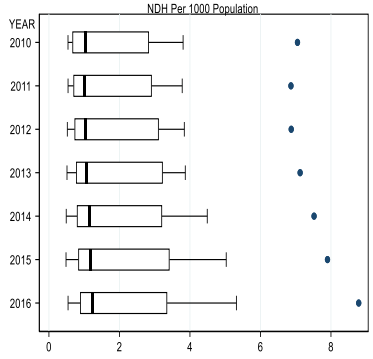

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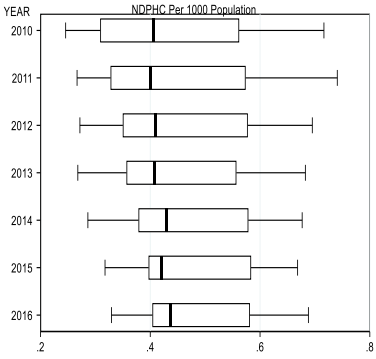

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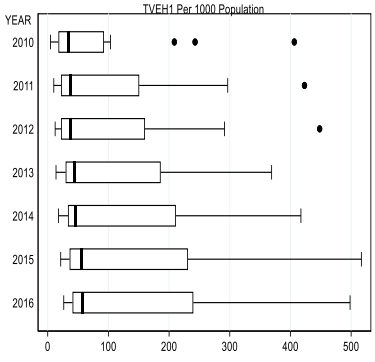

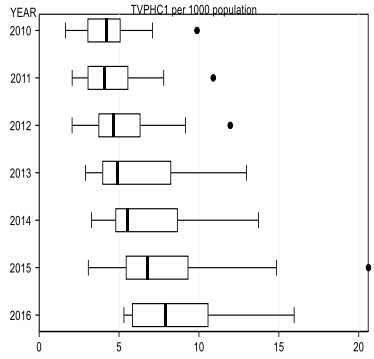

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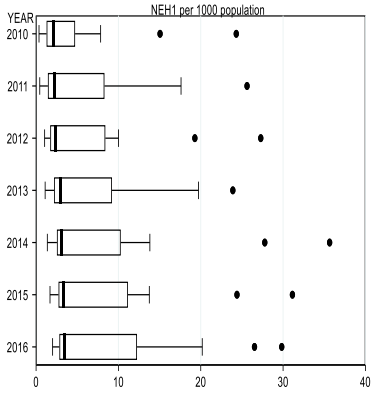

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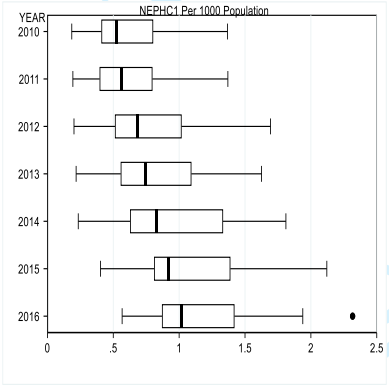

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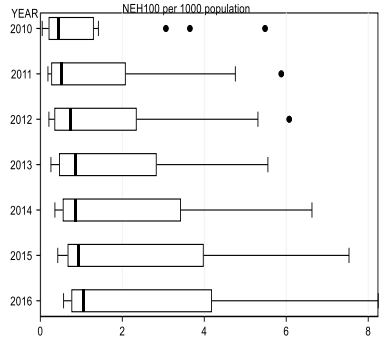

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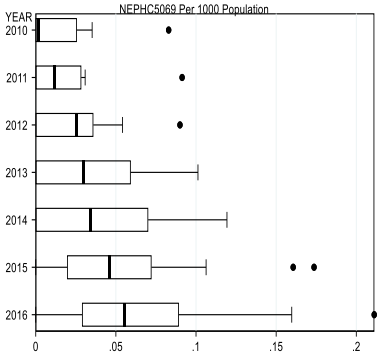

Fig.S Changes for each indicator with whiskers box plot per every year from 2020 to 2016(per 1000).a) and b) presents the number of technicians in hospitals and PHCs,respectively; c) and d) presents the number of doctors in hospitals and PHCs, respectively; e) and f) presents total value of equipment above RMB 10,000 (US$ 1,424) in hospitals and PHCs, respectively; g) and h) presents number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals and PHCs, respectively; I) and j)) present number of equipment items valued above RMB 1,000,000 (US$ 142,410)) in hospitals and number of equipment items valued above RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs,respectivlely.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Noted
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	Page4
Methods			
Study design	4	Present key elements of study design early in the paper	Page4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	No applicable
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	No applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*Page4-6*
Bias	9	Describe any efforts to address potential sources of bias	Page14
Study size	10	Explain how the study size was arrived at	Page5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page6
		(*b*) Describe any methods used to examine subgroups and interactions	Page6

		(*c*) Explain how missing data were addressed	No applicable
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	No applicable

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page7-8
		(b) Give reasons for non-participation at each stage	No applicable
		(c) Consider use of a flow diagram	No applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page7
		(b) Indicate number of participants with missing data for each variable of interest	No applicable
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	No applicable
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*No applicable*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*No applicable*
		Cross-sectional study—Report numbers of outcome events or summary measures	*Page7-11*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No applicable
		(*b*) Report category boundaries when continuous variables were categorized	No applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page11-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	**Page15**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Differences in regional distribution and inequality in health-resource allocation at hospital and primary health center levels: A longitudinal study in Shanghai, China

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Differences in regional distribution and inequality in health-resource allocation at hospital and primary health center levels: A longitudinal study in Shanghai, China

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Abstract

Objectives: To analyze differences in regional distribution and inequality in health-resource allocation at the hospital and primary health center (PHC) levels in Shanghai over 7 years.

Design: A longitudinal survey using 2010–2016 data, which were collected for analysis.

Setting: The study was conducted at the hospital and PHC levels in Shanghai, China.

Outcome measures: Ten health-resource indicators were used to measure health-resource distribution at the hospital and PHC levels. In addition, the Theil index was calculated to measure inequality in health-resource allocation.

Results: All quantities of health-care resources per 1000 people in hospitals and PHCs increased across Shanghai districts from 2010 to 2016. Relative to suburban districts, the central districts had higher ratios, both in terms of doctors and equipment, and had faster growth in the doctor indicator and slower growth in the equipment indicator in hospitals and PHCs. The Theil indices of all health-resource allocation in hospitals had higher values compared with those in PHCs every year from 2010 to 2016; furthermore, the Theil indices of the indicators, except for technicians and doctors in hospitals, all exhibited downward time trends in hospitals and PHCs.

Conclusions: Increased health-care resources and reduced inequality of health-resource allocation in Shanghai during the 7 years indicated that measures taken by the Shanghai government to deepen the new round of healthcare reform in China since 2009 had been successful. Meanwhile there still existed regional difference between urban and rural areas and inequality across different medical institutions. To solve these problems, we prescribe increased wages, improved working conditions, and more open access to career development for doctors and nurses; reduced investments in redundant equipment in hospitals; and other incentives for balancing the health workforce between hospitals and PHCs.

Keywords: Health-care resources, regional difference, inequality, hospital, primary health center (PHC)

Strengths and limitations of this study

►► Few studies have focused on the association between health-resource allocation and healthcare reform, making the findings of the present study generalizable and applicable to countrywide policies and interventions.

►► A future study will be conducted on health-resource distribution and inequality in health-

resource allocation in Shanghai from 2017 until the present, and its findings will be compared with those of the present study, to provide robust policy prescriptions for China and other developing countries.

►► The measurement of inequality in the allocation of resources carried out in this study does not account for differences in health status and need for health care.

►► Because this study chose indicators of the quality of health-care resources rather than of health service, unaccounted-for factors represented by these indicators could have influenced the observed differences. Thus, the study's conclusion should be generalized with caution.

1. Introduction

Reasonable health-resource allocation is essential to achieving health service equity, which contributes to public health and mitigates social conflict [1–3]. In many countries, healthcare reform aims to provide universal and equitable access to health care, which is recognized as a fundamental human right. The distribution of health-care resources is a critical component of health-care access. Furthermore, equity is a basic principle of health-resource allocation, and it is foundational to achieving fairness in the provision of health services. Many studies have demonstrated that wide access to health care can play a crucial role in promoting regional health equity [4–6]. The equitable allocation of health-care resources helps deliver health-care resources to those most in need and ensures accessibility to basic health services as well as fairness for vulnerable populations[7]. Moreover, inequality in health-care resources has adverse consequences, such as the uneven distribution of health-care allocation, which in turn leads to growing inequalities between the rich and poor with respect to health and the economic burden of disease [8]. In 2009, China launched a new round of healthcare reform with the aim of providing households with secure, efficient, convenient, equitable, and affordable health-care services by reversing the early 1980s' moves to a market-oriented health system. The reform strengthened the government's role in healthcare, its commitment to equity, and its willingness to experiment with regulated market approaches. Besides genetic characteristics, the Chinese healthcare system also has some more specific features. Take the health financing system as an example, it collects revenues from three main sources: government expenditure, social expenditure and (out-of-pocket) OOP payments in the domestic classification. The revenues are distributed through the basic medical security system consisting of Basic Medical Insurance (BMI) schemes and Medical Financial Assistance (MFA) schemes for the poor to cover urban and rural residents in China. Under BMI, more specifically, employees in

urban areas are covered by Urban Employee Basic Medical Insurance (UEBMI), unemployed residents in urban areas are covered by Urban Residents Basic Medical Insurance (URBMI) and residents in rural areas are covered by New Rural Cooperative Medical System (NRCMS). The MFA is the security net for the poor in both urban and rural areas, which helps them to enroll in basic medical insurance and also provides extra reimbursement for medical expenses. The public health system, which is mainly financed by the government, provides basic public health services to all residents free of charge. The Chinese Ministry of Health divides medical institutions into three levels by their tasks and functions to form a hierarchical medical system. In this hierarchy, PHCs (the first level), secondary hospitals (the second level), and tertiary hospitals (the third level) provide primary, secondary, and tertiary care, respectively[9]. In this hierarchical medical system in China, patients are channeled toward the appropriate-level institution for treatment and are encouraged to first visit PHCs when they need to see a doctor. Patients are then referred up the hierarchy where necessary, and doctors have the right to decide such referrals. This hierarchical medical system was designed to enable the government to allocate health-care resources efficiently among patients in China. However, due to the considerable gaps in health-care resources and medical techniques between hospitals and PHCs, patients' distrust of PHCs hinders the PHCs' role of being the first contact and the realization of the two-way referral. The first diagnosis occurring in PHCs and two-way referral is still a practice with obstructions and poor effectiveness, thus highlighting the problem of 'difficult and costly access to healthcare services' in China. So, the government has been making attempts to strengthen primary care to reduce self-referral to hospitals in the cities.

Accordingly, since 2009, the Shanghai government has implemented corresponding measures to allocate health-care resources between hospitals and PHCs, conforming tightly to national health reform strategies and guidelines. As a result of these measures, the quantity of medical equipment and numbers of doctors and nurses have increased, and the distribution of health-care resources has become more balanced [10–12]. However, many studies have noted widening urban–rural disparities in health-care resources across Chinese medical institutions of various types [13–18], including the one conducted in Shanghai [12]. Studies have examined variations in the quantity and inequality in health-resource allocation in China; however, they have overlooked differences over time in health-resource allocation at two institutional levels as well as their association with China's 2009 healthcare reform. Considering the overall goal of China's new health-care guidelines and plans to promote more equitable and efficient health-care resource distribution, it

is essential to study the differences in health-resource distribution and the inequity of allocation in Shanghai over time since the 2009 reforms.

Therefore, the purpose of this study was first, to investigate regional difference in health-resource distribution and second, to describe the inequity in their allocation at the hospital and PHC level over 7 years (2010–2016) in Shanghai, in order to see if both of them have changed after the new round of health reform in China since 2009.

2. Methods

2.1Patient and public involvement

This study used secondary data from Yearbooks (2010-2016) in Shanghai of China and did not require patient or public involvement.

2.2 Data source

This study used data from the Shanghai Medical Statistical Yearbook from 2010–2016 and the Shanghai Statistical Yearbook from 2010–2016, which are published by the Shanghai Health Commission and Shanghai Statistics Bureau, respectively. Because China has pushed hospitals and PHCs to establish a hierarchical medical system to improve health service quality, we measured health-resource allocation to evaluate the effect of these policies on hospitals and PHCs. The indicators used included the number of health technicians in hospitals or PHCs, the number of doctors in hospitals or PHCs, the total value of medical equipment above RMB 10,000 (US$ 1424) in hospitals or PHCs, the number of medical equipment items valued above RMB 10,000 (US$ 1424) in hospitals or PHCs, and the number of medical equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals and between RMB 500,000 and 690,000 (US$ 71,205 and 98,263) in PHCs. These data were taken from the 2010 to 2016 editions of the Shanghai Medical Statistical Yearbook. Table 1 presents all 10 indicators and their definitions along with how they were measured. Per capita measures of all the indicators were calculated after obtaining the annual population of the whole city and every administrative district from the 2010–2016 editions of the Shanghai Statistical Yearbook

Table 1 Indicators of health-resource allocation, their definitions, and how they were measured

Indicators	Definitions	How they were measured
Number of technicians in hospitals	It refers to the workforce* in hospitals.	Number of technicians in hospitals divided by the population

Number of doctors in hospitals	It refers to the physicians[#] in hospitals.	Number of doctors in hospitals divided by the population
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	It refers to total monetary value equal to or more than RMB 10,000(US$ 1,424) of durable equipment[+] in hospitals	Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals divided by the population
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	It refers to the number of durable equipment[+] items valued at or more than RMB 10,000 (US$ 1,424) in hospitals.	Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals divided by the population
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	It refers to the number of durable equipment[+] items valued at or more than RMB 1,000,000 (US$ 1,424) in hospitals.	Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals divided by the population
Number of technicians in PHCs	It refers to the workforce[*] in PHCs.	Number of technicians in PHCs divided by the population
Number of doctors in PHCs	It refers to the actual physicians[#] in PHCs.	Number of doctors in PHCs divided by the population
Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	It refers to the total monetary value at or more than RMB 10,000 (US$ 1,424) of durable equipment[+] in PHCs.	Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs divided by the population
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	It refers to the number of durable equipment[+] items valued at or more than RMB 10,000(US$ 1,424) in PHCs.	Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs divided by the population
Number of equipment items valued at RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	It refers to the number of durable equipment[+] items valued between RMB 500,000 and 690,000 (US$ 71,205–98,263) in PHCs.	Number of equipment items valued at RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs divided by the population

*Workforce refers to who assist medical staff complete tasks around their assigned unit or clinic and accommodate patient needs, including pharmacists and radiologists; registered nurses were excluded. #Physicians refer to who hold a practicing physician certificate, including practicing physicians and assistants in China. Those who are engaged in the management of health workers as part of the health workforce, such as presidents, vice presidents, and party secretaries were excluded.+ Durable equipment refers to that is intended to withstand repeated use by professional and patients. This includes diagnostic equipment, including medical

imaging machines, such as ultrasound and MRI machines, PET and CT scanners, and X-ray machines; treatment equipment, including infusion pumps, medical lasers, and LASIK surgical machines; and other medical equipment in Chinese health institutions.

Shanghai is one of four directly controlled municipalities of the People's Republic of China, and it is further divided into 16 districts, among which are seven urban and nine suburban districts. Shanghai's urban administrative divisions are as follows: Huangpu, Xuhui, Changning, Jing'an, Putuo, Hongkou, and Yangpu. Its rural administrative divisions are Minhang, Baoshan, Jiading, Pudong New Area, Jinshan, Songjiang, Qingpu, Fengxian, and Chongming. Over 7 years from 2010 to 2016, Shanghai had three administration division mergers aimed at facilitating the long-term development of all the districts involved; enhance the administrative efficiency of urban function and resource distribution for the city; as well as reduce administrative costs. Specifically, in 2011, Luwan District was merged with a neighboring district to form the new Huangpu District; Zhabei was merged with Jing'an District in 2015; and Chongming County was upgraded to Chongming District in 2016. To maintain data comparability, we formatted the new data of the 16 administration divisions by integrating the data of the two merged districts of Luwan and Zhabei into those of Huangpu and Jing'an, respectively.

2.3 Data analysis

Many measures exist for evaluating the equity of health-resource allocation, such as the Lorenz curve, Gini coefficient, and Theil index. The Theil index is a statistic primarily used to measure income inequality or other economic phenomena among different individuals or within varied groups. It is a special case of the generalized entropy index and one of the most widely used measures of inequality in regional economic development. The Theil index was proposed by econometrician Henri Theil at Erasmus University Rotterdam [19], and it can be formulated as follows:

$$T = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{\overline{y}}\log(\frac{y_i}{\overline{y}}), \quad (1)$$

where T is the Theil index, which represents income allocation inequality, and y_i and $\overline{y}$ is the income of individual *i* and the average income of the population, respectively.

The Theil index has another form to measure the inequality between different groups, which is known as the between-region difference. This formula can be written as follows:

$$T = \sum_{i=1}^{k} w_i \ln(\frac{w_i}{e_i}), \quad (2)$$

where w_i represents the proportion of the income of group *i* accounting for the total income of all groups and e_i represents the proportion of the people in group *i* accounting for the overall population of all groups. In this study, we defined w_i as the proportion of health-care resources in district *i* accounting for the resources of the whole city, and we defined e_i as the proportion of the people in district *i* accounting for the overall population of the city. The value of the Theil index ranges from 0 to 1 and 0 represents perfect equality, while 1 means completely unequal.

3. Results

3.1 Differences in regional distribution of health-resource allocation at the hospital and PHC levels in Shanghai from 2010 to 2016

Table 2 presents descriptive statistics of indicators of health-resource allocation in Shanghai's hospitals and PHCs. Table 3 presents changes in numbers and growth rates related to health-resource allocation in Shanghai's hospitals and PHCs. Further details of changes for each indicator with whiskers box plot per every year from 2020 to 2016 are presented in appendix (see the additional file). As indicated by the table, the health-care resources in hospitals and PHCs increased gradually from 2010 to 2016, the quantities of health-care resources per 1000 of the population all increased, and the number of equipment items grew faster than did the health workforce in hospitals and PHCs overall. For example, from 2010 to 2016, the number of equipment items valued above RMB 10,000 (US$ 1424) per 1000 people and above RMB 1,000,000 (US$ 142,410) per 1000 people in hospitals increased by 73.9% and 122.7%, respectively; furthermore, the numbers of technicians and doctors per 1000 people in hospitals increased by 30.6% and 25.5%, respectively, more than twice the corresponding numbers of technicians and doctors in PHCs during the same period.

As for administrative divisions, from 2010 to 2016, an increasing trend was observed in the numbers of doctors and equipment items per 1000 people both in hospitals and PHCs across all districts except for Chongming District. Chongming had an unexpected decrease from 0.94 in 2010 to 0.87 in 2016 for the number of equipment items valued above RMB 10,000 (US$ 1424) per 1000 people in PHCs.

In common for every district was a similar trend of the number of equipment per 1000 of the population growing faster than that of doctors, in both hospital and PHCs from 2010 to 2016. Noticeably, whether in hospitals or PHCs, central districts had higher ratios than did

Table 2 Descriptive Statistics of indicators of health-resource allocation in Shanghai's hospitals and PHCs (2010–2016; per 1000)

Indicators	Obs.	Min.	Max.	Mean.	Median
Number of technicians in hospitals	112	1.42	26.14	6.04	3.34
Number of doctors in hospitals	112	0.49	8.79	2.07	1.10
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	112	4.51	516.87	114.33	46.49
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	112	0.36	35.65	6.77	2.95
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	112	0.05	8.24	1.87	0.81
Number of technicians in PHCs	112	0.76	2.06	1.23	1.17
Number of doctors in PHCs	112	0.25	0.74	0.46	0.42
Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	112	1.65	20.61	6.33	5.35
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	112	0.19	2.32	0.86	0.79
Number of equipment items valued above RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	112	0.00	0.21	0.04	0.03

Table 3 Changes in the numbers and growth rates related to health-resource allocation in Shanghai's hospitals and PHCs (2010–2016; per 1000)

Indicator	2010	2011	2012	2013	2014	2015	2016	GR
Number of technicians in hospitals	4.21	4.33	4.48	4.75	4.97	5.21	5.49	30.6%
Number of doctors in hospitals	1.42	1.44	1.48	1.53	1.61	1.70	1.78	25.5%
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	62.31	75.23	75.78	79.03	88.00	100.58	108.82	74.7%
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	3.66	4.38	4.76	5.09	6.39	6.20	6.36	73.9%
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	0.09	0.11	0.12	0.13	0.15	0.18	0.19	122.7%
Number of technicians in PHCs	1.06	1.08	1.10	1.12	1.15	1.18	1.21	13.4%
Number of doctors in PHCs	0.40	0.41	0.42	0.42	0.44	0.44	0.45	11.6%

Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	4.22	4.42	5.21	5.89	6.53	7.68	8.26	95.8%
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	0.58	0.58	0.70	0.77	0.88	0.99	1.09	89.0%
Number of equipment items valued above RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	0.01	0.01	0.01	0.01	0.02	0.02	0.02	112.4%

GR = growth rate.

suburban districts both in the number of doctors and equipment per 1000 of the population. This indicated an unchanged distribution concentration in health-care resource allocation among central areas other than rural ones in Shanghai. Figures 1 (a) and (b) illustrate the numbers of doctors in hospitals and PHCs, respectively, per 1000 of the population across Shanghai's districts from 2010 to 2016. As for the number of doctors per 1000 people in hospitals, central districts grew faster than suburban ones did over this period; for example, in hospitals, Xuhui exhibited an increase of 39.47%, Hongkou of 28.57%, and Huangpu of 28.57%, whereas Songjiang and Qingpu only exhibited increases of under 1% in the same period. Even Fengxian, the fastest growing division for ratios of doctors across all rural districts, only exhibited an increase of 14.29%, lower than the 15% average growth rate for hospitals in central districts over the 7 years. By contrast, no PHCs in either central or suburban districts exhibited a marked increase in the number of doctors per 1000 of the population.

Figure 2 (a) and (b) illustrate the number of equipment items valued above RMB 10,000 per 1000 people in hospitals and PHCs, respectively, from 2010 to 2016. A different trend was observed between central and suburban districts in that central districts grew slower in terms of hospitals and PHCs in the same period. For example, from 2010 to 2016, in terms of equipment ratios in hospitals, Huangpu, Xuhui, Jing'an, and Hongkou Districts all exhibited increases in growth rates of 22.75, 76.16, 157.40, and 354.23%, respectively, while Songjiang, Qingpu, and Fengxian Districts all experienced rapid development of more than five-fold in per capita equipment. Similarly, in terms of equipment ratios in PHCs, Changning, Putuo, Jing'an, and Hongkou increased by 100%, while Qingpu and Jinshan increased by more than 200%.

3.2 Inequality in health-resource allocation at the hospital and PHC levels in Shanghai from 2010 to 2016

Table 4 and Fig. 3 present the Theil indices of health-resource allocation in Shanghai's hospitals and PHCs from 2010 to 2016. In the same year at different levels of medical institutions, the Theil indices in hospitals were higher than those in PHCs for overall health-care resources, especially for equipment. This indicated greater unfairness of health-care resource allocation in hospitals than in PHCs in Shanghai during this period. For example, in 2016, the Theil indices of the numbers of technicians and doctors in hospitals were 0.33 and 0.34, respectively, whereas the corresponding indices in PHCs were both 0.02. The Theil indices of the total value of equipment above RMB 10,000 (US$ 1424) and the number of equipment items valued above RMB 10,000 (US$ 1424) in hospitals were 0.53 and 0.46, respectively, whereas the corresponding indices in PHCs were 0.05 and 0.06, respectively.

Table 4 Theil indices related to health-resource allocation in hospitals and PHCs in Shanghai (2010–2016)

Indicators	2010	2011	2012	2013	2014	2015	2016
Number of technicians in hospitals	0.27	0.26	0.26	0.25	0.25	0.25	0.33
Number of doctors in hospitals	0.34	0.33	0.33	0.32	0.33	0.34	0.34
Total value of equipment above RMB 10,000 (US$ 1,424) in hospitals	0.62	0.58	0.63	0.52	0.54	0.54	0.53
Number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals	0.51	0.48	0.46	0.37	0.48	0.36	0.46
Number of equipment items valued above RMB 1,000,000 (US$ 142,410) in hospitals	0.66	0.61	0.58	0.50	0.50	0.50	0.47
Number of technicians in PHCs	0.04	0.03	0.03	0.02	0.02	0.02	0.02
Number of doctors in PHCs	0.04	0.04	0.03	0.03	0.02	0.02	0.02
Total value of equipment above RMB 10,000 (US$ 1,424) in PHCs	0.08	0.08	0.07	0.09	0.07	0.09	0.05
Number of equipment items valued above RMB 10,000 (US$ 1,424) in PHCs	0.09	0.09	0.10	0.09	0.08	0.06	0.06
Number of equipment items valued RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs	0.10	0.14	0.13	0.14	0.09	0.06	0.05

As for Theil index trends for health-care resources in Shanghai from 2010 to 2016, the indices of all indicators exhibited a decline for both hospitals and PHCs, except for the numbers of technicians and doctors in hospitals. This indicated a reduction in the inequality in health institutions with respect to most health-care resource indicators in Shanghai over the 7 years. From 2010 to 2016, the Theil indices of all the equipment indicators in hospitals, the total value of equipment above RMB 10,000 (US$ 1424), the number of equipment items valued above RMB 10,000 (US$ 1424), and the number of equipment items valued above RMB 1,000,000 (US$ 142,410) all exhibited declines (despite a slight increase from 2013 to 2014). This indicated a reduction in the inequality of hardware construction in hospitals in that period.

Similarly, regarding the Theil indices of the health-care workforce in PHCs, those for the numbers of technicians and doctors both exhibited consistent downward trends during the period. Furthermore, after experiencing some fluctuations during this period, the indices for the total value of equipment above RMB 10,000 (US$ 1424), number of equipment items valued above RMB 10,000 (US$ 1424), and number of equipment items valued RMB 500,000–690,000 ($71,205–98263) in PHCs exhibited continual decreases. However, for the Theil indices of the health-care workforce in hospitals, reverse trends were observed in both the numbers of technicians and doctors during this period; for example, the index of technicians in hospitals decreased from 0.27 in 2010 to 0.25 in 2013, followed by an increase to 0.33 in 2016; similarly, the index of doctors in hospitals exhibited the same trend, which demonstrated that the problem of inequality in health-care workforce allocation in hospitals had not been solved.

4. Discussion

This study analyzed the temporal trends and inequality of health-resource allocation at the hospital and PHC levels in Shanghai, noting trends of improvements in the quantity and inequality in health-resource allocation from 2010 to 2016. However, various regions have an unbalanced distribution of health-care resources, especially equipment and health workforce in hospitals, which exhibited serious inequalities in either number or temporal trend.

First, this study observed that the number of technicians, number of doctors, total value of equipment above RMB 10,000 (US$ 1424), number of equipment items valued above RMB 10,000 (US$ 1424) in hospitals and PHCs, number of equipment items valued above RMB

1,000,000 (US$ 142,410) in hospitals, and number of equipment items valued RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs all increased over the 7 years. These results indicated that the Chinese government's goals of reforming the healthcare system to operate smoothly and provide a safe, efficient, and convenient health service over past 7 years have been achieved. To expand and optimize health-care resources on the supply side, according to the "Healthy China 2030" planning outline and other health policy plans, China has integrated health subsystems by investing financially in health institutions to purchase various types of equipment; recruit and train technicians and doctors; make health institutions function reoriented; update the health-care service model based on the state of public health; and present a collaborative hierarchical medical system that meets people's health-care demands [20–23]. This included not only perfecting plans for the geographical distribution of health-care resources across different regions and districts [24] but also maintaining a dynamic balance in allocation between hospitals and PHCs. On the demand-side, the government has educated Chinese people about the "big health" concept to foster healthy lifestyles, as well as re-designed medical insurance to widen coverage among poorer people [25], providing an increasing number of patients with reasonable access to health-care resources. Thus, the aforementioned measures of the Chinese and Shanghai governments have resulted in increased numbers of technicians, doctors, and equipment items across different institutions and varied districts, and also reduced the inequality in health-resource allocation from 2010 to 2016. Numerous studies have supported these results [17,26–27].

Second, this study observed regional differences in health-resource distribution at the hospital and PHC levels from 2010 to 2016. Health programs were unbalanced in their development when hospitals and PHCs were compared, which resulted in an aberrant phenomenon named an "inverted triangle," as opposed to an "equilateral triangle," meaning that increasing numbers of technicians and doctors in PHCs have been attracted to tertiary and specialty public hospitals. This has caused losses in medical human resources in the PHCs. This has happened because of lower salaries and limited career advancement causing PHC doctors and nurses to leave to work at larger hospitals. Some relevant studies have also noted an "inverted triangle" [5,28]. Furthermore, more larger hospitals were distributed in urban districts than in rural ones, which led to increasing numbers of the health workforce being attracted from suburban to central districts. Additionally, suburban districts grew faster than urban ones did in terms of numbers of equipment items in hospitals and PHCs because—due to fewer health-care resources and the slower development of

health institutions in rural areas—expanding the equipment in health institutions was urgent. Moreover, this goal was easier to achieve than quickly recruiting and training doctors and nurses was when the government invested significantly in Shanghai from 2009 onward. This result on the regional difference is similar to those of studies that discovered rapidly growing numbers of equipment items in suburban areas in China and an overcentralized health workforce in urban areas [29–30].

Third, this study used the Theil index to analyze inequality in health-resource allocation. The index has some disadvantages, such as being complex to calculate and interpret; a wide variety when distribution varies regardless of the change that occurs in the top, middle, or bottom tier of resources; and the fact that when comparing populations with different sizes, the calculation is dependent on the number of individuals in the population or group. Nonetheless, this measurement method can still be robust when determining inequality within and between group components, with high sensitivity to the efficiency of health-resource allocation. This is because the index is decomposable by groups, can incorporate group-level data, and is particularly effective at paring effects in hierarchical data sets [31]. This study confirmed the inequality among technicians, doctors, and equipment in hospitals from 2010 to 2016. On the one hand, hospitals had higher Theil indices than did PHCs in numbers of all health-care resources, especially equipment in Shanghai in every year, again demonstrating unbalanced distribution of health-care resources between hospitals and PHCs. This is attributable to the fact that with the rapid development of hospitals, many hospitals have profited and have thus continually invested in the recruitment and education of doctors and have bought large quantities of advanced medical equipment to meet the medical needs of an increasing number of patients. This has resulted in overinvestment in the health workforce and equipment, whereas PHCs have not invested enough in these health-care resources and cannot compete with hospitals because they have fewer patients and are less profitable. This result is consistent with the findings reported by Zhang T. et al. [32]and Wang YY. et al. [26]. On the other hand, the Theil indices of the health workforce in hospitals, such as technicians and doctors, increased during this period, indicating worsening inequality in health-resource allocation. The reason is that the elevated provision of human resources does not necessarily indicate a decline in inequity, as has been noted in other countries [33–36]. As mentioned, increasing numbers of technicians and doctors flow into larger urban hospitals from rural, new, or private hospitals for reasons of salary and career advancement. Another reason is that hospitals will compete for more

patients and profit because of the Matthew effect in the medical field, indicating that an increasing number of patients have been seeing doctors in famous tertiary or larger hospitals, and fewer patients trust doctors in nonfamous or small hospitals, leading to more human resources in health institutions pouring into larger hospitals, thereby further exacerbating the disparities between larger and smaller hospitals. This finding is similar to those of some relevant studies, which have confirmed the health workforce distribution gap among hospitals of various sizes[37–39].

The present study has several limitations. First, the data used potentially only reflect the health-resource allocation status in Shanghai at the cut-off because we could only obtain them from the Chinese Yellowbooks, which are often published officially at least 2 years after the year the data were for; therefore, crucial information could have been omitted from our data. In the future, a new study on changes in health-resource allocation from 2017 to the present, along with comparisons with the present study, can be conducted when the data are available. Second, this study did not consider the effect of the population's health outcomes on health-resource allocation. According to the health capacity paradigm theory [40], the population's health status in a region will have mutual effects on health-resource allocation in that area. Due to time and resource constraints, we did not consider these factors, which may have affected the results. Third, we selected indicators for health-resource allocation at different institutional levels rather than indicators of the quality of health services. Factors represented by other unmeasured indicators may have influenced the results. Thus, integrating the indicators of health-resource allocation used in this study with those of health service quality may yield more robust results in a future study.

5. Conclusion

Health-care resources increased and inequality in resource allocation decreased in Shanghai from 2010 to 2016. This indicates the success of the measures taken by the Chinese government since its 2009 reforms, specifically with respect to technicians, doctors, and equipment in hospitals and PHCs. However, the distribution of health-care resources differed between urban and rural areas and between hospitals and other institutions. To achieve an institutional and regional balance in health-care resource distribution between central and rural areas, a comprehensive solution to raise wages and improve working conditions of health workers in PHCs and rural areas is required, which will prevent their excessive flow to hospitals and urban areas. This will prevent the inverted triangle from occurring and mitigate the institutional burden for the government. In addition, motivational efforts are required to cultivate and train more medical students to a high degree and

encourage them to work in rural areas. Policies should not only be focused on the imbalance in the health workforce distribution between larger urban hospitals and smaller ones—such as policies for raising salaries for doctors and nurses in small-scale suburban hospitals and implementing job performance evaluation reform in all hospitals—they should also be focused on reducing redundant equipment investments and health workforce disparity in hospitals—such as implementing cost-benefit analyses and input/output optimization as well as controlling the scale of operations in the trial reform of public hospitals. To more deeply explore health-resource allocation, future studies must be conducted that integrate the indicators used in the present study with indicators of health service quality.

Contributor statement

ED, HW, LC,TW and LZ designed the study together， acquired the data and developed the statistical plan. SL,MC and TX carried out the survey. HW and LC performed the statistical analysis. ED,TW and LZ interpreted the analysis. ED and LZ drafted and revised the manuscript. All authors read and approved the final manuscript.

Competing interests None declared

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Data sharing statement Data are available upon reasonable request.

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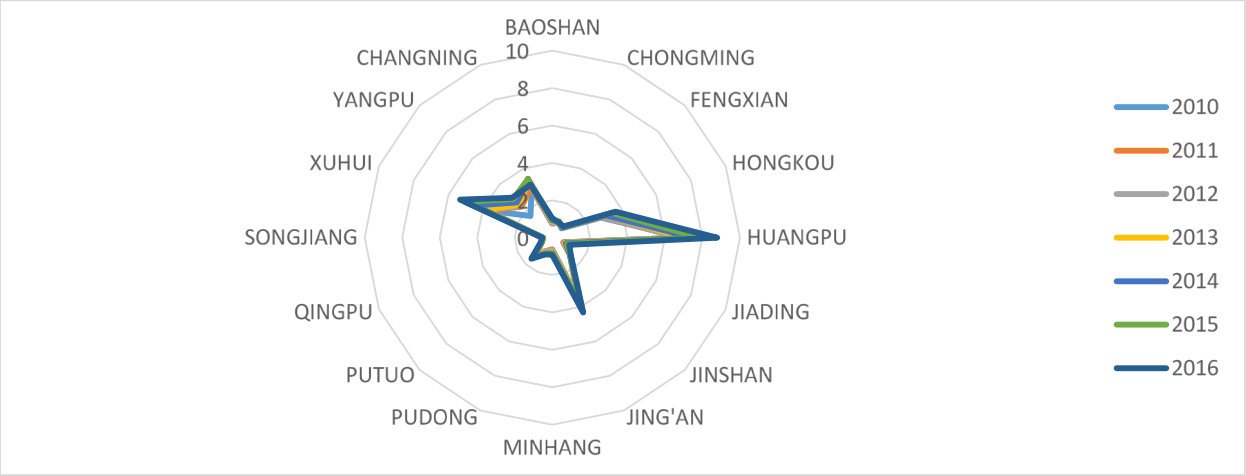
Fig.1 Per 1000 doctors in health institutions across the districts from 2010 to 2016. (a) presents per 1000 doctors in hospitals across the districts from 2010 to 2016;(b) presents per 1000 doctors in PHCs across the districts from 2010 to 2016

Fig.2 The number of equipment above ￥10,000 (US$ 1,424) per 1000 in health institutions from 2010 to 2016 (a) presents the number of equipment above ￥10,000 (US$ 1,424) per 1000 in hospitals from 2010 to 2016;(b) presents the number of equipment above ￥10,000 (US$ 1,424) per 1000 in PHCs from 2010 to 2016

Fig. 3 Trends of the Theil indexes for the health resource in health institutions from 2010 to 2016 (a) presents trends of the Theil indexes for the health resource in hospitals from 2010 to 2016;(b) presents trends of the Theil indexes for the health resource in PHCs from 2010 to 2016

(a)



(b)

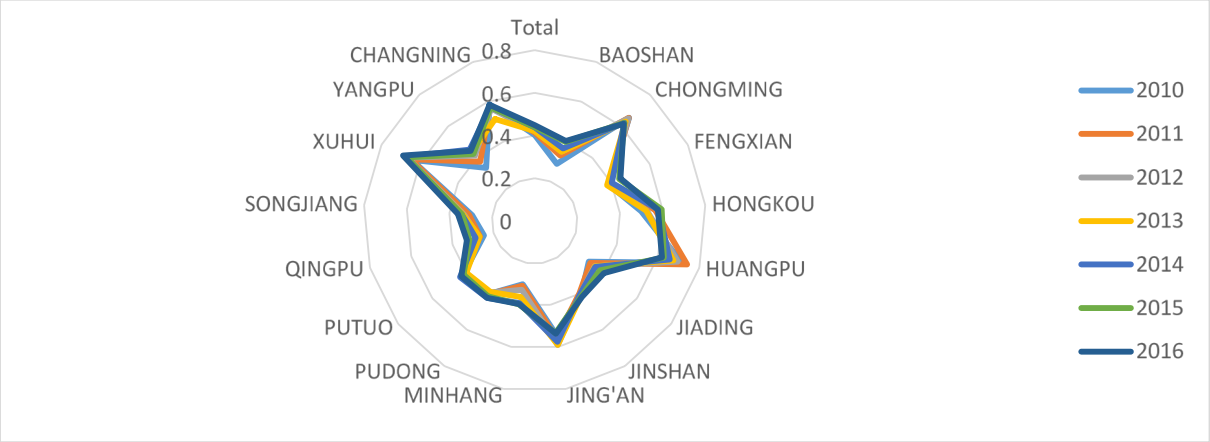
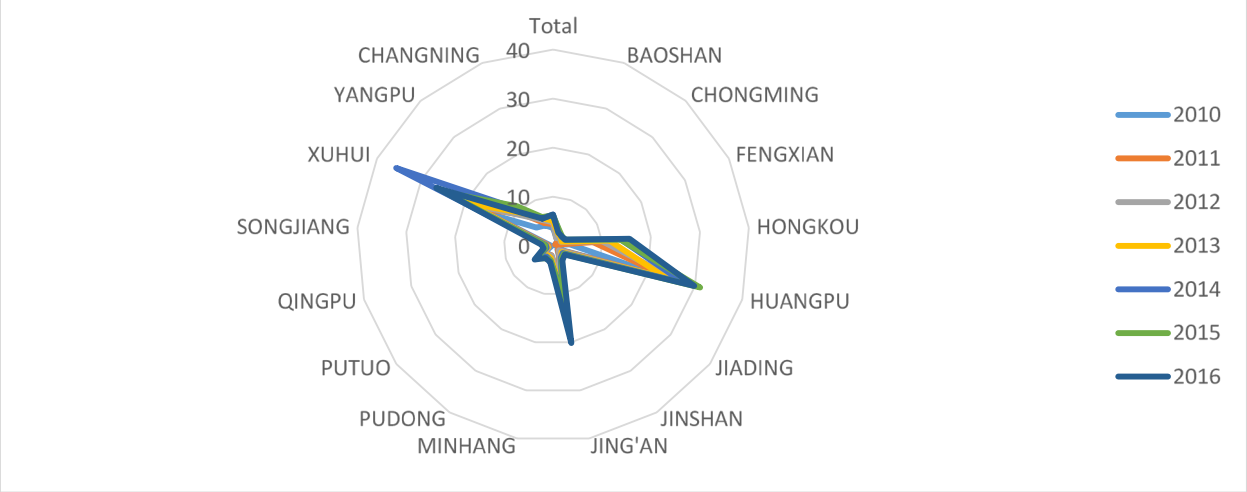


Fig.1 Per 1000 doctors in health institutions across the districts from 2010 to 2016. (a) presents per 1000 doctors in hospitals across the districts from 2010 to 2016;(b) presents per 1000 doctors in PHCs across the districts from 2010 to 2016

(a)



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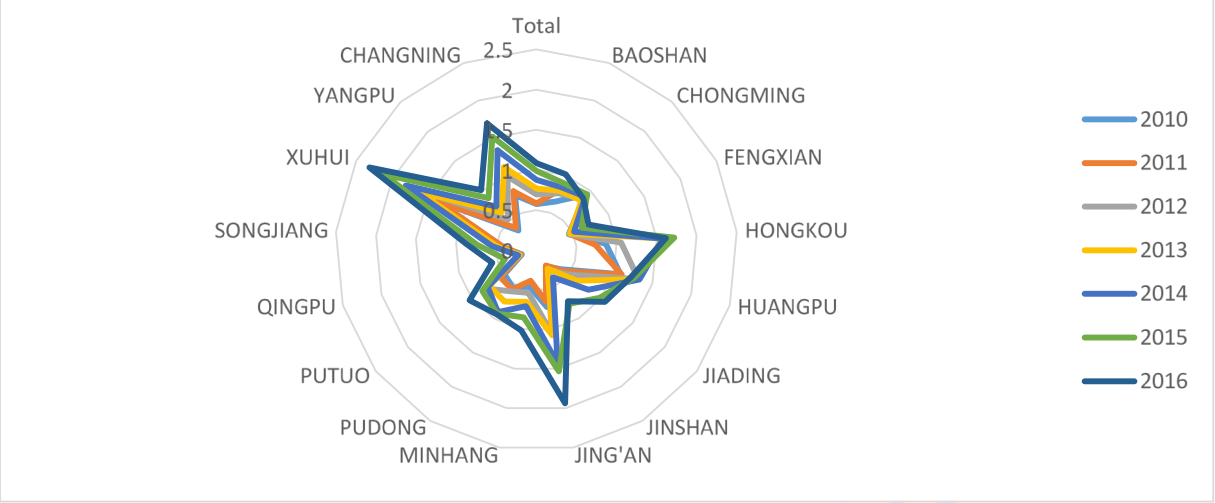
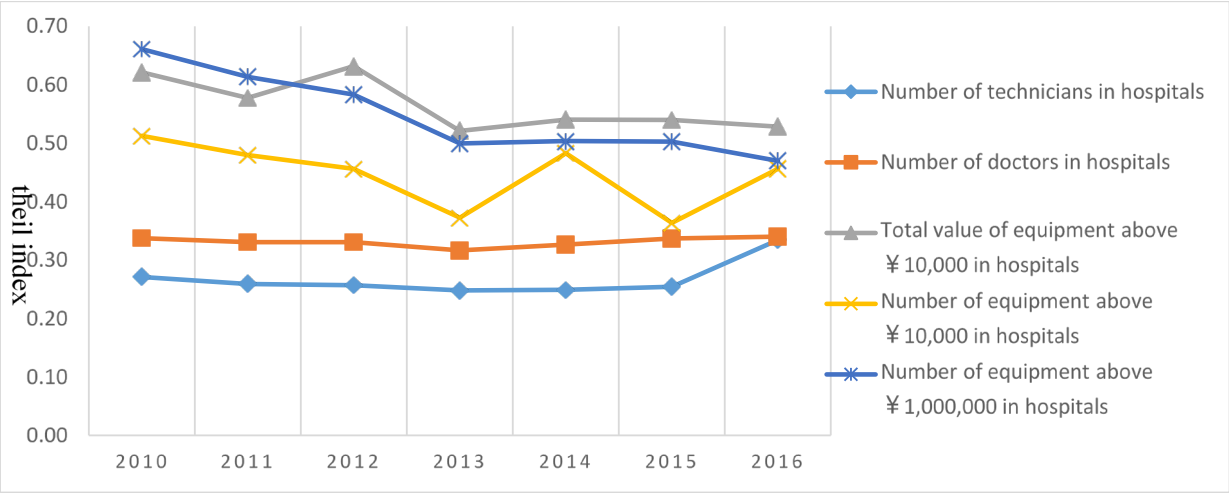


Fig.2 The number of equipment above ￥10,000 (US$ 1,424) per 1000 in health institutions from 2010 to 2016 (a) presents the number of equipment above ￥10,000 (US$ 1,424) per 1000 in hospitals from 2010 to 2016;(b) presents the number of equipment above ￥10,000 (US$ 1,424) per 1000 in PHCs from 2010 to 2016

(a)



(b)

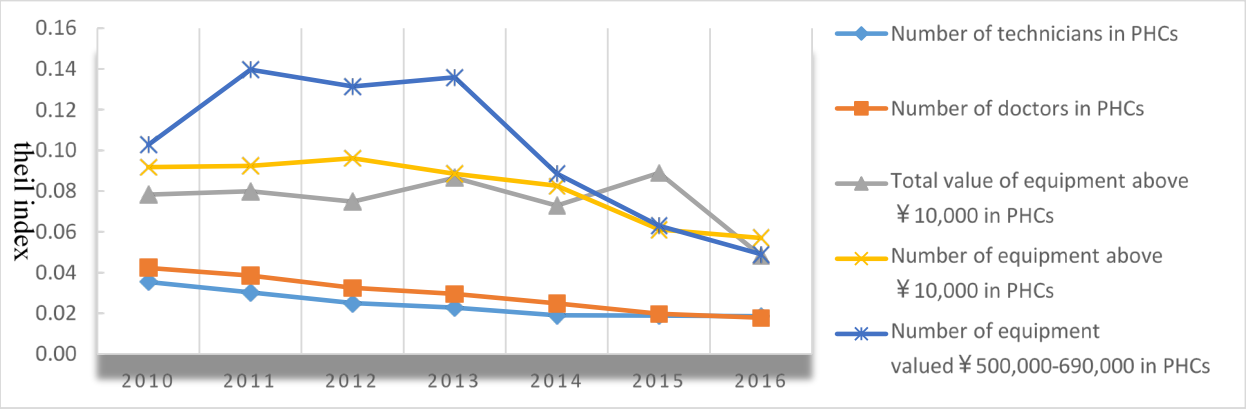
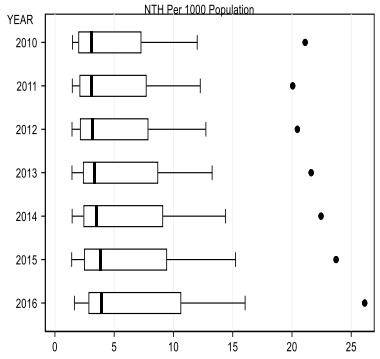


Fig. 3 Trends of the Theil indexes for the health resource in health institutions from 2010 to 2016 (a) presents trends of the Theil indexes for the health resource in hospitals from 2010 to 2016;(b) presents trends of the Theil indexes for the health resource in PHCs from 2010 to 2016

Appendix 1

a)



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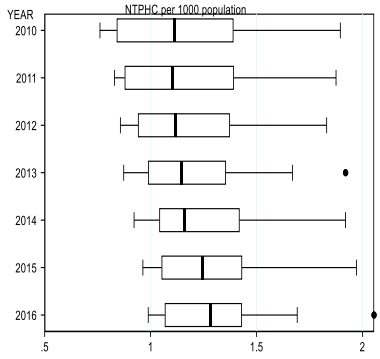
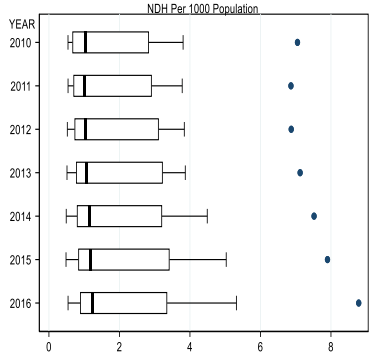
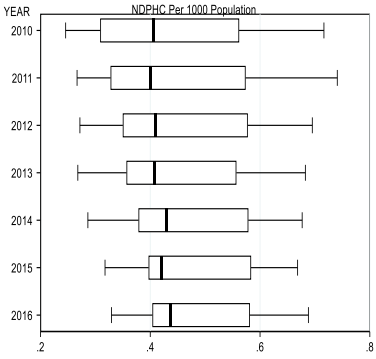
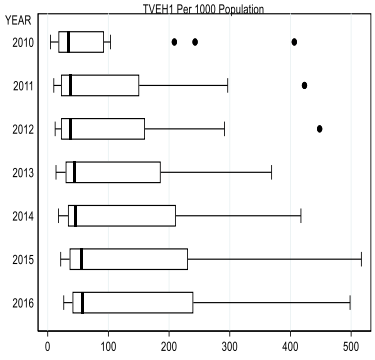


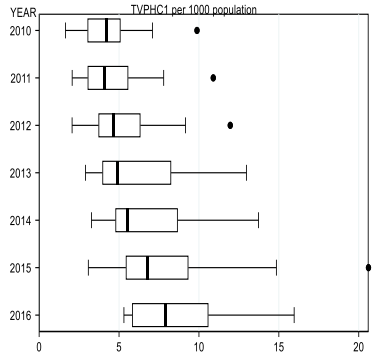


d)



e)





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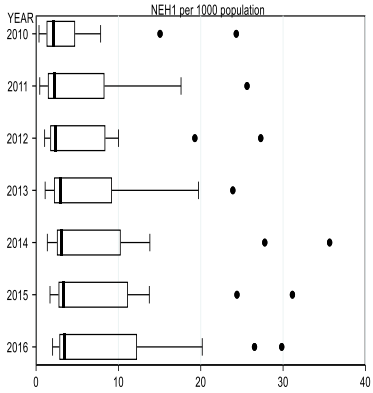

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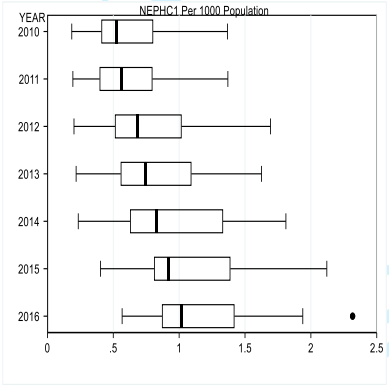
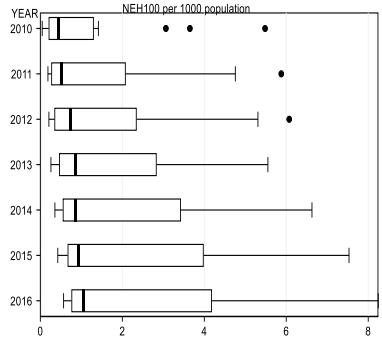


i)



j)

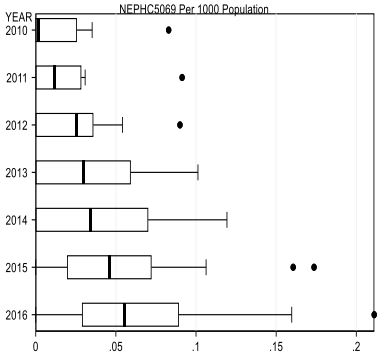


Fig.S Changes for each indicator with whiskers box plot per every year from 2020 to 2016(per 1000).a) and b) presents the number of technicians in hospitals and PHCs,respectively; c) and d) presents the number of doctors in hospitals and PHCs, respectively; e) and f) presents total value of equipment above RMB 10,000 (US$ 1,424) in hospitals and PHCs, respectively; g) and h) presents number of equipment items valued above RMB 10,000 (US$ 1,424) in hospitals and PHCs, respectively; I) and j)) present number of equipment items valued above RMB 1,000,000 (US$ 142,410)) in hospitals and number of equipment items valued above RMB 500,000–690,000 (US$ 71,205–98,263) in PHCs,respectivlely.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Noted
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	Page4
Methods			
Study design	4	Present key elements of study design early in the paper	Page4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	No applicable
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	No applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*Page4-6*
Bias	9	Describe any efforts to address potential sources of bias	Page14
Study size	10	Explain how the study size was arrived at	Page5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page6
		(*b*) Describe any methods used to examine subgroups and interactions	Page6

		(*c*) Explain how missing data were addressed	No applicable
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	No applicable

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page7-8
		(b) Give reasons for non-participation at each stage	No applicable
		(c) Consider use of a flow diagram	No applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page7
		(b) Indicate number of participants with missing data for each variable of interest	No applicable
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	No applicable
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*No applicable*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*No applicable*
		Cross-sectional study—Report numbers of outcome events or summary measures	*Page7-11*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No applicable
		(*b*) Report category boundaries when continuous variables were categorized	No applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page11-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	**Page15**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.