Equity and Efficiency of Medical and Health Resource Allocation in Western China Based on Health Resources Agglomeration Degree and Malmquist Index

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Research

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Abstract

Background: There is unequal distribution and low utilization efficiency of medical and health resources among regions in China for regional inequality social and economic development. The social and economic development in western China is relatively backward nationwide. The quantity and quality of medical and health resources have become a social problem in western China. This study aims to evaluate the equity and efficiency of health resource allocation in western China.

Methods: The research data are extracted from China Statistical Yearbook (2009 – 2019). We choose the health resource agglomeration degree (HRAD) theory and Malmquist index to evaluate the equity and efficiency of health resource allocation in western China. The HRAD shows the impact of demographic and geographic factors on health resource aggregation.

Results: From the latest data in 2019, the equity of medical and health resources allocation based on geographical area in Inner Mongolia, Tibet, Qinghai and Xinjiang is poor. The equity of medical and health resources allocation based on population allocation in Yunnan, Tibet, Gansu, Qinghai, Ningxia and Xinjiang is poor. From 2009 to 2019, the equity of health resource allocation in western China are poor nationwide. The total factor productivity of Tibet, Qinghai, Ningxia and Xinjiang was less than 1, which were 0.994, 0.984, 0.974 and 0.994, respectively. The allocation of medical and health resources in western China is unfair.

Conclusion: The government should pay attention to the horizontal flow of medical and health resources when investing in medical and health resources. Population and geographical factors should be taken into account when allocating health resources. The total factor productivity in the western region is greatly affected by the technological progress rate. We should increase investment in medical and health technology, and effectively optimize the equity and efficiency of medical and health resource allocation.

1. Background

The effective allocation of medical and health resources will improve people's health level, and the equity and efficiency of its supply are of great significance to the healthy development of the public[1]. Therefore, the equity and efficiency of health resource allocation has long been a top priority[2,3]. In 2009, China formulated a new medical reform policy. The direct reason for the new health-care reform of China that began in 2009 was the decline in the fairness of medical services and the low efficiency of health investment caused by the last round of health-care reform[4]. The Chinese government stressed increasing investment in health care, establishing universal health insurance and gradually improving the health of the population[5]. The utilization level of medical and health resources in western China has improved. However, due to traffic conditions, regional environment and other factors, the overall structure of medical resources in western China is still not reasonable[6,7].

Therefore, we need to focus on the equity and efficiency of medical and health resources allocation in western China, in order to improve the health level of local residents. Some scholars are also devoted to studying the equity and efficiency of health resource allocation. However, most studies focus on a certain area or one aspect and are based on data from early national yearbooks[8-10]. For instance, Shen et al. studied the equity of maternal health service utilization in western rural areas based on the investigation of Shaanxi Province[11]. Wang et al. conducted a study on inequality of primary medical resources in Liaoning Province in Northeast China [12]. Ying et al. analyzed the equity of health service utilization among urban residents in western China[13]. Zhang et al. studied the unequal distribution of health resources and services between hospitals and primary medical institutions in China[14]. In

these studies, Lorenz curve, Gini coefficient, Theil index, concentration index and other methods were usually used to analyze the equity of health resource allocation[15-16]. However, these methods only consider the impact of single factor on the allocation of health resources, and have certain limitations. When analyzing the equity of medical and health resources, the research usually needs to combine the two methods. For example, the Gini coefficient needs to be combined with the Lorenz curve, and the concentration index needs to be combined with the concentration curve. In this study, we selected the theory of health resource agglomeration to evaluate, which can comprehensively analyze the impact of geographical factors and population distribution on the equity of health resource allocation[17]. Besides, Huang analyzed the equity and efficiency of maternal and child health resource allocation in Hunan Province of China[18]. Cheng et al. researched the technical efficiency and productivity of county-level hospitals in Henan Province, China[19]. Li analyzed the efficiency and productivity of county-level public hospitals in Anhui, China[20]. Most of these scholars studied the efficiency of a field or industry based on DEA model and Malmquist index[21,22].

On the basis of previous studies and the applicability of the method, We select HRAD theory to analyze the equity of medical and health resources allocation in western China, and use Malmquist index model to evaluate the efficiency of medical and health resources allocation in western China. HRAD shows the impact of demographic and geographic factors on the aggregation of health resources, while avoiding prejudice caused by a single population or geography. And the Malmquist index model measures total factor productivity by describing the change of productivity from current period to next period.

The following arrangement of this article is: (1) In section one : We introduce the HRAD theory and Malmquist index selected in this paper. (2) In section two : We use HRAD to evaluate the equity of medical resource allocation in western China. (3) In section three: We use Malmquist index to analyze the efficiency of medical resource allocation in western China. (4) In section four: We discuss the results and propose solutions. (4) In section four: We conclude this paper and describe the prospects for the future of this research. Overall, the specific goal of this study is to provide suggestions for further optimizing the allocation of medical resources in the western region and promote the sustainable development of medical resources allocation.

2. Methods

2.1 Setting

According to geographical location, economic conditions and other factors, China was divided into three regions, namely, eastern, central and western regions. And, due to inconsistent statistical standards, the data do not include Macao, Hong Kong Special Administrative Region and Taiwan Province[23]. The eastern region is the earliest province with a high level of coastal opening policy and economic development. The central region refers to economically underdeveloped regions. The west region refers to economically underdeveloped regions. And, the eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan(11 provinces and municipalities). The central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan(8 provinces). The western China includes Chongqing, Sichuan, Shaanxi, Yunnan, Guizhou, Guangxi, Gansu, Qinghai, Ningxia, Tibet, Xinjiang and Inner Mongolia(12 provinces, autonomous region and municipalities) (Fig. 1).

2.2 Data sources and Indicators

The data of geographical area, population and selected indicators in this study come from China Statistical Yearbook (2009-2019) (<http://www.stats.gov.cn/tjsj/ndsj/>) (Table 1). The series of longitudinal data were used to analyse the equity and efficiency of medical and health resources allocation in western China from 2009 to 2019. Considering the representativeness, continuity and availability of data, we selected five indicators to evaluate the equity of health resources allocation in western China, including the number of health institutions, medical beds, health technicians, licensed (registered) physicians and registered nurses. When evaluating the efficiency of resource allocation, health institutions, medical beds and health technicians are selected as input indicators, while the number of patients, the number of inpatients and the utilization rate of beds were selected as output indicators. The data of 2019 were the latest public data. We specially analyze the allocation of health resources in 2019. (Table 2)

Table 1. Population and geographical area of China from2009 to 2019

	Population in western China	Geographical Area of Western China	population of china	Geographical Area of China
2009	363850000	6830600	1395380000	9600000
2010	360690000		1390080000	
2011	362220000		1382710000	
2012	364280000		1374620000	
2013	339640000		1367820000	
2014	368390000		1360720000	
2015	371330000		1354040000	
2016	374140000		1347350000	
2017	376950000		1340910000	
2018	379560000		1334500000	
2019	38180000		1400050000	

Table 2. Data on Health Resources in Western China in 2019

	Health institutions	Beds	Health workers	Practicing (assistant) physician	Registered nurse	geographical area	population
Inner Mongolia	24564	161100	196402	78094	80434	1183000	25400000
Guangxi	33679	277400	341421	115091	152390	237600	49600000
Chongqing	21057	231800	224646	83293	103147	82000	31240000
Sichuan	83756	631800	602411	221689	270545	486000	83750000
Guizhou	28511	265000	267604	89798	121386	176000	36230000
Yunnan	25587	311900	339709	114031	158461	383000	48580000
Tibet	6940	17100	20943	9317	5986	1200000	3510000
Shanxi	35404	265800	353840	108685	150423	206000	38760000
Gansu	26697	181200	178843	62807	79468	426000	26470000
Qinghai	6513	41400	47359	17402	18910	720000	6080000
Ningxia	4397	41000	55412	20755	24307	66000	6950000
xinjiang	18376	186400	185934	67875	77306	1665000	25230000
Western China	315481	2611900	2814524	988837	1242763	6830600	381800000

2.3 Measuring tool

2.3.1 health resources degree agglomeration—HRAD

Agglomeration refers to the concentration degree of a certain factor of production in a certain region relative to that in a larger region . This study evaluated the equity of health resources allocation in western China based on the Health resources agglomeration degree theory. Formula(1) is used to calculate health resource aggregation degree.

$$HRAD_i = [(HR_i / HR_n) \times 100\%] / [(A_i / A_n) \times 100\%] \quad (1)$$

$HRAD_i$: health resource aggregation degree of region i .

HR_i : quantity of health resource in region i .

HR_n : quantity of health resource in the upper region.

A_i : land area of region i .

A_n : area of land in the upper level.

Formula(2) is used to calculate population agglomeration degree

$$PAD_i = [(P_i/P_n) \times 100\%] / [(A_i/A_n) \times 100\%] \quad (2)$$

PAD_i : population agglomeration degree of region i .

P_i : population number of region i .

P_n : population number of the upper region.

A_i : land area of region i .

A_n : land area of the region at the next level up.

When $HRAD_i = 1$, health resources are in the optimal equity according to geographical allocation. When $HRAD_i$ is greater than 1, the equity is better, and when $HRAD_i$ is less than 1, the equity is worse. When the ratio of $HRAD_i$ to PAD_i is 1, health resources are in the optimal equity according to population allocation. When the value is greater than 1, it indicates excess health resources. When the value is less than 1, it indicates that health resources are short and cannot meet the population's demand for medical treatment[17].

2.3.2 Malmquist index

The Malmquist index model measures the total factor production index by describing the change of productivity from the current period to the next period[24,25]. Total factor productivity generally refers to the efficiency of resources (including human, material and financial resources) development and utilization [26,27]. Total Factor Productivity (TFP) includes Comprehensive Efficiency (EFF) and Technological Progress Efficiency (TECH)(2). Comprehensive efficiency is divided into pure technical efficiency (PEC) and scale efficiency (SE)[28-30]. Formula is used to calculate the Malmquist index(3).

$$EFF = PEC * SE = \frac{dt+1(X_{t+1}, Y_{t+1})}{dt(X_t, Y_t)} \quad (3)$$

$$TECH = \sqrt{\frac{dt(X_t, Y_t)}{dt+1(X_t, Y_t)}} * \sqrt{\frac{dt(X_{t+1}, Y_{t+1})}{dt+1(X_{t+1}, Y_{t+1})}} \quad (4)$$

$$TFP = EFF * TECH = \frac{dt+1(X_{t+1}, Y_{t+1})}{dt(X_t, Y_t)} * \sqrt{\frac{dt(X_t, Y_t)}{dt+1(X_t, Y_t)}} \quad (5)$$

$t, t+1$: point in time.

(X_t, Y_t) : input and output efficiency of resources at t time points.

(X_{t+1}, Y_{t+1}) : input and output efficiency of resources at $t+1$ time points.

$dt(X_t, Y_t), dt(X_{t+1}, Y_{t+1})$: The input distance function of the production point compared with the production technology in the same time period.

$d_{t+1}(X_{t+1}, Y_{t+1}), d_{t+1}(X_t, Y_t)$: The input distance function of the production point in the mixing period compared with the production technology.

When Malmquist index >1, namely TFP>1, it indicates that the allocation efficiency of health resources has been improved. When TFP<1, efficiency decreases; When TFP=1, it means the efficiency is unchanged[31-33].

3. Results

3.1 Equity of medical and health resources in Western China in 2019

(1) Distribution of medical and health resources based on geographical area in western China in 2019

From Equ.1, *HRAD* of Inner Mongolia was obtained as follow.

$$HRAD_{Inner\ Mongolia} = [(HR_{Inner\ Mongolia} / HR_{Western\ China}) \times 100\%] / [(A_{Population\ of\ Inner\ Mongolia} / A_{Population\ in\ western\ China}) \times 100\%] = [(24564 / 31548) \times 100\%] / [(1183000 / 6830600)] = 0.45.$$

Other results are shown in the Table 3. (See Table 3).

From Table 3, we find the agglomeration degree of medical and health resources in Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu and Ningxia was greater than 1 in 2019, indicating that the equity of geographical area allocation was good.

In 2019, the agglomeration degree of medical and health resources in Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu and Ningxia was greater than 1, indicating that the equity of geographical area allocation was good. Among them, Chongqing was the most typical. The agglomeration degree of various medical and health resources was much higher than the standard of equity of 1, and the geographical area allocation was the best in the western region. The agglomeration degree of medical and health resources in Inner Mongolia, Tibet, Qinghai and Xinjiang is far less than 1, indicating that the equity of geographical allocation needs to be improved. (See Table 3)

(2) Distribution of health resources based on population size in western China in 2019

From Equ.1 and Equ.2, *PAD* in Inner Mongolia was obtained as follow.

$$PAD_{Inner\ Mongolia} = [(P_{Inner\ Mongolia} / P_{Western\ China}) \times 100\%] / [(A_{Population\ of\ Inner\ Mongolia} / A_{Population\ in\ western\ China}) \times 100\%] = [(25400000 / 381800000) \times 100\%] / [(1183000 / 6830600)] = 0.384.$$

Then, Rate = $HRAD_{Inner\ Mongolia} / PAD_{Inner\ Mongolia} = 1.17$.

Other results are shown in the table. (See Table 3)

The ratio of medical and health resources agglomeration degree to population agglomeration degree in 12 provinces and autonomous regions in the western region is between 0.007 and 1.979. Among them, Chongqing has the highest ratio of medical and health resources agglomeration degree to population agglomeration degree, reaching 1.489, 1.979, 1.780, 1.879 and 1.851, respectively, indicating that the surplus of medical and health resources was serious. The ratios of Tibet and Qinghai were between 0.007 and 0.054, indicating that there was a serious shortage of medical and health resources in these regions, which cannot meet the needs of population for medical treatment. Thus, there was a significant difference in the equity of medical and health resources allocation between regions in the western region.

Table 3 Analysis of *HRAD* and *PAD* in 12 Provinces and Autonomous Regions of Western China in 2019

City	PAD	Health institutions		Beds		Health workers		Practicing (assistant) physician		Registered nurse	
		HRAD	Rate	HRAD	Rate	HRAD	Rate	HRAD	Rate	HRAD	Rate
Inner Mongolia	0.384	0.450	1.170	0.433	0.927	0.403	1.049	0.456	1.187	0.374	0.973
Guangxi	3.735	3.069	0.822	3.710	0.818	3.487	0.934	3.346	0.896	3.525	0.944
Chongqing	6.816	5.560	1.489	8.982	1.979	6.649	1.780	7.017	1.879	6.914	1.851
Sichuan	3.083	3.731	1.000	4.131	0.910	3.008	0.805	3.151	0.844	3.060	0.819
Guizhou	3.683	3.507	0.939	4.785	1.054	3.690	0.988	3.524	0.944	3.790	1.015
Yunnan	2.269	1.446	0.387	2.588	0.570	2.153	0.576	2.057	0.551	2.274	0.609
Tibet	0.052	0.125	0.034	0.045	0.010	0.043	0.011	0.054	0.014	0.027	0.007
Shanxi	3.366	3.721	0.996	4.100	0.904	4.169	1.116	3.644	0.976	4.013	1.075
Gansu	1.112	1.357	0.363	1.352	0.298	1.019	0.273	1.018	0.273	1.025	0.275
Qinghai	0.151	0.196	0.052	0.183	0.040	0.160	0.043	0.167	0.045	0.144	0.039
Ningxia	1.884	1.442	0.386	1.974	0.435	2.038	0.546	2.172	0.582	2.024	0.542
xinjiang	0.271	0.239	0.064	0.356	0.078	0.271	0.073	0.282	0.075	0.255	0.068

Table 4 HRAD and PAD in Western China from 2009 to 2019

Year	PAD	Health institutions agglomeration degree	medical beds agglomeration degree	Health workers agglomeration degree	Practicing (assistant) physician agglomeration degree	Registered nurse agglomeration degree
2009	0.366	0.306	0.271	0.250	0.253	0.238
2010	0.365	0.308	0.273	0.249	0.247	0.241
2011	0.368	0.311	0.276	0.254	0.250	0.246
2012	0.372	0.316	0.281	0.257	0.248	0.250
2013	0.349	0.317	0.286	0.262	0.249	0.206
2014	0.380	0.318	0.288	0.266	0.248	0.260
2015	0.385	0.317	0.288	0.267	0.246	0.263
2016	0.390	0.316	0.289	0.270	0.247	0.267
2017	0.395	0.316	0.292	0.273	0.248	0.274
2018	0.400	0.314	0.293	0.274	0.246	0.275
2019	0.383	0.313	0.269	0.277	0.250	0.280

3.2 Equity of medical and health resource allocation in Western China from 2009 to 2019

(1) Distribution of medical and health resources based on geographical area in western China from 2009 to 2019

From 2009 to 2019, the agglomeration degree of various medical and health resources in the western region was between 0.206 and 0.318, with little fluctuation and no significant improvement in equity. The agglomeration degree of various medical and health resources was : medical institutions > registered nurses > health technicians > medical beds > licensed (assistant) physicians. Among them, practicing (assistant) physicians in these 11 periods of concentration decreased, need special attention. Overall, the allocation of various types of medical and health resources in the western region was relatively poor relative to the national equity, and medical and health resources was scarce. This is due to the complex terrain in the western region, traffic inconvenience, resulting in medical difficulties, poor geographical accessibility[34,35]. (See Table 4).

(2) Distribution of health resources based on population size in western China from 2009 to 2019

From the ratio of resource concentration and population concentration, the ratio of all kinds of medical and health resources in the western region was less than 1, indicating that all kinds of medical and health resources in the western region were seriously short and cannot meet the needs of the population. Among them, the development and reform commission issued "The " 12th Five-Year " Plan Western Development " to arrange the western development work in 2013, strengthen the construction of primary health care, and actively improve the level of health care. Perhaps affected by this, the ratio of resource concentration fluctuations, in addition to registered nurses have increased. (Fig. 2)

3.3 Efficiency analysis of medical and health resource allocation in 12 provinces in Western China from 2009 to 2019

In terms of comprehensive efficiency, the comprehensive efficiency of Guangxi, Chongqing, Sichuan, Guizhou and Gansu provinces is greater than 1, indicating that the comprehensive efficiency has improved. The comprehensive efficiency of Yunnan and Ningxia is 1, and the comprehensive efficiency has not changed. The comprehensive efficiency of Inner Mongolia, Tibet, Shaanxi, Qinghai and Xinjiang is less than 1, among which Qinghai ' s comprehensive efficiency is the most seriously reduced by 2.6 percentage points.

In terms of technological progress rate, Ningxia and Xinjiang in 12 provinces and cities showed a technological decline, the largest decline in Ningxia, a decline of 2.6 percentage points. The remaining 10 provinces and cities showed technological progress, of which Sichuan had the largest progress, an increase of 12 percentage points, and Tibet had a relatively low progress, an increase of 0.2 percentage points.

In terms of scale efficiency, the scale efficiency values of Tibet, Gansu, Qinghai and Xinjiang are less than 1, among which Tibet and Qinghai decrease greatly. The scale efficiency values of Guizhou, Yunnan and Ningxia are 1, and the efficiency does not change. The scale efficiency of the other provinces and cities has improved, and Sichuan has the largest increase by 1.7 percentage points.

In terms of total factor productivity changes, 8 of the 12 provinces and cities in the western region have total factor productivity greater than 1, of which Sichuan has increased by 13.9 percentage points, and Inner Mongolia has increased by 0.1 percentage points. In addition, the total factor production index of Tibet, Qinghai, Ningxia and

Xinjiang is less than 1, indicating that the efficiency of medical and health resource allocation in these four places decreased from 2009 to 2019.(See Table 5).

Table 5 Regional characteristics of health resource allocation from 2009 to 2019

City	EFF	TECH	PEC	SE	TEP
Neimenggu	0.995	1.006	0.989	1.006	1.001
Guangxi	1.012	1.021	1.000	1.012	1.003
Chongqing	1.017	1.025	1.013	1.004	1.043
Sichuan	1.017	1.120	1.000	1.017	1.139
Guizhou	1.003	1.010	1.002	1.000	1.013
Yunnan	1.000	1.021	1.000	1.000	1.021
Xizang	0.992	1.002	1.000	0.992	0.994
Shanxi	0.999	1.018	0.989	1.010	1.016
Gansu	1.017	1.028	1.019	0.998	1.045
Qinghai	0.974	1.010	1.002	0.972	0.984
Ningxia	1.000	0.974	1.000	1.000	0.974
xinjiang	0.996	0.998	0.998	0.998	0.994
Mean	1.002	1.019	1.001	1.001	1.021

3.4 Efficiency Analysis of Health Resource Allocation in Western China from 2009 to 2019

From 2009 to 2010, the total factor productivity of medical and health resources in the western region reached 2.012. In 2010 ~ 2011, 2012 ~ 2013, 2013 ~ 2014, 2014 ~ 2015, 2016 ~ 2017, 2017 ~ 2018, the total factor productivity was less than 1. The total factor productivity changed with the rate of technological progress. The total factor productivity of 2009 ~ 2019 was 1.021. It showed that although the efficiency of medical and health resources allocation has declined, it has generally increased by 2.1 percentage points.(See Table 6).

Table 6 Time characteristics of health resource allocation from 2009 to 2019

Time	EFF	TECH	PEC	SE	TEP
2009~2010	1.043	1.929	1.000	1.043	2.012
2010~2011	1.004	0.983	1.003	1.001	0.987
2011~2012	0.994	1.063	0.994	1.000	1.056
2012~2013	0.997	0.982	0.999	0.998	0.979
2013~2014	1.004	0.972	1.002	1.001	0.976
2014~2015	1.003	0.960	1.005	0.999	0.963
2015~2016	1.004	1.001	1.002	1.001	1.004
2016~2017	1.000	0.982	1.003	0.997	0.982
2017~2018	1.016	0.603	1.020	0.997	0.613
2018~2019	0.955	1.104	0.982	0.972	1.054
平均	1.002	1.019	1.001	1.001	1.021

4. Discussion

4.1 The equity of medical and health resource allocation in Western China

The results show that the equity of medical and health resources allocation in the western region is poor, including two aspects : First, the equity of medical and health resources among regions is poor. The agglomeration degree of medical and health resource allocation in Inner Mongolia, Tibet, Qinghai and Xinjiang is far below the standard of equity of 1, and the allocation according to geographical area cannot meet the demand of population for medical treatment, which is consistent with the research results of Shen et al.[36] on the western region. The main reason is that these areas are geographically large and sparsely populated, resulting in poor geographical accessibility . However, the medical and health resources in Guangxi, Chongqing, Sichuan, Guizhou, Shaanxi and other places are over-resourced according to the geographical area, which can meet the medical needs of the population. Therefore, the government pays attention to horizontal flow when planning the allocation of medical and health resources, and imports surplus medical and health resources into the scarce areas to achieve the optimal allocation of medical and health resources. Second, the medical and health resources in the western region, whether allocated according to geographical area or population size, are poor in equity and can not meet the needs of population for medical treatment. When the government invests in medical and health resources in western China, it is necessary to take into account population and geographical factors, consider the service radius of medical institutions, and rationally allocate medical and health resources according to actual needs.

4.2 Rational optimization of resource allocation is the key to improve the efficiency of medical resource allocation in western China

The allocation efficiency of medical resources in Tibet, Qinghai, Ningxia and Xinjiang in the western region decreased from 2009 to 2019. The results show that the decrease in the allocation efficiency of medical and health resources in Tibet and Qinghai is caused by the decrease in scale efficiency, and the allocation efficiency of medical and health resources in Ningxia depends on medical technology. The allocation of medical and health resources in Xinjiang needs to be improved in terms of technology and scale. Therefore, in the allocation of medical and health

resources in the western region, the focus is on the decline of total factor productivity in four areas. For areas with reduced scale efficiency, in line with regional health planning, the government should encourage hospitals to appropriately expand the scale and improve the utilization rate of medical resources by establishing sub-hospitals and restructuring small hospitals. For technology-oriented areas, timely updating of medical equipment, innovation of diagnosis and treatment technology, guidance of practice with new theories and new knowledge.

4.3 Pay attention to the progress of medical technology, focus on the allocation of technical resources

The total factor productivity of medical and health resource allocation in the western region from 2009 to 2019 has fluctuated in these 11 years, but it has an overall upward trend. The research shows that total factor productivity changes with the change of technological progress rate, and the fluctuation is consistent, indicating that the improvement of health resource allocation efficiency in the western region is technology-oriented. Therefore, to improve the allocation efficiency of medical and health resources in the western region, we need to pay attention to technological progress. Through the sharing of knowledge, technology and management experience among regions, professional and technical talents are cultivated and introduced to innovate drug development and medical services and improve medical service ability. The introduction of external advanced medical equipment, diagnosis and treatment technology, and strive to achieve a breakthrough in the allocation efficiency of medical and health resources.

4.4 Reasonable allocation of health resources should take fairness and efficiency into account

Health care reform has been more than 10 years, the total amount of health resources in the western region and the level of resource utilization have improved, which also shows that the country 's counterpart support policies and financial investment in recent years have achieved some results, but the total amount of health resources is still behind the national ranking. The results of this study also show that the equity of medical resources in the western region is relatively poor whether according to geographical distribution or population allocation. Therefore, health resources departments need to continue to increase support for the western region in the overall planning. In addition, while emphasizing the fairness of the allocation of medical resources, it is necessary to make full and effective use of medical resources, both of which should be integrated. For regions with lower total factor productivity, medical institutions can improve medical utilization efficiency by introducing advanced technology and telemedicine. Health resource departments should strengthen the efficiency assessment of medical institutions and encourage medical institutions to improve the quality of medical services.

5. Conclusions

Based on the data of medical and health resource allocation in western China from 2009 to 2019, this study adopts the theory of health resource agglomeration degree(HRAD) and the Malmquist index model to analyze the equity and efficiency of medical and health resource allocation in western China. The main conclusions are as follows :

(1) In 2009, medical and health resources in Inner Mongolia, Tibet, Qinghai and Xinjiang was scarce, regardless of geographical area or population size distribution. The other eight provinces and cities—Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu and Ningxia—medical resources met the needs of the population, and there are surplus. Therefore, the allocation of medical and health resources in 12 provinces in western China was unfair.

(2) In 2009-2019, the allocation of medical and health resources in the whole western region of China was unfair compared with the national medical resources allocation, which could not meet the medical needs of the

population. The state needs to increase investment in medical resources in western China.

(3) From 2009 to 2019, the total factor production (TFP) indexes of Tibet, Qinghai, Ningxia and Xinjiang were 0.994, 0.984, 0.974 and 0.994, respectively, indicating that the efficiency of medical allocation in these four places was reduced. The government needs to pay special attention to the allocation efficiency of medical resources in these four places.

(4) From 2009 to 2019, the total factor productivity (TFP) in western China was 1.021, an increase of 2.1 percentage points, indicating an overall improvement in the efficiency of medical and health resource allocation. However, in 2010 ~ 2011, 2012 ~ 2013, 2013 ~ 2014, 2014 ~ 2015, 2016 ~ 2017 and 2017 ~ 2018, the total factor productivity were less than that. The analysis results showed that the efficiency were reduced due to technological degradation.

This study is expected to provide reference for the sustainable development of medical and health resources allocation in western China. In the subsequent studies, more appropriate methods will be constantly tried to accurately evaluate the equity and efficiency of resource allocation. At the same time, we should continue to pay attention to the latest data released by the Chinese government to better evaluate the allocation of health resources in Western China.

Abbreviations

HRAD: health resources degree agglomeration; PAD: population agglomeration degree; TFP: Total factor productivity; EFF: Comprehensive Efficiency; TECH: Technological Progress Efficiency; PEC: pure technical efficiency; SE: scale efficiency

Declarations

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Availability of data and materials

Please contact author for data requests.

Authors' contributions

QJ collected and analyzed the data and wrote the manuscript. Y RX designed and modified the manuscript. The final version submitted for publication is read and approved by all authors.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

Geographical location of western China

Figure 2

Ratio of concentration degree of medical and health resources and population in western China from 2009 to 2019