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Building an integrated healthcare system of China: an assessment of coupling coordination between disease prevention, medical services, and healthcare financing from 2012 to 2021

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Abstract

Background Universal Health Coverage (UHC) is a central component of the Sustainable Development Goals, and integrated healthcare is recognized as a key pathway to achieving UHC. China's healthcare reform, aimed at realizing the "Healthy China 2035" goal, faces challenges in ensuring the coordinated development of disease prevention, medical services, and healthcare financing. However, empirical research assessing the integration of these three systems in China is scarce.

Purpose This study aims to assess the coupling and coordination between disease prevention, medical services, and healthcare financing in China from 2012 to 2021, with the goal of providing a comprehensive evaluation of the progress made in building an integrated healthcare system.

Methods The study employs the Entropy Weight Method (EWM) to determine the weight of each system index, followed by the Coupling Coordination Degree Model (CCDM) to measure the coordination among the three components. The Grey Correlation Analysis (GCA) is used to identify key driving factors, and the Grey Prediction Model (GM (1,1)) is applied to forecast future trends of integrated healthcare development across Chinese provinces.

Results The coupling coordination degree of the three systems ranged from 0.12 to 0.73 from 2012 to 2021, reflecting a shift from moderate imbalance to mild imbalance over time. Regional disparities were observed, with eastern provinces showing higher levels of integration than western provinces. The disease prevention subsystem emerged as the primary constraint to the overall integration process. Most regions exhibited a consistent upward trend in the coupling coordination index, though development speeds varied significantly across provinces.

Conclusion While China's integrated healthcare system has shown progress, there is still considerable room for improvement. Strengthening disease prevention efforts is critical to enhancing the overall coordination of the healthcare system. This study provides valuable insights for other developing countries facing similar challenges in healthcare integration.

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Keywords Integrated healthcare system, Coupling coordination degree model, Disease prevention, Grey system, China

Introduction

Universal Health Coverage (UHC) is a crucial component of the Sustainable Development Goals (SDGs) proposed by the United Nations and World Bank to be achieved by the year 2023. UHC reflects the level at which all residents have access to basic health care without having to suffer from poverty, which involves three major aspects, namely preventive healthcare, disease treatment and financial protection [1]. Health reform remains a critical issue embedded throughout the development of worldwide nations, with remarkable milestones achieved in the reform progress of UHC [2]. However, due to the common nature shared by many healthcare systems implemented under different contexts, the interlocking core modules inherent in the system typically demonstrate distinct hierarchy and diversity, along with the inevitable coexistence of a wide range of internal and external factors, such as ageing population, increasing incidence and prevalence of chronic diseases, rising medical expenditures as well as disease profiles becoming more complicated over time. Under such climate, the public demand for healthcare services has evolved from the basic coverage of preventive health, disease treatment and financial protection at the initial stage, to the integrated promotion of medical service quality that largely relies on the interrelation of three aforementioned dimensions [3]. Under such context, integrated health service has emerged as an effective solution to maintaining the continuity, integration, and coordination of medical service via minimizing fragmented service delivery through an integrated reform approach. As such, integrated health service demonstrates significant practical value for worldwide nations in terms of contributing to the constant promotion of their national health governance level from a long-term perspective [4].

During China's transition from a planned economy to a market economy, the quality and efficiency of medical and health services has significantly improved. However, a couple of prominent issues persistently exist, including the inequity of medical service quality, unreasonable cost structures and lagging construction of public health infrastructure [5]. Firstly, from the dimension of medical insurance coverage, China ranked fourth from the bottom among 191 countries investigated in the World Health Organization's 2000 Global Health Financing Fairness Survey, which has been prominently reflected as over 75% of rural residents failing to be covered by any type of medical insurance plans during the disease outbreak of SARS, thus leading to approximately 60% of medical costs posed on residents themselves via the out-of-pocket method [6], This suggests the existence of huge gap embedded in China's rural health insurance system and there is a high degree of inequality in the distribution of insurance benefits under China's social medical insurance system [7]. Secondly, as the consequence of China's medical pricing systems reform, as well as the over-commercialization of medical service in the healthcare market, constantly increasing burden from medical expenditures has been added to Chinese residents over the past decades [8]. The rapid emergence of profit-oriented services driven by the uncontrolled market has created conditions for medical service providers to pursue increased monetary interests at the sacrifice of user benefits, leading to constantly increasing burden posed on residents' medical expenditures, and ultimately undermining the entire healthcare system [9]. Last but not least, the separation of management and funding during the early stage of China's healthcare reform has resulted in fragmented governance and lack of coordination among different governmental divisions, due to the fact that the Ministry of Health was only responsible for rural cooperative medical insurance, while basic medical insurance for urban employees and medical assistance for impoverished rural residents were under the jurisdiction of the Ministry of Human Resources and Social Insurance and the Civil Affairs Bureau, respectively [10, 11]. Striving to fulfill its political commitment to achieve a comprehensive well-off society as well as to respond to the urgent needs of the people, the Chinese government launched a large-scale healthcare reform in 2009. Through increasing governmental financial investment, expanding the penetration of medical insurance coverage as well as improving the quality and efficiency of medical service deliveries, the government redefined its role and position in providing financial support for the healthcare system and public goods supply [12]. However, it should be pointed out that the problems in the reform of China's medical and health services cannot be solved solely by increasing financial investment [13]. On the one hand, China's decentralized and progressive universal health coverage reform has led to the fragmentation of the social healthcare financing system, which has not fully played its role in society [14, 15]. On the other hand, Wu et al. [16] found that the health care reform launched in 2009 has reduced the efficiency of provincial public health services. As highlighted by Yip and Hsiao [17], the core issue persistently embedded in

China' s healthcare system remains unresolved, namely how to facilitate the transformation from a fragmented medical service system centered around profit-oriented hospitals, to an integrated healthcare system centered around the provision of basic medical care. In 2016, after an evaluation of China's health reform, the World Bank and the World Health Organization also recommended that China adopt the 'people-oriented integrated health services' (People-Centered Integrated Care, PCIC) model, which aims to overcome the fragmentation issues embedded in health care delivery that potentially undermines the ability of health systems to provide safe, accessible, high quality and cost-effective care with the goal of improving residents' health care experiences and outcomes.

The aim of this paper is to provide a comprehensive assessment of the development of an integrated healthcare system in the context of China's new healthcare reform. We propose a model for the coupling and coordination of disease prevention, medical services, and healthcare financing, focusing on the core objectives of UHC across the three dimensions of "preventive healthcare", "disease treatment", and "financial protection". Through quantitative analysis of the coupling and coordination between these three systems, we present a detailed profile of China's integrated healthcare service system at each stage of its development. Additionally, we evaluate whether the system has progressed from "coverage" to "integration" and ultimately to "coupling". Based on this assessment, we identify the key obstacles hindering the realization of integrated healthcare, offering valuable insights to support the achievement of true UHC.

Literature review

Components of integrated healthcare

The concept of 'integrated health service' was initially proposed by the World Health Organization in 1978. It refers to the integration of functions and services of the healthcare system, while strengthening coordination and cooperation between departments via institutional reform in order to achieve the goal of universal access to healthcare [18]. As to the term 'integration', Shortell et al. [19] suggests that it should form a continuous and collaborative service system for individuals or organizations to achieve specific goals. Subsequently, other scholars such as Niskanen [20] applied the theory of integration to the field of healthcare service, proposing the construction of integrated health services based on a holistic view of patients, which is the process of connecting and coordinating various functions of the healthcare service system to ultimately meet and improve the needs of patients. On top of this, Kodner and Spreeuwenberg [21] further explained that integration involves a series of methods and models from the dimensions of finance, administration, organization, service provision and clinical care, with the aim of establishing connections between health prevention, disease treatment, and financial support to achieve coordinated development between different systems. An increasing number of scholars believe that integrated health services serve as an effective means to achieve higher-level healthcare reform goals, such as promoting public health levels, improving the quality of healthcare services, and reducing per capita healthcare costs, as proposed by Berwick et al. [22]. This further emphasizes the importance of coupling and coordinating the development of disease prevention, medical service and healthcare financing within the integrated health service model. Meanwhile, the research on integrated health services is closely connected with theories of collaborative governance, change management, system integration, as well as institutional reform and element reconstruction, thus providing a wide range of theoretical perspectives for researchers to explore [23, 24].

Influencing factors of integrated healthcare construction

The integrated healthcare service system, as a comprehensive entity with multiple levels and dimensions, is influenced by a wide range of factors, including social environment, professional background, institutional and cultural disparities [25]. As pointed out by Collins-Dogrul [26], the integration of medical service would be largely affected by multiple factors in practice, such as region-specific contexts of different administrative or cultural regions, or rules and regulations under different healthcare financing or health surveillance systems. Conflicts of interest is another issue that often undermines the cooperation between different organizations. As found by Zou et al. [27] in their study on the cooperation of tuberculosis services between two hospitals in China, mandatory integration tends to undermine the political and economic interests of different stakeholders, who are unwilling to cooperate but forced to do so under pressure, thus leading to low-quality integration. At the same time, at the level of mechanism design, the balance and coordination of power profoundly affect the outcomes of integrated health services. Scott [28] suggests that in situations of power imbalance, organizations usually defend their own resources and authority, resulting in power conflicts. Furthermore, in terms of clinical practice, integrated health services also involve the contradiction between confidentiality and information exchange [29]. Lyngsø et al. [30] highlighted that the lack of information exchange would impede cross-organizational collaboration and increase the risk of healthcare professionals making mistakes, such as in the situation where previous health examination results of patients or treatment plans during referrals are absent.

Different practice paths for integrated healthcare

According to the integrated health service models implemented by different countries, the World Health Organization has proposed three different approaches of medical service integration in summary. The first approach mainly focuses on integrating services, known as vertically integrated services, where different healthcare services are provided at a specific location in a comprehensive manner [31]. The second approach involves establishing a coordinated comprehensive service mechanism via planning and management, which includes integrating comprehensive budgets and financial management, establishing an integrated information system, ensuring data interoperability across different systems, synchronizing personnel through coordinated training, towards the ultimate goal of achieving coordination and integration of resources, with overall service surveillance provided at the final stage on an ongoing basis. The third approach involves more thorough service integration via diverse dimensions, from the integration of health services across departments and the establishment of coordinating mechanisms such as health committees, to the integration of medical service providers operating at different levels and in different regions, as well as the involvement of communities and households in medical service-related activities. In terms of different countries, the characteristics of integrated health services also demonstrate variations. For instance, Blum [32] indicated that Germany primarily focuses on the integration of treatment process via the establishment of disease management plans and the promotion of performance-based initial referrals in community clinics. Another study conducted by A. J. He and Tang [33] investigated integrated health services for the elderly population among four countries, namely Hong Kong, Singapore, Malaysia, and Indonesia. The authors reported a general trend in the community setting to combine long-term elderly care with treatment and prevention, and further emphasized the pivotal role of primary healthcare in the construction process of an integrated health service system. On the other hand, Dafny et al. [34] summarized that the integration of medical services in the United States mainly emphasizes the consolidation of healthcare institutions and insurance agencies at different levels and cross regions to arrive at unified service delivery. Under the context of China's healthcare system, X. Wang et al. [35] provided a detailed account of the patient-centered comprehensive healthcare model in Luohu District of Shenzhen city. This model establishes a legal entity by forming the Luohu Hospital Group with its affiliated public medical institutions within the jurisdiction. Through the reform of the total amount of healthcare financing funds 'being accountable for the overall amount with flexible rewards based on the actual surplus' in healthcare financing funding, the jurisdiction managed to build an integrated management system for hospitals and communities healthcare services.

Scholars have made a profound analysis of the concept definition, constituent elements and development mode of integrated health service. At the same time, under different social, institutional and cultural backgrounds, different characteristics and influencing factors developed by the integrated health service system have been observed, and a large number of case studies have been conducted for in-depth discussion. Different types of development models and experiences are summarized. However, most of these studies are case analysis, mode comparison, experience summary, etc., while quantitative studies are mostly limited to horizontal observation of a region, lacking comprehensive dynamic assessment of the horizontal and vertical development of integrated health service system construction in a region and analysis of its influencing factors. This also reduces the effectiveness of the improvement plan in the face of problems and obstacles in the development of different types of integrated health services.

Confronting with this dilemma, this paper proposes a comprehensive index system reflecting the coupling relationship between disease prevention, medical service and healthcare financing in integrated health service, as enhancing public health outcomes, elevating the overall quality of healthcare provisions, and alleviating individual healthcare expenditure. Moreover, this study also evaluates whether it can realize the transformation of medical service from 'coverage' to 'integration' and then to 'coupling'. First of all, entropy weight (IEW) is used to objectively obtain the weight, and on this basis, a coupling coordination degree model (CCDM) is constructed to construct the construction of integrated health service, and based on this standard, an accurate portrait of each development stage of China's integrated health service system construction is provided. Secondly, on this basis, grey correlation method (GRA) is used to find out the driving factors of the coupling coordination, and on this basis, the obstacles faced by achieving integrated medical service are clarified. Finally, the grey prediction model GM (1.1) is used to predict the future development trend of integrated health service in various provinces in China. This paper mainly has the following three aspects of value: First, from the two dimensions of time and space, the accurate portrait of the construction of China's integrated health service system in each stage is completely presented, and the practice path of coupling and coordination of related core contents is clearly presented; Second, based on the policy evolution of China's health care reform, it analyzes the realistic challenges faced in promoting integrated health care services and the driving factors in different environments.

Data and methods

Study area and data source

This project selected the health development data of 31 Chinese provinces, municipalities and autonomous regions (excluding Hong Kong, Macao and Taiwan) between 2012 and 2021 as the research object. The reason for this selection is that, first, in 2012, China's new leaders came to power, and started a series of new measures to deepen the reform of the medical and health system, including hierarchical diagnosis and treatment, integrated medical construction, etc., which promoted the overall development of the medical and health system from different dimensions; Second, from 2012 to 2021, China carried out poverty alleviation governance, in which health poverty alleviation laid a solid foundation for solving the main causes of poverty from the three dimensions of prevention, treatment and cost sharing, and the core content of health poverty alleviation and integrated medical construction have internal consistency; Third, the development level of medical and health services in different regions in China varies greatly, because comparing the development differences in different regions is conducive to a more profound understanding of the development status of integrated health services in China. Specific raw data are available from Statistical and health Statistical Yearbook of China, Labor Statistics Yearbook of China, Statistical Yearbook of Medical Security of China, and Provincial Statistical Yearbooks of China from 2013 – 2022, as well as Development Bulletin of Regional Healthcare and Healthcare Insurance from 2012–2021. For missing data (about 0.9%), this study employed the method of linear interpolation with data from adjacent years or matching with national-level data.

Index system construction

The construction of the index system is based on the comprehensive health coverage measurement framework proposed by the World Health Organization and the World Bank, which includes the dimensions of disease prevention, medical service and healthcare financing [36]. Meanwhile, it takes into account the actual situation of China's integrated healthcare service system, where medical service and cost-sharing are put under the jurisdiction of different departments. Following the principles of rationality, availability, operability for establishing data indicators, and based on the 'input-process-output' paradigm [37], a comprehensive evaluation indicator system for disease prevention, medical service and healthcare financing coordination in China's integrated healthcare service construction process has been constructed. This system includes six indicators for disease prevention service indicators, eight indicators for medical services and seven indicators for healthcare financial protection.as shown in Table 1.

(1) In the aspect of disease prevention systems, this paper presents Handler et al. [38] framework for measuring the concept of disease prevention and the views of some scholars [39, 40], on the development of disease prevention according to [38] to facilitate the selection of the following indicators. The quantity of health technicians in disease control centers and the quantity of personnel in disease prevention institutes were selected as input indicators. Their calculation methods comprehensively take into account the abundance as well as the accessibility of public health medical resources across regions, which are both positive indicators, meaning that larger values suggest more sufficient public health resources. The health management enrollment rate for child under 3 years and the proportion of health checkups were selected to indicate the disease prevention service process, both of which are positive indicators. The incidence of infectious diseases of class A and B,[1] as well as the mortality of pregnant women were selected to measure the output of disease prevention, all of which are negative indicators, with smaller values indicating better development of the disease prevention system.

The process indicators of disease prevention systems aim to measure the coverage and intensity of implementation of preventive services. These indicators directly reflect the efforts of disease prevention systems in health promotion and preventive management, for example, the health management enrollment rate for child reflects the standardization of maternal and child health care services, while the proportion of health checkups reflects the prevalence of early screening for

[1] Class A infectious diseases are the most perilous ones, characterized by rapid transmission and formidable challenges in prevention and control. They possess high levels of contagiousness and pathogenicity, making them prone to large-scale outbreaks, thus endangering public health and the welfare of the population. In the event of an outbreak, a prompt and extensive response is typically initiated at the national, provincial, or even global levels. Notable examples of Class A infectious diseases include plague, cholera, and rabies.

Class B infectious diseases are a category of infectious diseases that pose significant harm, with fast transmission rates, yet they are relatively easier to control and prevent compared to Class A infectious diseases. They exhibit a certain level of contagiousness and pathogenicity and have the potential to cause regional outbreaks. Local governments and health authorities pay considerable attention to the control and prevention of these diseases. Representative examples of Class B infectious diseases include influenza, tuberculosis, and dysentery.

Table 1 Indicators and weights for assessing disease prevention, medical service and healthcare financing

Sub-system	Index		Calculation method and unit	Attribute	Weight
Disease prevention	Input	CDC health technician coverage	The total number of the CDC technician/(total population × geographical area),%	+	0.474
		disease prevention agency staff coverage	The total number of disease prevention agency staff/(total population × geographical area),%	+	0.449
	Process	Health management enrollment rate for child under 3 years	%	+	0.005
		The proportion of health checks in the total population	%	+	0.053
	Output	The incidence of Class A and B infectious diseases	Per 100,000 people	-	0.015
		maternal actual	Per 100,000 people	-	0.004
Medical service	Input	Coverage of practicing (assistant) physicians	The total number of practicing (assistant) physicians/(total population × geographical area),%	+	0.434
		Coverage of beds in medical and health institutions	The total number of beds in medical and health institutions/(total population × geographical area),%	+	0.377
		The proportion of financial appropriations from health institutions in total revenue	%	+	0.084
	Process	Hospital bed utilization rate	%	+	0.013
		Hospital doctors pay the average number of visits	Person-time	+	0.019
		Hospital doctors pay for their average daily inpatient bed days	Day	+	0.049
	Output	Average day of hospitalization	Day	-	0.012
		The proportion of per capita hospitalization expenses and residents' disposable income	%	-	0.012
Healthcare financing	Input	Portion of individual healthcare financing contributions in per capita disposable income	%	-	0.069
		The proportion of government health expenditure in total health expenditure in all region	%	+	0.193
	Process	The proportion of the insured number of employees in the total population	%	-	0.354
		Coverage rate of maternity insurance participation	%	+	0.063
	Output	The proportion of the basic healthcare financing fund expenditure in the total health care expenses	%	+	0.086
		The total amount of medical assistance accounts for the expenditure of healthcare financing funds for urban and rural residents	%	-	0.205
		Health-care costs as a share of disposable income	%	-	0.030

(1) *CDC* Centers for Disease Control and Prevention

diseases. Output indicators, on the other hand, are the ultimate expression of the effectiveness of disease prevention services. Although the number of process and output variables is small, the logic chain is clear, i.e., broad coverage of preventive services can affect the incidence of infectious diseases and the risk of maternal mortality [41, 42]. In the data related to disease prevention, process indicators are more statistically sound, while there is a lag in the long-term monitoring of output indicators. The data for the indicators selected in this paper are relatively easy to obtain, the statistical caliber is clearer, and there is better consistency and comparability in different regions and time periods, and the selection of existing high-frequency, high-credibility indicators ensures the operability and timeliness of the study.

(2) The specific indicators of the medical service system in this study were selected based on X. Li et al. [43] of the indicators adopted to assess medical service projects implemented in China over the past 30 years. The number of practicing (assistant) doctors, the number of beds in healthcare facilities and the proportion of financial allocation in the total income were selected to measure the input of medical resources from the aspects of personnel, equipment and finances, which are all positive indicators. The hospital beds utilization rates, the average number of patients treated by doctors per day, and the average number of hospital bed days per doctor per day (Actual total bed days occupied/average number of physicians/365) were selected to measure the utilization of medical resources, all of which are positive indicators. The average length of stay for discharged patients and the proportion of hospital expenses per capita to disposable income were selected to measure the output of medical services from the perspectives of disease treatment and cost control, both of which are reverse indicators.

(3) The main process of the healthcare financing systems involves funding, operation and benefits. Due to the particularity of China's universal medical insurance system, the specific measurement indicators refer to the index framework used by Xiong et al. [44] in the evaluation of the correlation between China's medical insurance system and the medical service system. In the funding part, the proportion of personal funding to per capita disposable income and the proportion of government health expenditure to total regional health expenditure were selected represent individual funding and governmental funding, with the former being a negative indicator and the latter being a positive indicator. In the operation part, the number of employees participating in medical insurance and the number of people participating in maternity insurance were chosen ass positive indicators. As to the benefits part, the proportion of basic medical insurance fund expenditure to total regional health expenditure, the proportion of total amount of medical assistance to rural residents' medical insurance fund expenditure, and the proportion of medical expenses to disposable income were selected as indicators, with the former being a positive indicator and the latter being a negative indicator. In the treatment part, the proportion of the basic medical insurance fund to the total health expenditure, the total amount of medical assistance to the urban and rural residents and the proportion of the medical care fund in the disposable income are selected. The former is the positive index, while the latter is the reverse index.

The process indicators of the healthcare financing systems focus on the breadth of coverage of the system, reflecting financing and operational capacity. Output indicators reflect the effectiveness of coverage and the fairness of cost-sharing. The logical chain can also be understood as an increase in the participation rate directly expands the size of the covered population, which in turn affects the structure of fund expenditures. As China's health insurance system is dominated by social health insurance, the choice of process indicators reflects the reform priorities of system expansion and policy convergence, while the output indicators focus on measuring the burden of medical care on the population, which is closely related to China's goal of common wealth. This choice is also consistent with the variable design of many scientific studies [45, 46]. Although the number of variables is limited, they can effectively capture the core contradiction of China's health insurance system from "broad coverage" to "burden reduction".

The Entropy weight method

The Entropy weight method (EWM) is a widely used weighting technique in decision-making that utilizes the concept of entropy to evaluate the dispersion and validity of data indicators. By measuring the degree of dispersion, the method identifies the level of differentiation and the amount of information that can be extracted from the data. As a result, indicators with higher dispersion are assigned greater weight in the decision-making process, while those with lower dispersion receive lower weight [47, 48]. Using the EWM, we can estimate the weight of each integrated medical system index, which serves as a crucial foundation for conducting comprehensive evaluations with multiple indices. The assessment process is presented as follows.

First, the decision matrix composed of indicators from each province was established as follows:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{bmatrix} \quad (1)$$

where $i=1,2,\ldots,m$; $j=1,2,\ldots,n$ where **X** is decision matrix composed of indicators from each province. x_{ij} is the original value of the i-th index in the j-th region.

To make the different indicators comparable, it is necessary to standardize them first, as they may have different units and value ranges.

Second, the range method was employed to standardize original decision matrix **X**. Specifically, for positive indicators:

$$d'_{ij} = \frac{x_{ij} - min(x_{ij})}{max(x_{ij}) - min(x_{ij})} \quad (2)$$

For negative indicator:

$$d'_{ij} = \frac{max(x_{ij}) - x_{ij}}{max(x_{ij}) - min(x_{ij})} \quad (3)$$

The decision matrix after normalization is presented as follows:

$$D' = \begin{bmatrix} d_{11} & \cdots & d_{1j} \\ \vdots & \ddots & \vdots \\ d_{i1} & \cdots & d_{ij} \end{bmatrix} \quad (4)$$

where i=1,2,...m; j=1,2,...,n

Third, the proportion of the i-th index in the j-th region is denoted as p_{ij}, and the calculation model is described by Eq. (5):

$$p_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (5)$$

Fourth, the entropy value e_i of the i-th indicator is is defined as shown in Eq. (6) [48, 49]:

$$e_i = \frac{\sum_{j=1}^{n} p_{ij} * lnp_{ij}}{ln\ n} \quad (6)$$

where $e_i \in [0,1]$

In Eq. (6), we set p_{ij}*$lnp_{ij}=0$ when $p_{ij}=0$. The value of e_i increases with the degree of differentiation of index i, indicating that the index carries more information and plays a more significant role in the decision-making process as its differentiation degree grows larger. Consequently, a higher weight should be given to this index, and the calculation model of weight in EWM is shown as Eq. (7)

$$w_i = \frac{1 - e_i}{\sum_{i=1}^{m} e_i} \quad (7)$$

Last, the comprehensive evaluation index U_i of each region is calculated based on the Eq. (8):

$$U_{j} = \sum_{i=1}^{m} w_i p_{ij} \quad (8)$$

The Coupling coordination degree method (CCDM)

Coupling is an academic term in physics, which refers to the interaction and coordination between two or more systems. In this study, the Coupling Coordination Degree Model (CCDM) is utilized to quantitatively measure the relationships of coupling and coordination among disease prevention, medical services, and healthcare financing. The Coupling Coordination Degree determines the structure and order of the key subsystems and indicates the development trend of the system from disorder to order [50]. Based on the references to related research results [51] and combined with the specific research of this paper, the Coupling Coordination Degree is constructed as follows:

$$C = \sqrt{\left[1 - \frac{\sum_{a>b,b=1}^{r} \sqrt{(U_a - U_b)^2}}{\sum_{s=1}^{r-1} s}\right] \times \left(\prod_{a=1}^{r} \frac{U_a}{\max(U_a)}\right)^{\frac{1}{r-1}}} \quad (9)$$

where C represents the degree of coupling, a, b denotes the systems, r denotes the number of systems studied, s is used as a counting symbol, and U is the comprehensive evaluation index of systems.

Based on the model shown in Eq. (9), we construct a coupling disease prevention, medical services and healthcare financing ternary system, the model is shown in Eq. (10):

$$C = \sqrt{\left[1 - \frac{\sqrt{(U_3 - U_1)^2} + \sqrt{(U_2 - U_1)^2} + \sqrt{(U_3 - U_2)^2}}{3}\right] \times \sqrt{\frac{U_1}{U_3} \times \frac{U_2}{U_3}}} \quad (10)$$

where U_1, U_2, U_3 represent the comprehensive evaluation index of three systems of disease prevention, medical service and healthcare financing. However, the coupling degree model only assesses the strength of the interaction and does not reflect the level of coordinated development. Therefore, the coupling coordination model of the three systems is constructed in Eq. (11):

$$G = \sqrt{C * T} \quad (11)$$

where $T = \alpha u_1 + \beta u_2 + \gamma u_3$where G is the coupling coordination degree; T is the linear combination of comprehensive evaluation index of the research area disease prevention, medical services and healthcare financing; α, β, γ are the undetermined parameters of disease prevention, medical service and healthcare financing system respectively. In this study, drawing on relevant research results [52], the baseline scenario assumes that disease prevention, medical services, and healthcare financing sub-systems contribute equally. Hence, the parameters α, β, and γ are set to 1/3 each.

In this study, to facilitate a more intuitive understanding of the coupling coordination development status among disease prevention, medical services, and healthcare financing, a decile method is adopted for interval division [53]. The specific division criteria are presented in Appendix Table 1.

The Grey correlation method (GRA)

The Gray correlation model is distinguished by its focus on the proximity of the reference sequence to the comparison sequence, specifically the proximal distance of the assessment indicators to the assessment criteria [54]. The relevant indicators section draws from the research of Binder et al. [55], Wagstaff et al. [56], and T. Zhang et al. [57] to determine the following:

First, the reference sequence $Y(i)$ was determined. The reference sequence should serve as an ideal comparison standard, representing either the best value or the worst value for each index. The selection of the reference value can be based on any relevant criterion that aligns with the evaluation purpose. In this study, the sequence of the coupling coordination degree was chosen as the reference sequence, while disease prevention was represented by the reported incidence of Class A and B infectious diseases, medical services were represented by the number of licensed (or assistant) physicians, and healthcare financing was based on the ratio of the total income of the basic healthcare financing fund to GDP, and these were considered the comparison sequences.

Second, as with the EWM, before conducting the analysis, it is necessary to preprocess the raw indicators to eliminate the influence of units. This step ensures that different indicators are on the same scale, facilitating comparisons between them. The data should be standardized or normalized before applying the GRA method. This enables fair and accurate comparisons among indicators with different units. Specifically, the model to process the original indicators is as follows:

$$d_{\mathrm{a}}(i) = \frac{x_{\mathrm{a}}(i)}{x_{\mathrm{a}}(1)} x_a(i) / \frac{1}{m} \sum\nolimits_{i=1}^{m} x(i) \tag{12}$$

where $x_a(i)$ is the original value of the i-th index in the a-th system, including disease prevention, medical services, and healthcare financing; $d_a(i)$ is the standardize value of i-th index in the a-th system.

Last, the grey correlation coefficient is calculated as Eq. (13):

$$r_a = \frac{1}{m} \sum_{i=1}^{m} \xi_a(i) \tag{13}$$

where $\xi_{\mathrm{a}}(\mathrm{i}) = \frac{\min_a \min_i |\mathrm{y(i)} - \mathrm{x_a(i)}| + \rho \max_a \max_i |\mathrm{y(i)} - \mathrm{x_a(i)}|}{|\mathrm{y(i)} - \mathrm{x_a(i)}| + \rho \max_a \max_i |\mathrm{y(i)} - \mathrm{x_a(i)}|}$ where $\mathrm{r_a}$ denotes the gray correlation coefficient, which measures the degree of explanatory effect on the construction of integrated health services. Specifically, it represents the strength of the impact of a particular factor on the degree of coupling and coordination among the three major systems of the Chinese medical and health system. A higher value of $\mathrm{r_a}$ indicates a stronger influence of the factor being studied on the integration and coordination of the different components within the Chinese medical and health system. The value of $\rho = 0.5$ is set based on existing studies [1, 58].

The Grey prediction model GM (1, 1)

The Grey prediction model GM (1, 1) is a dynamic model that employs differential equations based on raw data to reveal the developmental process of phenomena and predict their future development patterns. It finds extensive applications in engineering control, economic management, and futurology research [59, 60].

In this paper, the Grey prediction model GM (1, 1) is utilized to assess the developmental trends of each system index in the provinces of China. The model aims to provide valuable insights into the future trajectories of these indices. By applying the GM (1, 1) model, this study gains a deeper understanding of the development patterns and potential changes in the various provinces' indices.

First, the initial data series is constructed according to Eq. (14):

$$X^{(0)} = \left\{ x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(q) \right\} \tag{14}$$

where q denotes the total number of the modeling data, (0) represents the initial data series.

Second, the first-order accumulated generation (or accumulation generating operation formation) of the initial data series is defined as follows:

$$X^{(1)} = \left\{ x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(q) \right\} \tag{15}$$

where $x^{(1)}(1) = x^{(0)}(1), x^{(1)}(\mathrm{q}) = \sum_{q=1}^{Q} x^{(0)}(q)$

By establishing a first order differential equation for $x^{(1)}(q)$, the Grey prediction model GM (1, 1) was established as Eq. (16):

$$\frac{dx^{(1)}}{dt} + \varphi x^{(1)} = \mu \tag{16}$$

where φ denotes the developmental gray number and μ is the endogenous control gray number.

The solution of GM (1, 1) based on least square method is described by Eq. (17):

$$\widehat{x}^{(1)}(q+1) = \left[x^{(0)}(1) - \frac{\mu}{\varphi} \right] \mathrm{e}^{-\varphi q} + \frac{\mu}{\varphi} \tag{17}$$

Finally, the accuracy test is conducted following the procedures outlined in existing studies for gray prediction formulas [61]. If the test results meet the condition requirements, the calculation can proceed as planned. However, if the test results do not meet the condition

Table 2 Results of coupling coordination degree of integrated health system

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Beijing	0.592	0.580	0.613	0.623	0.624	0.634	0.653	0.664	0.689	0.667
Tianjin	0.549	0.572	0.573	0.589	0.604	0.603	0.616	0.617	0.615	0.636
Hebei	0.185	0.191	0.194	0.191	0.193	0.191	0.202	0.206	0.211	0.217
Shanxi	0.206	0.242	0.203	0.203	0.205	0.210	0.209	0.211	0.232	0.239
Inner Mongolia	0.152	0.154	0.158	0.159	0.156	0.159	0.159	0.163	0.173	0.174
Liaoning	0.194	0.184	0.183	0.182	0.185	0.185	0.186	0.182	0.189	0.191
Jilin	0.189	0.191	0.192	0.191	0.200	0.200	0.204	0.209	0.239	0.221
Heilongjiang	0.142	0.144	0.149	0.148	0.152	0.159	0.156	0.158	0.190	0.179
Shanghai	0.655	0.638	0.645	0.664	0.682	0.687	0.697	0.712	0.705	0.732
Jiangsu	0.190	0.194	0.208	0.209	0.212	0.214	0.214	0.218	0.228	0.233
Zhejiang	0.205	0.209	0.218	0.221	0.245	0.226	0.223	0.228	0.231	0.242
Anhui	0.178	0.182	0.184	0.184	0.186	0.184	0.181	0.185	0.185	0.209
Fujian	0.195	0.205	0.208	0.208	0.206	0.213	0.208	0.210	0.210	0.214
Jiangxi	0.180	0.177	0.182	0.183	0.189	0.199	0.204	0.206	0.221	0.215
Shandong	0.211	0.217	0.217	0.215	0.219	0.220	0.230	0.223	0.228	0.231
Henan	0.197	0.206	0.213	0.215	0.214	0.218	0.212	0.216	0.227	0.231
Hubei	0.179	0.185	0.187	0.190	0.192	0.196	0.200	0.199	0.211	0.218
Hunan	0.162	0.170	0.181	0.182	0.185	0.190	0.194	0.195	0.192	0.205
Guangdong	0.175	0.177	0.178	0.179	0.184	0.183	0.191	0.195	0.198	0.206
Guangxi	0.180	0.183	0.192	0.194	0.199	0.200	0.207	0.198	0.207	0.204
Hainan	0.333	0.350	0.373	0.382	0.397	0.411	0.423	0.410	0.436	0.432
Chongqing	0.201	0.201	0.200	0.207	0.208	0.209	0.222	0.224	0.244	0.244
Sichuan	0.151	0.152	0.158	0.159	0.159	0.157	0.162	0.162	0.172	0.171
Guizhou	0.167	0.172	0.182	0.182	0.185	0.207	0.195	0.203	0.200	0.212
Yunnan	0.146	0.148	0.157	0.158	0.166	0.168	0.166	0.173	0.186	0.189
Xizang	0.162	0.165	0.173	0.174	0.173	0.184	0.192	0.192	0.195	0.206
Shaanxi	0.193	0.200	0.208	0.206	0.209	0.204	0.198	0.202	0.232	0.232
Gansu	0.168	0.173	0.188	0.188	0.194	0.193	0.180	0.178	0.186	0.190
Qinghai	0.142	0.149	0.157	0.158	0.151	0.164	0.167	0.158	0.167	0.175
Ningxia	0.275	0.291	0.296	0.300	0.292	0.320	0.333	0.328	0.320	0.327
Xinjiang	0.126	0.130	0.140	0.140	0.160	0.165	0.158	0.177	0.184	0.180

requirements, the formula will be revised accordingly (as shown in Appendix Table 2).

All data management and data analyses were performed using Excel.

Results

Results of the development of coupling

The coupling coordination degree of 31 provinces in China from 2012 to 2021 has been calculated, as shown in Table 2. Meanwhile, in order to make the data more expressive, this paper links the measured value of coupling coordination degree with the spatial analysis unit in vector format through ArcGIS 10.2 software according to Table 3. The spatial distribution map of the coupling coordination degree of disease prevention, medical service and healthcare financing in China in 2012, 2017 and 2021 was formed, as shown in Fig. 1.

In 2012, the coupling coordination degree was between [0.12–0.65]. The coupling coordination degree was mainly severe imbalance, accounting for 71%, and the 'intermediate imbalance' area was 16%, mostly concentrated in Beijing, Shanghai and its neighboring provinces, and the overall level was relatively low while the regional development was unbalanced. In 2017, the coupling coordination degree was between [0.15–0.68], which showed an improvement compared with 2012. The proportion of severe imbalance decreased to 52%, and the number of moderately dysfunctional provinces increased to 39%, showing two banded distributions, one of which was mainly in coastal provinces such as Shandong, Jiangsu and Zhejiang. The other is mainly in the central provinces of Shaanxi, Chongqing, Henan, Guizhou and other places. Compared with 2017, the coupling coordination degree of disease prevention, medical service and

Table 3 Coupling coordination degree and driver factors

Region	Disease prevention	Medical service	Healthcare financing
Beijing	0.653	0.499	0.649
Tianjin	0.740	0.595	0.575
Hebei	0.585	0.527	0.425
Shanxi	0.687	0.466	0.662
Inner Mongolia	0.754	0.535	0.580
Liaoning	0.768	0.545	0.586
Jilin	0.683	0.427	0.684
Heilongjiang	0.597	0.500	0.642
Shanghai	0.594	0.608	0.510
Jiangsu	0.742	0.672	0.506
Zhejiang	0.659	0.696	0.521
Anhui	0.799	0.721	0.552
Fujian	0.748	0.674	0.552
Jiangxi	0.756	0.678	0.530
Shandong	0.778	0.611	0.488
Henan	0.823	0.463	0.690
Hubei	0.667	0.705	0.509
Hunan	0.635	0.645	0.479
Guangdong	0.635	0.645	0.479
Guangxi	0.761	0.550	0.513
Hainan	0.648	0.646	0.546
Chongqing	0.663	0.609	0.470
Sichuan	0.762	0.553	0.511
Guizhou	0.731	0.657	0.486
Yunnan	0.656	0.570	0.429
Xizang	0.711	0.605	0.473
Shaanxi	0.696	0.605	0.524
Gansu	0.807	0.431	0.658
Qinghai	0.651	0.577	0.472
Ningxia	0.651	0.577	0.472
Xinjiang	0.446	0.634	0.718
Average	0.693	0.588	0.545

healthcare financing in China in 2021 is between [0.17–0.73], and more than half of the regions have changed from severe to intermediate imbalance, mainly in eastern China.

The revised objective now reads: The degree of coupling coordination among Chinese provinces generally shows a significant difference of "high in the east and low in the west". In terms of economic factors, the eastern provinces represented by Shanghai (D = 0.732 in 2021) and Zhejiang (D = 0.242) have economic advantages that can support a large amount of financial investment in health, thus realizing efficient cross-system synergies, while the western provinces of Xinjiang (D = 0.180) and Gansu (D = 0.190) have realized a jump in growth rate through health poverty alleviation, but are limited by the financial dependence on transfer payments, resulting in obvious shortcomings in public health services. This has led to obvious shortcomings in public health services. In terms of policy factors, Fujian (D = 0.214) has broken through the institutional barriers through the "three medical institutions" of the Sanming medical reform, effectively improving the degree of system coupling and coordination, while some other provinces are constrained by administrative fragmentation and the problem of sectoral division is prominent.

Using the frequency analysis method, the classification types of coupling coordination degree are synthesized. The share of each type of coupling coordination in the same historical period was analyzed by grouping, and the results were synthesized into the evolution curve of coupling coordination degree in 2012, 2017 and 2021 (Fig. 2): The peak of the evolution curve of the coupling coordination degree of disease prevention, medical service and healthcare financing continues to advance, and the growth curve of disease prevention, medical service and healthcare financing is close to "S" shape from 2012 to 2021.

In general, the spatial and temporal characteristics of the coupling coordination degree of disease prevention, medical service and healthcare financing in China are as follows: (1) the coupling coordination degree of the whole country is enhanced, and the overall level is gradually improved; (2) Part of the severe disorder area gradually changed to the medium disorder and even the slight disorder area. (3) The coupling coordination degree is high in the east and low in the west, and spreads from the coast to the inland.

Driving factors of integrated healthcare construction in China

The measurement results of the coupling coordination degree of disease prevention, medical service and healthcare financing and the correlation degree of the three driving factors are shown in Table 3.

As can be seen from Table 3, the average value is basically greater than 0.5, indicating that there is a close relationship between each driving factor and the coupling coordination degree. From the national level, the impact of the three subsystems on the coupling coordination degree according to the degree of correlation is: disease prevention, healthcare financing, medical service. At the regional level, the disease prevention subsystem of 21 provinces, municipalities and autonomous regions has the greatest impact on the coupling coordination degree, accounting for 68% in the country, 7 regional healthcare financing subsystems have the greatest impact, and 3 regional medical service subsystems have the greatest impact. On the whole, disease prevention is the main key

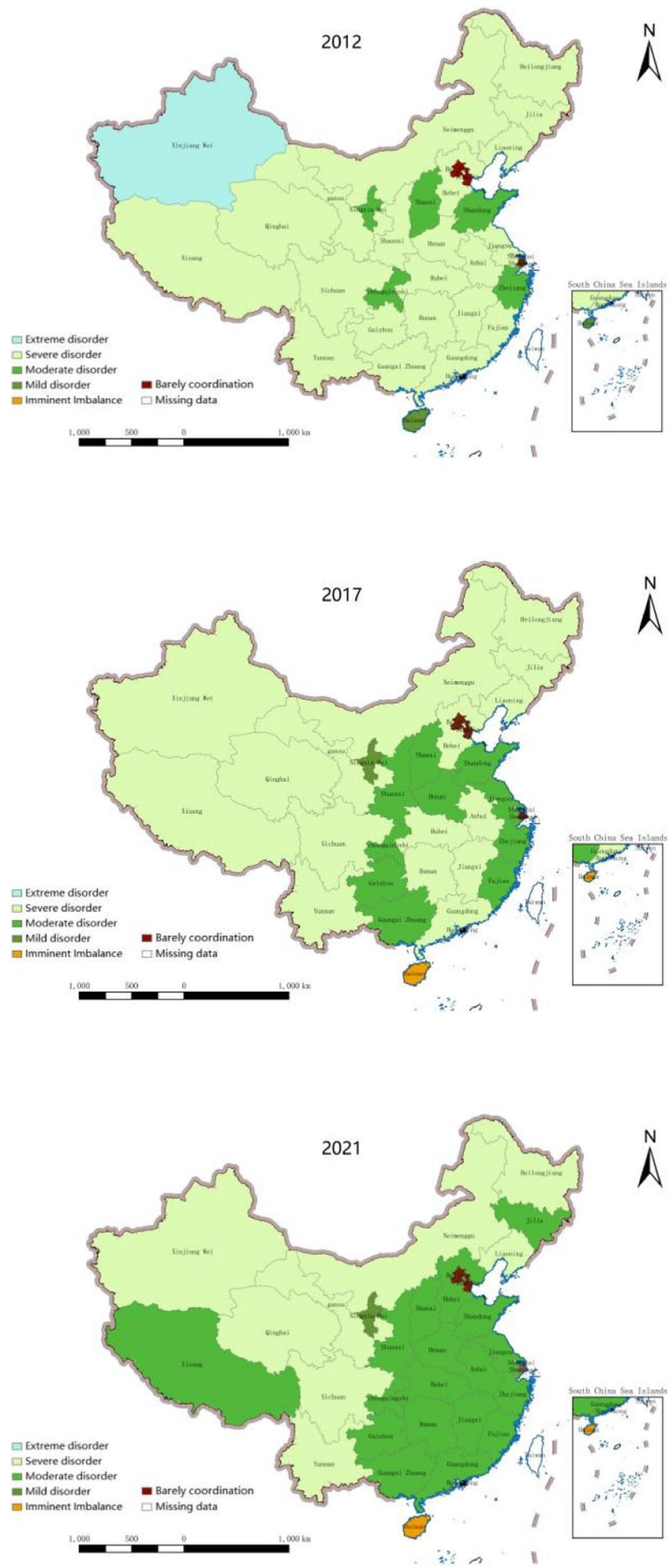

Fig. 1 Spatial distribution of coupling coordination degree

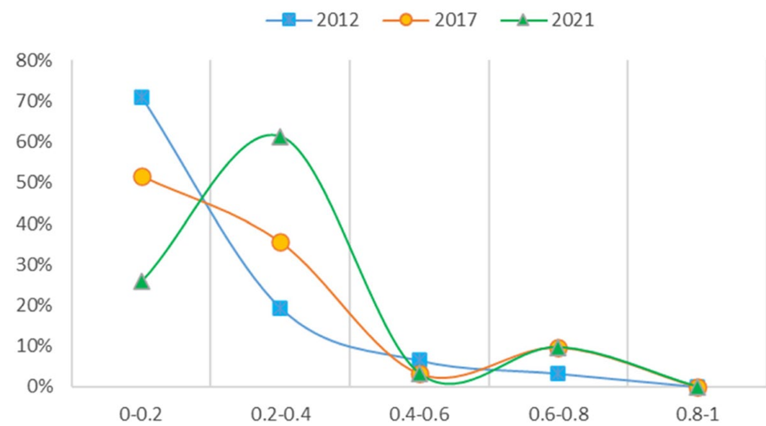

Fig. 2 Evolution curve of coupling coordination degree

factor restricting the coupling and coordination of integrated health service construction. At the same time, on the other hand, it also shows that the influencing factors and degrees of the coupling coordination degree of the three major systems in different provinces are not the same, indicating that there is no single and precise evolution law among the coupling coordination influencing factors of the three major systems in China's provincial regions.

Prediction of coupling coordination degree in China's provinces

Based on the grey prediction model GM (1,1), a dynamic simulation was carried out with the coupling coordination degree of disease prevention, medical service and healthcare financing in 31 provinces and regions of China from 2012 to 2021, and the model test was passed. The test results are shown in Table 4. The C value of all provinces and cities is less than 0.35, and the *P* value is greater than 0.95. The prediction effect is good, so this paper continues to forecast the coupling and coordination situation of various provinces and regions in China in the next 31 years, as shown in Fig. 3.

The results show that the 31 provinces in China will continue to change the characteristics of disease prevention medical service and healthcare financing, and the coupling coordination index in most regions shows a steady rising trend, with the national average annual growth rate of 1.83%, but the development speed is different among regions, and the average annual growth rate of each province is different. Among them, the fastest developing Xinjiang region reached 4.23%, and the slowest developing Fujian region, with an average annual growth rate of 0.15%, so the difference in development levels will become larger and larger.

Table 4 Error test based on the GM (1.1) grey prediction model

Region	φ	C	P
Beijing	1.20%	0.06	1.00
Tianjin	0.67%	0.05	0.90
Hebei	1.40%	0.08	1.00
Shanxi	5.08%	0.17	1.00
Inner Mongolia	1.69%	0.06	1.00
Liaoning	0.69%	0.12	1.00
Jilin	2.41%	0.11	1.00
Heilongjiang	2.84%	0.11	1.00
Shanghai	0.65%	0.04	1.00
Jiangsu	1.29%	0.05	1.00
Zhejiang	2.15%	0.16	1.00
Anhui	2.34%	0.18	1.00
Fujian	0.69%	0.07	1.00
Jiangxi	1.26%	0.05	1.00
Shandong	0.86%	0.09	1.00
Henan	1.34%	0.08	1.00
Hubei	0.97%	0.05	1.00
Hunan	1.14%	0.05	0.90
Guangdong	0.78%	0.05	1.00
Guangxi	1.51%	0.08	1.00
Hainan	1.74%	0.05	1.00
Chongqing	1.61%	0.06	0.90
Sichuan	1.18%	0.07	1.00
Guizhou	1.90%	0.09	1.00
Yunnan	1.52%	0.05	1.00
Xizang	1.07%	0.04	0.90
Shaanxi	3.36%	0.14	1.00
Gansu	2.81%	0.14	1.00
Qinghai	2.20%	0.08	1.00
Ningxia	1.91%	0.10	0.80
Xinjiang	3.05%	0.04	0.80
Average	1.72%	0.08	0.97

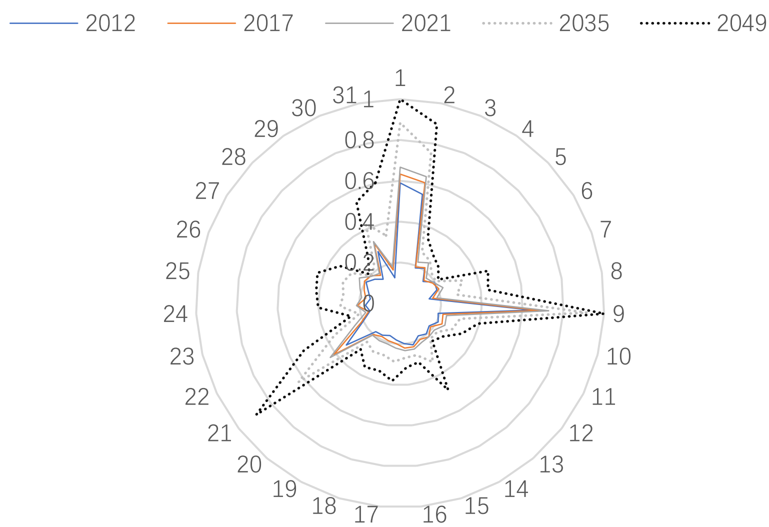

Fig. 3 Prediction radar diagram of coupling coordination of disease prevention, medical service and healthcare financing. 1-Beijing-2-Tianjin, 3-Hebei, 4-Shanxi, 5-Inner Mongolia, 6-Liaoning, 7-Jilin, 8-Heilongjiang, 9-Shanghai, 10-Jiangsu, 11-Zhejiang, 12-Anhui, 13-Fujian, 14-Jiangxi, 15-Shandong, 16-Henan, 17-Hubei, 18-Hunan, 19-Guangdong, 20-Guangxi-, 21-Hainan, 22-Chongqing, 23-Sichuan, 24-Guizhou-25-Yunnan, 26-Tibet, 27-Shaanxi, 28-Gansu, 29-Qinghai, 30-Ningxia, 31-Xinjiang

Conclusion and suggestion

Conclusion

Based on the ten-year survey data of 31 provinces in China from 2012 to 2021, this study provides new evidence for the profile of the integrated health services construction process in China and draws the following conclusions: First, the spatio-temporal patterns demonstrate large variations among different regions in China in terms of the coupling coordination degree of disease prevention, medical services and healthcare financing. This is mainly related to the fragmentation, division and service discontinuity within the three major systems internally. In the spatial dimension, it presents a 'higher in the east and lower in the west' spatial characteristic. Eastern developed provinces and cities such as Beijing, Shanghai, Jiangsu and Zhejiang have issued various integrated health service development related documents during the early stage of development [62, 63]. At the same time, China's poverty alleviation program has made great contributions to boosting the construction of integrated health services in western regions, which demonstrated relatively fast pace during the past decades. For example, in the deeply impoverished areas represented by 'Three Districts and Three Prefectures' including Tibet, the government expenditure accounted for 66.87% of the total health expenditure in Tibet in 2019, far higher than the national level of 27.36%.

In the time dimension, the coupling coordination degree of disease prevention, medical service and healthcare financing presents a wavy evolution from severe imbalance to relatively mild imbalance. The evolution trend from 2012 to 2021 resembled an S-shaped growth curve, which is also consistent with the overall reform process of China's medical system.

In December 2015, China integrated the basic healthcare financing system for urban and rural residents, and various regions gradually overcame the obstacles of separate management of urban and rural healthcare financing. In 2018, the National healthcare financing Administration was established, integrating the strength of multiple ministries and commissions, which unified the management of healthcare financing that was previously scattered among various ministries and commissions, thus achieving the convergence of healthcare financing and medical assistance work.

At the same time, disease prevention has the most significant impact on the development of the coupling coordination degree of the three major systems in various regions of China. At the current stage of development, disease prevention remains the primary weak point in the coupling and coordination development of different regions, which is consistent with the research of scholars such as Yip and Hsiao [5]. The relatively lagging development of the disease prevention system has restricted the overall improvement of the coupling coordination degree of medical and health system to some extent, and as such improving disease prevention to boost the driving effect of the coupling and coordination of the three major systems serves as a more prominent solution. Therefore, China initiated the implementation of the Healthy China Action (2019–2030) in 2019, clearly stating that the development of integrated health services will be addressed as the future development path, with the aim of promoting the level of disease prevention construction with a series of specific goals. Finally, the predictive studies showed that the coupling coordination index in most regions presents a steady upward trend, while the development pace demonstrates large variations among different provinces. If the current institutional mechanisms as well as its corresponding growth in finance and service supply are maintained, the gap embedded in development level between regions will likely keep expanding.

Discussion

This paper constructs a comprehensive evaluation index system for the coupling and coordination of the three systems of disease prevention, medical services and healthcare financing under China's integrated healthcare service system, and systematically assesses the spatial and temporal differences of China's integrated healthcare service system and its driving factors. In terms of research methodology, compared with the existing literature that relies on qualitative analysis or a single model, this paper employs the coupling coordination model, the gray correlation model and the GM(1.1) gray prediction model, which not only reveals the S-shaped evolution of the coupling coordination of the three systems, but also predicts the development trend of the three systems in the next 30 years, thus compensating for the lack of dynamics and foresight in traditional research. It also predicts the development trend in the next 30 years, which makes up for the shortcomings of traditional research in dynamics and foresight. In terms of research results, this paper quantifies the coupling gap of the three systems, validates the assertion that "the development of the disease prevention system is growing at a slower rate" [64], and points out the general pattern of China's coupling coordination in the east and west. Future research could further extend the data span to capture the long-period pattern, so that the development trend of the three coupled systems could be more clearly defined. Meanwhile, the influence of subjective factors such as cultural concepts and governance capacity on the system coupling synergy can be explored, and the design of indicator weights combining subjectivity and objectivity will be conducive to more accurate results.

Suggestion

This study has certain significance and value for the central and local governments in promoting a healthcare system centered around the well-being of residents. First, there is a need to further deepen the reform of the health management system, eliminating the issues with respect to low coupling coordination and weak governance force caused by departmental segmentation. From the strategic perspective of 'big health', the exploration of a comprehensive health system or the establishment of a more closely-knit collaborative mechanism for development on a short-term basis should be pursued. However, this reform faces the challenge of conflicting sectoral interests, powers, and responsibilities. The healthcare, health insurance, and civil affairs departments have long experienced cross-functional issues and operate under vertical management systems, with rigid boundaries of authority and responsibility. These differences in departmental objectives make it more difficult to integrate resources across systems. Secondly, continuous attention and increased investment are required for the construction and development of the disease prevention system, especially in disease prevention and health promotion. Attempts should be made towards breakthroughs where constraints previously posed by resource allocation are removed, as well as towards the establishment of an incentive-compatible mechanism for the coordinated utilization of disease prevention funds and healthcare financing funds that combines prevention and treatment. However, fiscal pressures and regional imbalances are significant, which to some extent exacerbates the challenges of reform. Public health expenditures in some regions rely heavily on centralized transfers, and flexibility of funding is limited by the constraints of the earmarking mechanism. Thirdly, each province should focus on key driving factors within their respective three major system couplings, providing targeted policy preferences for weaker systems, including increased investment, standardization of processes, and optimization of output quality throughout the entire process. Specifically, provinces need to accurately identify the shortcomings of local coupling and coordination through big data analysis and research, for example, regions with slower development of disease prevention systems can prioritize the strengthening of the disease control system and the primary health service network, and regions with relatively low efficiency of medical services can actively promote the construction of hierarchical diagnosis and treatment and medical association. In addition, it is necessary to strengthen cross-sectoral coordination mechanisms, integrate the resources of health care, health insurance, finance and other departments, raise the level of coordination, break down administrative barriers, and promote the synergistic development of disease prevention, medical service and healthcare financing guarantee with a systematic mindset. Finally, gradually narrowing the health gap between regions is an essential component of building shared prosperity. On one hand, the central and eastern regions need to continue increasing support for the relatively underdeveloped provinces in the central and western regions. For example, the central government has allocated targeted funds to support the construction of integrated medical services in the west, and tertiary hospitals in the developed regions of the east have provided peer-to-peer support to county-level hospitals in the west, dispatching specialists to each other for exchanges and learning. On the other hand, the central and western provinces should strengthen their own reform efforts, implementing structural adjustments to the three major systems, and fully utilizing modern information technology to overcome the spatial–temporal constraints of healthcare services, so as to gradually reduce the long-standing negative impacts of geographical disadvantages on the development of the healthcare industry.

Supplementary Information

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Supplementary Material 1

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Authors' contributions
G.H. and J.P. conceived of the presented idea. G.H. and L. L. developed the theory and performed the computations. G.H. and L. L verified the analytical methods. W.W. and Q W. analyzed the data. G.H., J.P., and L. L. drafted the manuscript. All author reviewed the article. All authors agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
As the discharge data didn't involve any experimentation or human subjects, IRB approval and patient consent were not required for this study.

Consent for publication
The work described has not been published before, and not under consideration for publication elsewhere; This work publication has been approved by all co-authors.

Competing interests
The authors declare no competing interests.

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References

1. Lee BX, Kjaerulf F, Turner S, Cohen L, Donnelly PD, Muggah R, Davis R, Realini A, Kieselbach B, MacGregor LS, Waller I, Gordon R, Moloney-Kitts M, Lee G, Gilligan J. Transforming Our World: Implementing the 2030 Agenda Through Sustainable Development Goal Indicators [Article]. J Public Health Policy. 2016;37:S13–S31.
2. Maeda A, Araujo E, Cashin C, Harris J, Ikegami N, Reich MR. Universal health coverage for inclusive and sustainable development: a synthesis of 11 country case studies. World Bank Publications. 2014.
3. Yip W, Fu H, Chen AT, Zhai T, Jian W, Xu R, Pan J, Hu M, Zhou Z, Chen Q. 10 years of health-care reform in China: progress and gaps in universal health coverage. The Lancet. 2019;394(10204):1192–204.
4. Enthoven AC, Tollen LA. Competition in health care: it takes systems to pursue quality and efficiency: if systems are the best locus of accountability for health care quality and efficiency, then competition should be designed to encourage evolution toward 'systemness'. Health Aff (Millwood). 2005;24(Suppl1):W5-420-W425-433.
5. Yip W, Hsiao WC. The Chinese health system at a crossroads. Health Aff. 2008;27(2):460–8.
6. Biao X. SARS and migrant workers in China: An institutional analysis. Asian Pac Migr J. 2003;12(4):467–99.
7. Tian S, Zhou Q, Pan J. Inequality in social health insurance programmes in China: a theoretical approach. J Asian Public Policy. 2015;8(1):56–68.
8. Meng Q, Xu L, Zhang Y, Qian J, Cai M, Xin Y, Gao J, Xu K, Boerma JT, Barber SL. Trends in access to health services and financial protection in China between 2003 and 2011: a cross-sectional study. Lancet. 2012;379(9818):805–14.
9. Ramesh M, Wu X, He AJ, planning. Health governance and healthcare reforms in China. Health Policy. 2014;29(6):663–72.
10. Hsiao WC. The Chinese health care system: lessons for other nations. Soc Sci Med. 1995;41(8):1047–55.
11. Teh-wei H. Financing and organization of China's health care. Bull World Health Organ. 2004;82(7):480–480.
12. Fei T. Building a healthy China: The development process and experience of China's medical and health services under the leadership of the CPC. Journal of Management World. 2021;37(11):26–40.
13. He JA. China's ongoing public hospital reform: initiatives, constraints and prospect. J Asian Public Policy. 2011;4(3):342–9.
14. He AJ, Meng Q. An interim interdisciplinary evaluation of China's national health care reform: emerging evidence and new perspectives. Journal of Asian Public Policy. 2015;8(1):1–18.
15. He AJ, Wu S. Towards universal health coverage via social health insurance in China: systemic fragmentation, reform imperatives, and policy alternatives. Applied health Econ Health Policy. 2017;15:707–16.
16. Wu S, Wang C, Zhang G. Has China's new health care reform improved efficiency at the provincial level? Evidence from a panel data of 31 Chinese provinces. Journal of Asian Public Policy. 2015;8(1):36–55.
17. Yip W, Hsiao W. Harnessing the privatisation of China's fragmented health-care delivery. Lancet. 2014;384(9945):805–18.
18. WHO. Primary health care: report of the International Conference on primary health care, Alma-Ata, USSR, 6–12 September 1978. World Health Organization. 1978:16.
19. Shortell SM, Gillies RR, Anderson DA. The new world of managed care: creating organized delivery systems. Health Aff. 1994;13(5):46–64.
20. Niskanen JJ. Finnish care integrated. Int J Integr Care. 2002;2:e16.
21. Kodner DL, Spreeuwenberg C. Integrated care: meaning, logic, applications, and implications–a discussion paper. Int J Integr Care. 2002;2:e12.
22. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. Health Aff. 2008;27(3):759–69.
23. Hjelmar U, Hendriksen C, Hansen K. Motivation to take part in integrated care—an assessment of follow-up home visits to elderly persons. Int J Integr Care. 2011;11:e122.
24. Ling T, Bardsley M, Adams J, Lewis R, Roland M. Evaluation of UK integrated care pilots: research protocol. Int J Integ Care. 2010;10:e056.

25. Auschra C. Barriers to the integration of care in inter-organisational settings: a literature review. Int J Integr Care. 2018;18(1):5.
26. Collins-Dogrul J. Managing US–Mexico "border health": An organizational field approach. Soc Sci Med. 2006;63(12):3199–211.
27. Zou G, Wei X, Walley JD, Yin J, Sun Q. Factors influencing integration of TB services in general hospitals in two regions of China: a qualitative study. BMC Health Serv Res. 2012;12:1–11.
28. Scott D. Inter-organisational collaboration in family-centred practice: A framework for analysis and action. Aust Soc Work. 2005;58(2):132–41.
29. Cooper M, Evans Y, Pybis J. Interagency collaboration in children and young people's mental health: a systematic review of outcomes, facilitating factors and inhibiting factors. Child Care Health Dev. 2016;42(3):325–42.
30. Lyngsø AM, Godtfredsen NS, Frølich A. Interorganisational integration: Healthcare professionals' perspectives on barriers and facilitators within the Danish healthcare system. Int J Integr Care. 2016;16(1):4.
31. Foreit KGF, Hardee K, Agarwal K. When does it make sense to consider integrating STI and HIV services with family planning services? International Family Planning Perspectives. 2002;105–107.
32. Blum K. Integrated primary care in Germany: the road ahead. Int J Integr Care. 2009;9:e14.
33. He AJ, Tang VF. Integration of health services for the elderly in Asia: A scoping review of Hong Kong, Singapore, Malaysia. Indonesia Health policy. 2021;125(3):351–62.
34. Dafny L, Duggan M, Ramanarayanan S. Paying a premium on your premium? Consolidation in the US health insurance industry. Am Econ Rev. 2012;102(2):1161–85.
35. Wang X, Sun X, Birch S, Gong F, Valentijn P, Chen L, Zhang Y, Huang Y, Yang H. People-centred integrated care in urban China. Bull World Health Organ. 2018;96(12):843-52.
36. WHO. Tracking universal health coverage: first global monitoring report. World Health Organization. 2015:7–8.
37. Ilgen DR, Hollenbeck JR, Johnson M, Jundt D. Teams in organizations: From input-process-output models to IMOI models. Annu Rev Psychol. 2005;56:517–43.
38. Handler A, Issel M, Turnock B. A conceptual framework to measure performance of the public health system. Am J Public Health. 2001;91(8):1235–9.
39. Jeet G, Thakur J, Prinja S, Singh M. Community health workers for non-communicable diseases prevention and control in developing countries: evidence and implications. PLoS ONE. 2017;12(7): e0180640.
40. Wolfe I. Satherley RM, Scotney E, Newham J, Lingam R. Integrated care models and child health: a meta-analysis. Pediatrics. 2020;145(1):e20183747.
41. Wei ZQ, Wei KK, Li Y, Nie LJ, Zhou YZ. Measurement of China's public health level: compilation and research of an index. BMC Public Health. 2024;24(1):686.
42. Zou H, Xiao H, Xu H. Does China's Equalization of Basic Public Health Services policy improve delivery care for migrant women? BMC Public Health. 2023;23(1):74.
43. Li X, Lu J, Hu S, Cheng K, De Maeseneer J, Meng Q, Mossialos E, Xu DR, Yip W, Zhang H. The primary health-care system in China. TLancet. 2017;390(10112):2584–94.
44. Xiong X, Zhang Z, Ren J, Zhang J, Pan X, Zhang L, Gong S, Jin S. Impact of universal medical insurance system on the accessibility of medical service supply and affordability of patients in China. PLoS ONE. 2018;13(3): e0193273.
45. Arhin K, Oteng-Abayie EF, Novignon J. Effects of healthcare financing policy tools on health system efficiency: Evidence from sub-Saharan Africa. Heliyon. 2023:9(10):e20573.
46. Ivankova V, Rigelsky M, Kotulic R, Gonos J. THE GOVERNANCE OF EFFICIENT HEALTHCARE FINANCING SYSTEM IN OECD COUNTRIES. Pol J Manag Stud. 2020;21(2):179–94.
47. Coifman RR, Wickerhauser MV. Entropy-based algorithms for best basis selection. IEEE Trans Inf Theory. 1992;38(2):713–8.
48. Zhu Y, Tian D, Yan F. Effectiveness of entropy weight method in decision-making. Math Probl Eng. 2020;2020:1–5.
49. Dong G, Shen J, Jia Y, Sun F. Comprehensive evaluation of water resource security: Case study from Luoyang City. China Water. 2018;10(8):1106.
50. Wang J, Wang S, Li S, Feng K. Coupling analysis of urbanization and energy-environment efficiency: Evidence from Guangdong province. Appl Energy. 2019;254: 113650.
51. Wang SJ, Kong W, Ren L, Zhi D, Dai B. Research on misuses and modification of coupling coordination degree model in China. J Nat Resour. 2021;36(3):793–810.
52. Tomal M. Analysing the coupling coordination degree of socio-economic-infrastructural development and its obstacles: The case study of Polish rural municipalities. Appl Econ Lett. 2021;28(13):1098–1103.
53. Zhang X, Chi T. Differentiating and analysis of the coordination degree between economic development and environment of provinces (regions) in China. Geogr Res. 2001;20(4):506–15.
54. Julong D. Introduction to grey system theory. J Grey Syst. 1989;1(1):1–24.
55. Binder S, Levitt AM, Sacks JJ, Hughes JM. Emerging infectious diseases: public health issues for the 21st century. Science. 1999;284(5418):1311–3.
56. Wagstaff A, Flores G, Smitz M-F, Hsu J, Chepynoga K, Eozenou P. Progress on impoverishing health spending in 122 countries: a retrospective observational study. Lancet Glob Health. 2018;6(2):e180–92.
57. Zhang T, Xu Y, Ren J, Sun L, Liu C. Inequality in the distribution of health resources and health services in China: hospitals versus primary care institutions. International journal for equity in health. 2017;16(1):1–8.
58. Li J, Zhou H. Correlation analysis of carbon emission intensity and industrial structure in China. China Popul Resour Environ. 2012;22(1):7–14.
59. Ju-Long D. Control problems of grey systems. Systems control letters. 1982;1(5):288–94.
60. Sheu T-W, Nguyen P-H, Nguyen P-T, Pham D-H, Tsai C-P, Nagai M. Using the combination of GM (1, 1) and Taylor approximation method to predict the academic achievement of student. SOP Transactions on Applied Mathematics. 2014;1(2):55–69.
61. Yang X, Zou J, Kong D, Jiang G. The analysis of GM (1, 1) grey model to predict the incidence trend of typhoid and paratyphoid fevers in Wuhan City, China. Medicine. 2018;97(34):e11787.
62. Jiang L, Song S, Guo W. Study on the models and development status of regional longitudinal medical alliance in China. Med Soc. 2014;27(5):35–8.
63. Liang S, He L, Song S, Jin Y, Yuan B, Meng Q. The development and practice of integrated healthcare in China. Chinese Journal of Health Policy. 2016;42–48.
64. Blanc DC, Grundy J, Sodha SV, O'Connell TS, von Mühlenbrock HJM, Grevendonk J, Lindstrand A. Immunization programs to support primary health care and achieve universal health coverage. Vaccine. 2024;42:S38–42.

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