

Predictive Analysis of Clinical Pharmacist Talent Demand in Yunnan: A Grey GM(1,1) Model Approach with Insights from Kunming Medical University

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ABSTRACT

Objective: Leveraging the Grey GM(1,1) model, we aimed to forecast the clinical pharmacist demand in Yunnan province. This was done using Kunming Medical University as a case study to inform effective talent cultivation strategies.

Material and Methods: Historical demographic and educational data from Yunnan informed our Grey GM(1,1) model to predict future demands for clinical pharmacists accurately.

Results: The population of Yunnan peaked at 46.53 million in 2014, experienced a slight decline in 2015, and then increased to 46.93 million in 2022. Concurrently, enrollment plans for clinical pharmacists at higher medical colleges are projected to grow, with an anticipated intake of 114 students in 2023. Despite this growth, and considering Yunnan's aging demographic, there is an emerging demand for 3,000 clinical pharmacists by 2027, with a forecasted shortfall of 1,250 personnel.

Conclusion: To address this significant gap, it is crucial to refine the clinical pharmacy curriculum at Kunming Medical University, by incorporating more hands-on experiences and strengthening collaborations with clinical medical institutions to enhance practical training opportunities for students.

Keywords: clinical pharmacist demand forecasting; Grey GM(1,1) Model; higher medical education; talent cultivation strategies; Yunnan province

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doi: 10.31584/psumj.2024266643
<https://he01.tci-thaijo.org/index.php/PSUMJ/>

PSU Med J 2024;4(2):81-92
Received 17 October 2023
Revised 18 April 2024
Accepted 18 April 2024
Published online 23 August 2024

INTRODUCTION

Clinical pharmacists bridge a crucial gap in modern healthcare, ensuring optimal medication plans and enhancing patient safety. Their value is pronounced in Western healthcare systems, wherein their expertise is indispensable. In contrast, China is in the midst of a transformative journey, and gradually integrating these professionals into its healthcare fabric¹⁻².

Historically, China has embarked on legislative measures to reinforce the clinical pharmacy domain. Starting in 2002, initiatives; such as the “Interim Regulations on Pharmaceutical Management” and subsequent directives, have laid the groundwork, advocating for the integration of clinical pharmacists in medical institutions³⁻⁴. However, surveys illuminate challenges; such as disparity in adoption across hospitals, ambiguous practice standards and limited awareness among healthcare personnel. Furthermore, the prevalent infrastructure in many medical institutions is inadequate for advanced pharmaceutical practices⁵.

In response to these challenges, particularly in Yunnan province, this study employs the Grey GM(1,1) model, a robust tool well-suited for situations with limited or incomplete data. The Grey GM(1,1) model enables us to forecast demand effectively, even with the uncertain and fluctuating data typical of new and transforming healthcare systems. By leveraging this model, it is predicted that clinical pharmacist requirements in Yunnan; based on its 2023 demographic metrics, shall provide a reliable prediction: despite the inherent data challenges⁶.

This study’s comprehensive analysis not only encapsulates Yunnan’s historical data spanning 17 years, but also anticipates the province’s evolving needs against the backdrop of an aging population. By bridging these insights with international standards, our aim extends beyond mere forecasting. We seek to craft a detailed and actionable roadmap for Yunnan’s healthcare stakeholders, ensuring they are primed to meet future demands and contribute meaningfully to the province’s healthcare renaissance. This study; therefore, sets precise objectives

to benchmark Yunnan’s needs against global standards, tailor interventions for its unique challenges, and outline strategic directions for integrating clinical pharmacists into its healthcare system more effectively⁷.

MATERIAL AND METHODS

Comprehensive data collection and integration

To explore the dynamics of Yunnan’s pharmaceutical workforce, we integrated multiple datasets. Comprehensive surveys from all 16 prefectures provided critical insights into the employment rates, job satisfaction and distribution of clinical pharmacists, which are essential for assessing regional disparities and understanding pharmacist availability. Additionally, data from the Yunnan Provincial Health Commission, which included details on healthcare facilities, services and staffing: specifically the number of clinical pharmacists currently employed and their projected needs, formed the core of our predictive model. This data links pharmacist availability to healthcare demands, enabling accurate forecasting of future workforce requirements. We also used demographic statistics from the Yunnan Provincial Bureau of Statistics; including age distribution and urban–rural segmentation, to calculate the pharmacist–to–population ratio: a factor that significantly influences the outputs of our model.

Data from various sources were meticulously preprocessed to ensure consistency and reliability before their integration into the Grey GM(1,1) model. The preprocessing steps included: cleaning, wherein inconsistencies were removed and missing values were filled using interpolation methods, based on neighboring data points. This was followed by normalization, which involved standardizing data units and scales to ensure comparability across different sources. Finally, the aggregation step combined data points to create a comprehensive view of the pharmacist workforce landscape in Yunnan. This thorough preprocessing ensures that the model’s inputs are not only accurate but also reflective of the actual conditions; enabling precise forecasting and strategic planning.

Comprehensive forecasting and sensitivity analysis using the Grey GM(1,1) Model

The Grey GM(1,1) model, a pivotal innovation from the 1980s, has been integral to our complex forecasting tasks; especially for predicting the demand for clinical pharmacists in Yunnan. Its proven efficiency via limited datasets and non-linear scenarios, utilizing the first-order Grey differential equation, dynamically integrates variables from historical trends and economic indicators to model demand accurately. To enhance the model's performance, we employed advanced optimization algorithms to refine the model parameters; significantly improving its predictive accuracy. This process involved adjusting the weights of different variables based on their impact on forecast outcomes, effectively capturing the nuanced dynamics of Yunnan's healthcare sector. We also conducted sensitivity analyses by perturbing key model parameters; such as economic indicators, to test the resilience of our forecasts under varying economic and demographic conditions, ensuring the model's robustness. These comprehensive modeling techniques have provided healthcare policymakers and stakeholders in Yunnan with actionable insights, aiding strategic planning and resource allocation to optimize healthcare delivery and improve patient outcomes in the province.

Analytical framework for forecasting pharmaceutical workforce dynamics

Utilizing descriptive statistical tools, we analyzed trends within China's pharmaceutical workforce relative to population metrics. Central to our approach, the Grey GM(1,1) model leveraged historical data to align with past trends and project future workforce dynamics through till 2030, ensuring model fidelity through rigorous verification. We also examined demographic shifts in Yunnan from 2006 to 2022, enabling us to forecast population trends up to 2027 as well as to assess the impact of an aging population on the demand for clinical pharmacists. Integrating these

insights with Yunnan's educational strategies in pharmacy, we developed policy recommendations that align future pharmacist training with anticipated demographic changes; ensuring a well-prepared pharmaceutical workforce.

Diving deeper: Kunming Medical University case study

Spotlighting Kunming Medical University, we embarked on an in-depth examination of its clinical pharmacist talent cultivation paradigm. Through meticulous data collection, which included analyzing graduate trajectories, academic accomplishments and employment outcomes, a comprehensive profile emerged. This process allowed us to capture a detailed snapshot of the university's effectiveness in preparing students for the workforce. A comparative analysis was then orchestrated, aligning the university's talent production with our forecasted demand, revealing potential misalignments. Feedback loops, incorporating insights from employers, alumni and current faculty, further refined our understanding and highlighted key areas for curriculum enhancement. These adjustments aim to better prepare graduates for the evolving demands of the healthcare sector. In addition to offering clear pathways for university curriculum enhancements and strengthening the bridge between academic preparation and professional success.

RESULTS

Trends in Yunnan province's population growth: 2006-2022

According to the population data published by the Yunnan Provincial Bureau of Statistics in previous years, this line graph delineates the population trend in Yunnan Province over a span of 12 years; from 2006 to 2022 (refer to [Figure 1](#) and [Table 1](#)). A consistent upward trajectory is observed, emphasizing the region's steady demographic growth over the specified period.

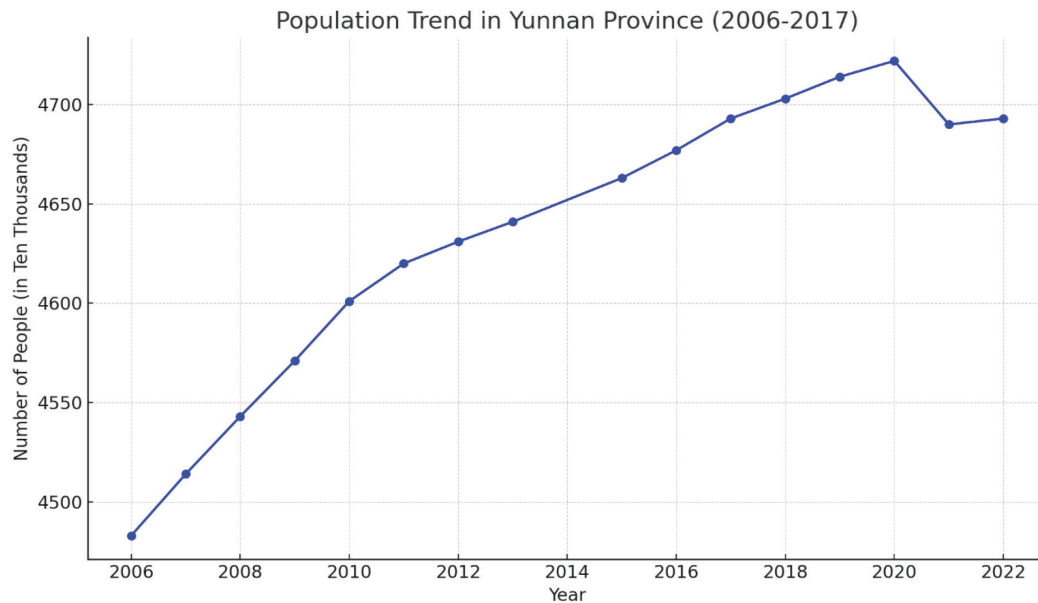


Figure 1 Population trend in Yunnan province from 2006 to 2022

Table 1 Population data in Yunnan province from 2006 to 2022

Year	Total population (thousand)
2006	44830
2007	45140
2008	45430
2009	45710
2010	46016
2011	46200
2012	46310
2013	46410
2014	46530
2015	46630
2016	46770
2017	46930
2018	47030
2019	47140
2020	47222
2021	46900
2022	46930

$X^{(0)} = (4483, 4514, 4543, 4571, 4601.6, 4620, 4631, 4641, 4653, 4663, 4677, 4693, 4703, 4714, 4722.2, 4690, 4693)$

We performed a cumulative sum on the original data $X^{(0)}$ to obtain:

$[X^{(1)} = (4483, 8997, \dots, 74119.8, 78812.8)]$

Next, we constructed the data matrix B and the data vector Y as follows:

$$Z^i = \frac{1}{2} (X^{(1)}(i) + X^{(1)}(i-1))$$

$$B = \begin{bmatrix} -Z(2) & 1 \\ -Z(3) & 1 \\ \dots & \dots \\ -Z(17) & 1 \end{bmatrix}$$

Projected population trends in Yunnan province

Step 1: Establishment of the Grey GM(1,1)

Model

We extract the population data of Yunnan Province from 2006 to 2022 as the original data sequence:

$$Y = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \dots \\ X^{(0)}(13) \\ X^{(0)}(14) \end{bmatrix}$$

Calculation

$$\tilde{u} = \begin{bmatrix} \tilde{a} \\ \tilde{b} \end{bmatrix} = (B^T B)^{-1} B^T Y$$

Model Establishment

$$\frac{dx^{(1)}}{dt} + \tilde{a}x^{(1)}(t) = \tilde{b}$$

Computation of Forecasted Sequence Values $\check{x}^{(1)}(k+1)$ and Model Restoration Values $\check{x}^{(0)}(k+1)$

Step 2: Model validation

Residual Analysis

The calculated forecasting error for this Grey GM(1,1) model is 0.003862251455202496, which is less than 0.01, indicating that the model exhibits high accuracy and is suitable for making predictions.

Step 3: Model prediction

Using the established model formula, we can predict the future (2023–2027) population total, obtaining forecasted values.

Forecasting clinical pharmacist enrollment trends in Yunnan's higher medical colleges

Based on publicly available enrollment plans from Kunming Medical University and Dali University as well as data obtained through contact and interviews, historical enrollment numbers and training plans for higher medical colleges within Yunnan Province were acquired. Similarly, as shown in Figure 2 and Table 2, a Grey GM(1,1) model was established to predict the trends in enrollment numbers for clinical pharmacist-oriented talent in higher medical colleges in Yunnan Province.

Estimation and prediction of clinical pharmacists in public hospitals in Yunnan province

Based on the number of pharmacy personnel (pharmacists) published by the Yunnan Provincial Health Commission for the years 2020 to 2022, an estimation was made for the number of clinical pharmacists. As shown in Figure 3 and Table 3, a Grey GM(1,1) model was established and applied to analyze the growth in the number of clinical pharmacists from the years 2020 to 2022.

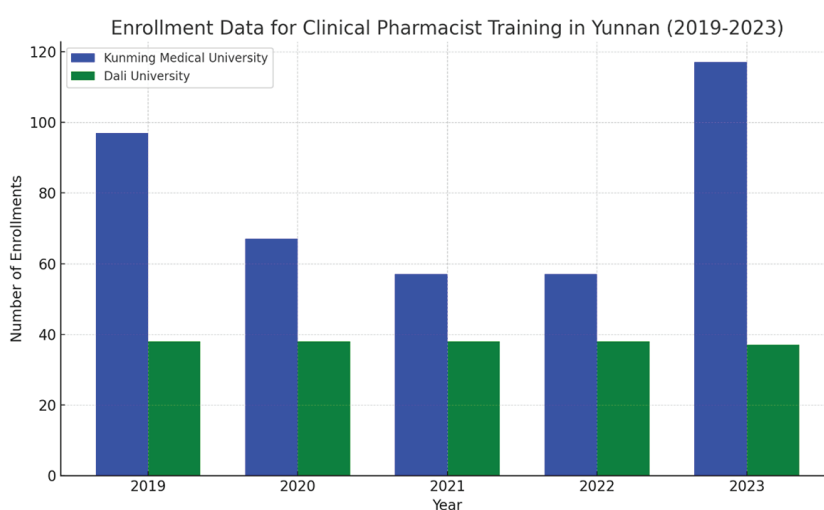


Figure 2 Enrollment data for the clinical pharmacist training plan in higher medical colleges in Yunnan province from 2019 to 2023

Table 2 Enrollment data for the training plan for clinical pharmacists in higher medical colleges in Yunnan province from 2019 to 2023

Year	Kunming Medical University planned enrollment (person)	Dali University planned enrollment (person)	Total (person)
2019	97	38	135
2020	67	38	105
2021	57	38	95
2022	57	38	95
2023	117	37	114

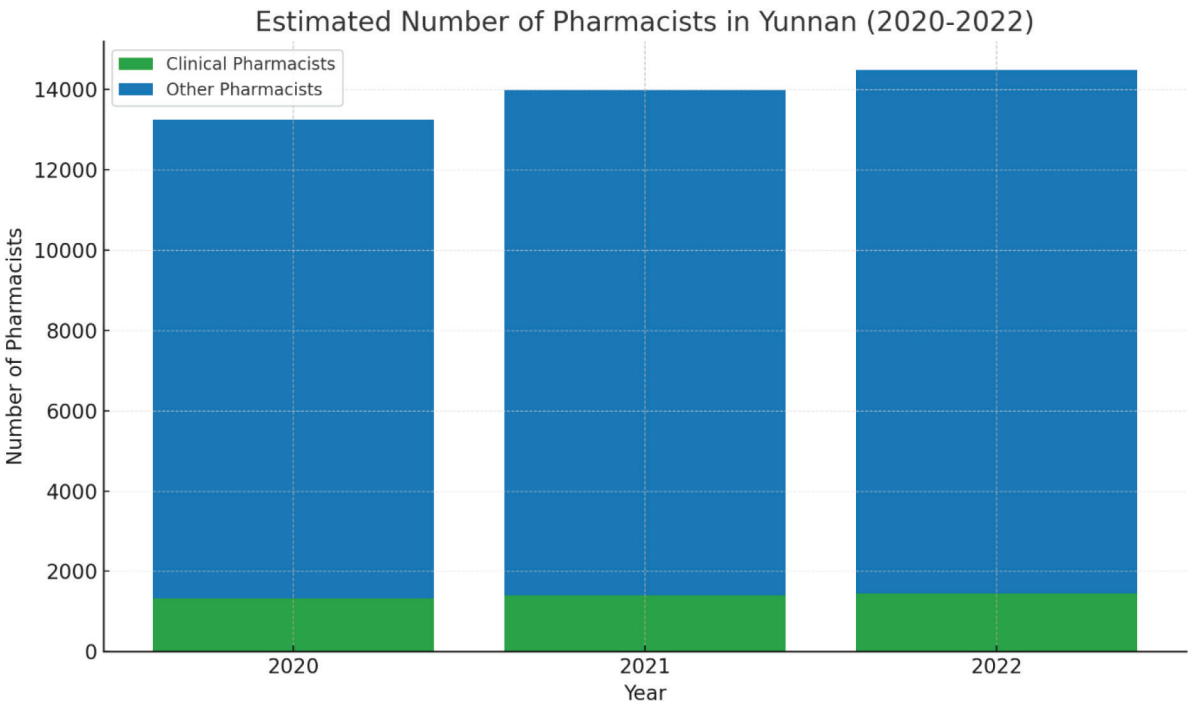


Figure 3 Estimated number of pharmacists in Yunnan province from 2020 to 2022

Table 3 Estimated data for the number of clinical pharmacists in Yunnan province from 2020 to 2022

Year	Number of pharmacists in Yunnan province	Estimated number of clinical pharmacists
2020	13,242	1,324
2021	13,987	1,399
2022	14,486	1,449

Forecasting clinical pharmacist demand from the perspective of Yunnan province's total population

As shown in Table 4, following the inherent growth patterns in Yunnan Province's population, it is projected that the population will reach 4.79,0.389 million by 2027. Additionally, with a slowing population growth trend, the aging of the population is also an essential factor to consider. The increasing demand for long-term medication among the elderly with chronic diseases will contribute to the rising demand for clinical pharmacists' medication guidance. Based on publicly available statistical data and surveys, the national ratio of clinical pharmacists to every ten thousand people is 2, significantly higher than the current ratio in Yunnan Province. Analyzing the forecasted data, it is estimated that by 2027, the minimum demand for pharmacists will be 3,000 individuals.

However, based on the current intrinsic growth patterns of clinical pharmacists, the forecasted results for 2023–2027 reveal that the natural growth in the number of clinical pharmacists will still not meet the demand for clinical pharmacy services from the total population of Yunnan Province by 2027. The shortfall in demand for clinical pharmacy-oriented personnel is expected to reach 1,250 individuals.

Forecasting the number of clinical pharmacists in Yunnan province from the perspective of the training plan for clinical pharmacists in higher medical colleges

As shown in Figure 4 and Table 5, the forecasted results indicate that; following the inherent patterns of the

training plan for clinical pharmacists in higher medical colleges within Yunnan Province, there will be relatively minor fluctuations in the enrollment of clinical pharmacy majors until 2028; with an increase of only 12 students compared to 2023. It is essential to consider that the undergraduate training for clinical pharmacy requires five years, whereas, population growth and the phenomenon of an aging population do not exhibit lag time, they are an existing social phenomena. Therefore, a more forward-looking approach is needed in the formulation of recruitment and training plans for clinical pharmacy-oriented talent.

Sensitivity and stability of the Grey GM(1,1) Model

To validate the robustness of our forecasting model, comprehensive sensitivity analyses were performed, introducing variances in key parameters; such as economic indices and educational metrics. The Grey GM(1,1) model exhibited exceptional stability and precision across various scenarios, confirming its effectiveness in predicting the demand for clinical pharmacists in Yunnan. This analysis demonstrated not only the model's resilience but also its reliability in adapting to diverse economic and educational dynamics. To enhance clarity and future application, we will outline a detailed study plan in subsequent publications, describing how we intend to test the model further and integrate additional data to refine our forecasts. This structured approach aims to provide Yunnan's policymakers, educators, and healthcare stakeholders with a robust tool for effective decision-making and strategic planning.

Table 4 Combined forecast of population data and clinical pharmacist demand in Yunnan province, 2023–2027

Year	Forecast for the next 5 years (thousand people)	Predicted number of clinical pharmacists (person)
2023	47,495.24	1,500
2024	47,619.42	1,554
2025	47,743.92	1,609
2026	47,868.74	1,666
2027	47,993.89	1,726

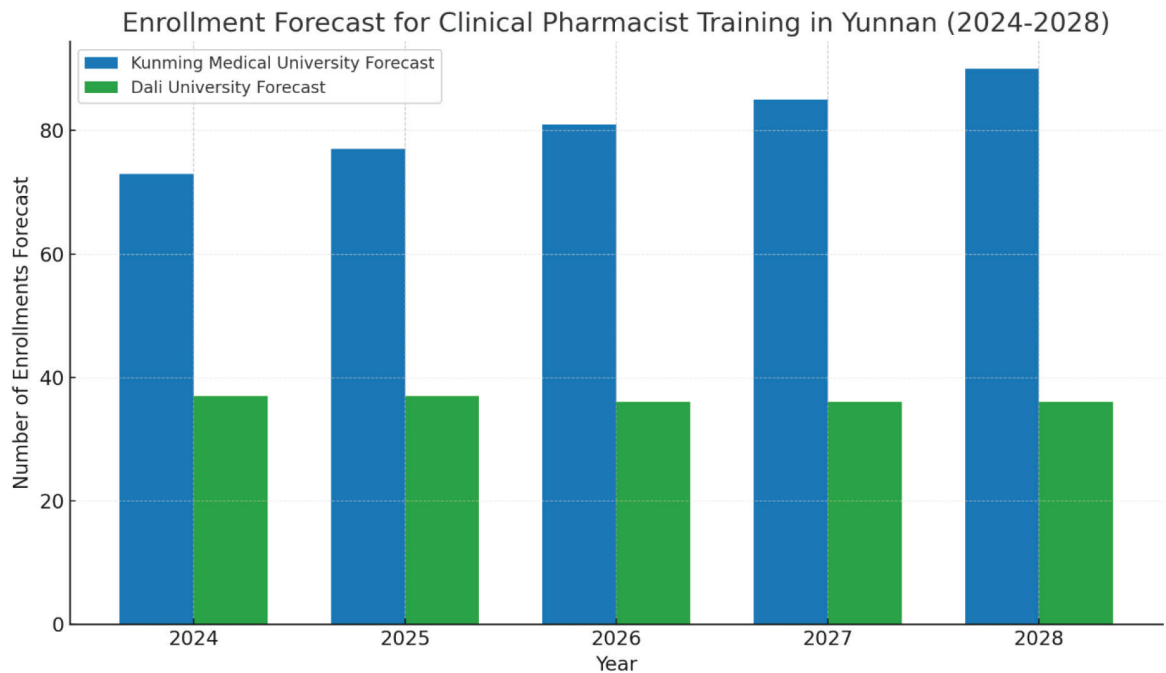


Figure 4 Enrollment forecast for the clinical pharmacist training plan in higher medical colleges in Yunnan province from 2024 to 2028

Table 5 Data forecast for the training plan for clinical pharmacists in higher medical colleges in Yunnan province from 2023 to 2027

Year	Kunming Medical University planned enrollment (person)	Dali University planned enrollment (person)	Total (person)
2024	73	37	110
2025	77	37	114
2026	81	36	117
2027	85	36	121
2028	90	36	126

Feedback-driven refinements at Kunming Medical University

In-depth analysis of feedback from employers and alumni has allowed us to assess the efficacy of Kunming Medical University's talent cultivation. Our findings highlight that:

1. Employers consistently praise graduates for their excellent competencies and readiness for their professional roles, indicating the university's alignment with the regional

healthcare demands.

2. Alumni testimonials reveal a positive employment landscape, with a significant number of graduates securing roles within Yunnan, reflecting the practical relevance and effectiveness of the education provided.

3. Graduates appreciate the university's practical and applied focus in clinical pharmacy education, validating the curriculum's design and its impact on their career preparedness.

These insights have prompted us to propose specific curriculum enhancements aimed at further aligning the university's programs with evolving healthcare needs. The feedback mechanism has proven essential in continuously refining educational strategies; thereby, ensuring that the training provided by Kunming Medical University remains cutting-edge and directly applicable to the healthcare sector in Yunnan.

DISCUSSION

Epidemic's influence on Yunnan's population dynamics

Since 2020, Yunnan Province has experienced a significant decrease in population growth, largely due to the COVID-19 pandemic's restrictions on mobility; as illustrated in [Figure 1](#). These restrictions hampered planned migrations and family reunions, directly affecting the natural population growth rate. Additionally, the economic impacts of the pandemic influenced decisions related to family planning⁸. However, with the establishment of herd immunity and effective epidemic control measures, a gradual rebound in the population is expected, driven by economic recovery. While our analysis primarily considers the effects of the epidemic and economic changes, it is important to note that the quality of healthcare and social welfare systems also significantly influence demographic trends, which could alter the accuracy of our forecasts⁹.

Strategic growth of clinical pharmacist roles in Yunnan

National strategies are actively shaping the development of clinical pharmacist systems to meet the growing demand for this expertise. According to the: "Yunnan Statistical Yearbook 2022," the healthcare sector is flourishing, with 20,022 registered pharmacists by the end of 2022, which translates to 4.24 pharmacists per ten thousand people¹⁰. The: "Healthy China 2030 Plan," sets ambitious goals for drug quality, aligning with international

standards and projecting the need for nearly 10,000 additional pharmacists in Yunnan by 2030¹¹. Beyond traditional roles, clinical pharmacists are increasingly crucial in enhancing medication-patient communication and promoting rational drug use; thereby, broadening their career opportunities¹². Forecasts from the Grey GM(1,1) model indicate a consistent annual increase in demand for these professionals, reflecting Yunnan's advancing healthcare services, economic growth and the challenges of an aging population.

Impact of aging population on clinical pharmacist demand in Yunnan

Yunnan's aging population combined with the increasing prevalence of chronic diseases are driving a significant rise in the demand for clinical pharmacists; particularly in areas of elderly care and chronic disease management. As China's demographic shifts towards an older age profile, healthcare models are increasingly leaning towards home-based services, facilitated by family doctors and home pharmacists; thus, amplifying the need for skilled clinical pharmacists¹³. This shift, along with technological advancements and the expansion of healthcare institutions, requires clinical pharmacists that possess not only extensive pharmaceutical knowledge but also strong communication skills and practical expertise. These professionals are becoming crucial in bridging the gap between medication management and patient care, ensuring the effective implementation of personalized healthcare services.

Redefining clinical pharmacy education in Yunnan

Yunnan faces considerable challenges in supplying sufficiently trained clinical pharmacists to meet the increasing demand. The region's clinical pharmacist training infrastructure struggles to keep up, hindered by limited resources and insufficient clinical training opportunities. Geographical factors further complicate the issue, driving talent towards larger metropolitan areas¹⁴. Currently, only

Kunming Medical University and Dali University offer clinical pharmacy programs; with a total annual capacity of approximately 120 students. This capacity is starkly inadequate compared to the projected demand for 3,000 clinical pharmacists by 2027, which reveals a deficit of 1,250 individuals. Even with an optimistic scenario, wherein enrollment increases by 100 students annually, the supply by 2027 would reach only 2,600: still short of meeting the anticipated demand¹⁵. This shortfall calls for a significant reevaluation and enhancement of the educational frameworks to align with the evolving healthcare landscape.

Developing a strategic framework for clinical pharmacist talent in Yunnan

To bridge the talent gap in Yunnan, a comprehensive, multi-faceted strategy is essential. Educational institutions, notably Kunming Medical University, must focus on enhancing clinical pharmacy education by expanding the curriculum, blending theoretical knowledge with practical application, and sharpening clinical skills¹⁶. Establishing partnerships with healthcare facilities can provide students with valuable, real-world clinical experiences; thereby, enhancing their practical competencies. Governmental support is also critical; increasing financial incentives, scholarships and creating targeted policies are key strategies to attract and retain pharmaceutical talent within the region. Furthermore, fostering inter-regional collaborations can bring external expertise to Yunnan's clinical pharmacy sector, enhancing the local talent pool and facilitating the exchange of knowledge¹⁷. Moreover, implementing a rigorous certification system and ongoing professional development initiatives are vital to raising the standards and adaptability of clinical pharmacists, ensuring they remain effective in dynamic healthcare environments¹⁸. This strategic approach aims to comprehensively address the current and future needs of the healthcare system in Yunnan.

Study limitations and prospective avenues

This research provides key insights into Yunnan's increasing demand for clinical pharmacists, but also faces limitations due to data integrity. Future research could broaden the forecasting timeframe to capture a wider scope of talent demand and delve into sub-regional disparities to distinguish urban versus rural needs. Further enhancements to our models could include: integrating variables; such as policy shifts and pharmaceutical innovations to refine prediction accuracy. Additionally, comparative studies with other regions or educational systems may uncover best practices and new avenues for improvement. These steps will help mitigate current limitations and expand the depth of subsequent analyses.

CONCLUSION

This study employed the Grey GM(1,1) model to highlight the increasing demand for clinical pharmacists in Yunnan, underscoring their critical role in the region's healthcare system. Despite growing demand, Yunnan faces significant challenges in meeting the supply of skilled pharmacists. Enhancing training programs at institutions; such as Kunming Medical University, and boosting partnerships with healthcare providers are crucial. To effectively address the talent shortage, it is essential to implement policy measures that provide academic incentives and financial support, aiming to cultivate a robust and skilled clinical pharmacist workforce.

Highlights: This paper employed the Grey GM(1,1) model as the primary research methodology, renowned for its accuracy in forecasting time series data; especially in cases with small sample sizes and nonlinear trends. Furthermore, data relevant to Yunnan Province, encompassing healthcare service demand and the employment status of clinical pharmacist talent, was collected to establish suitable models for predicting future demand trends.

Author's declaration

The study was conducted with a commitment to objectivity and impartiality.

Ethical approval

This study received ethical approval from the Institutional Review Board (IRB) of Kunming Medical University. The approval ensured that the research adhered to ethical standards and protected the rights and confidentiality of research participants.

Author contributions

Each author's contributions to this research are as follows: Yang Pengxiao: Literature Review, Editing, Visualization. Qin Dan: Conceptualization, Methodology, Data Analysis. Huang Lanjie: Data Collection, Writing – Original Draft. Yang Jian: Supervision, Funding Acquisition, Reviewing and Editing. All authors have read and approved the final manuscript.

ACKNOWLEDGEMENT

We express our sincere gratitude to all contributors of this research; especially the faculty of Kunming Medical University, for their invaluable insights. We also thank the employers, alumni, and graduates for their crucial feedback as well as the research participants and funding agencies whose support has been instrumental in advancing healthcare workforce research in Yunnan province.

FUNDING SOURCES

This work received financial support from several sources: [1] The Research Project on Education and Teaching of Kunming Medical University in 2023, bearing the Project Number 2023-JY-Y-090; [2] The project titled "Exploring the Establishment of a Model Modern Biomedical Industry College: A Study on Undergraduate Educational Reform in Yunnan Province", with the Project Number JG2023001; [3] The Kunming Medical University's 2021

initiative for online and offline mixed first-class course projects, under the Project Number 2021JXZ022. It is important to note that the funding bodies had no involvement in the design, data collection, analysis, interpretation of data or in the composition of the manuscript.

CONFLICT OF INTERES

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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