

Trends and Projections of Neonatal, Infant, and Under-Five Mortality in Rural Guangxi, China, 2000–2024

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Abstract

Background

China has made remarkable progress in reducing child mortality, yet substantial regional disparities persist, particularly in western and rural areas. This study aimed to analyse the long-term trends in neonatal mortality rate (NMR), infant mortality rate (IMR) and under-five mortality rate (U5MR) in rural Guangxi from 2000 to 2024 and to forecast these indicators up to 2030.

Methods

This ecological study used official NMR, IMR and U5MR data for rural Guangxi from 2000 to 2024. Joinpoint regression was applied to calculate annual percent change (APC) and average annual percent change (AAPC) and to identify trend joinpoints. Autoregressive integrated moving average (ARIMA) models were constructed to project mortality rates for 2025–2030.

Results

From 2000 to 2024, NMR, IMR and U5MR in rural Guangxi declined continuously, with AAPCs of -10.97% (95% CI: -11.47% to -10.33% , $P < 0.001$), -10.03% (95% CI: -10.65% to -9.61% , $P < 0.001$) and -9.04% (95% CI: -9.61% to -8.64% , $P < 0.001$), respectively. The ARIMA models projected that by 2030, NMR, IMR and U5MR will reach 0.90‰ , 1.13‰ and 1.80‰ , respectively.

Conclusions

Rural Guangxi achieved substantial reductions in child mortality between 2000 and 2024, but the decline has slowed markedly in recent years, suggesting a possible plateau. Future efforts should prioritise strengthening neonatal critical care networks and primary maternal and child health services in rural areas.

Introduction

Child mortality is a core indicator of public health development and social equity in a country or region, and it is a key component of Target 3.2 of the United Nations Sustainable Development Goals (SDGs) [1]. In alignment with these goals, China has set more ambitious targets in the Healthy China 2030 blueprint and the Program for the Development of Chinese Children (2021–2030), aiming to reduce NMR, IMR and U5MR to below 3.0‰ , 5.0‰ and 6.0‰ , respectively, by 2030, while progressively narrowing regional and urban-rural gaps [2, 3].

Over the past three decades, China has achieved remarkable success in reducing child mortality. Nationwide, NMR, IMR and U5MR fell from 33.1‰ , 50.2‰ and 61.0‰ in 1991 to 2.8‰ , 4.5‰ and 6.2‰ in 2023—a reduction of more than 80% for each indicator [4]. Although the urban-rural disparity has continued to narrow, rural areas still have significantly higher rates than urban areas [5], highlighting that rural regions remain a critical gap in child health improvement.

Most existing studies have focused on national or economically developed eastern and central regions, with relatively few long-term trend analyses for less-developed western rural areas [6, 7]. Moreover, many studies describe overall trends without thoroughly examining phase-specific characteristics within western rural areas [8]. The quantitative

relationship between major maternal and child health policies and phased changes in child mortality has not been fully evaluated [5].

Guangxi Zhuang Autonomous Region, located in southwestern China, is a less-developed region with a large ethnic minority population, extensive karst terrain, a high proportion of rural residents, and relatively weak primary maternal and child health services [9]. In 2024, Guangxi had a resident population of 50.13 million, of whom 42.61% lived in rural areas [10]. To improve child health, the government has continuously implemented a series of major policies, such as the “Reducing Maternal Mortality and Eliminating Neonatal Tetanus” programme and the rural maternity hospital delivery subsidy policy [11, 12]. However, the long-term effects and phase-specific characteristics of these policies on reducing rural child mortality have not been systematically quantified using long-term data.

This study collected NMR, IMR and U5MR data for rural Guangxi from 2000 to 2024, analysed long-term trends and phase-specific characteristics, and projected trends for 2025–2030, aiming to inform the dynamic optimisation and formulation of child health policies in western rural areas.

Methods

Data sources

The Guangxi Health Yearbook is an official annual publication that summarizes health service resources, public health activities, and population health indicators in Guangxi [13]. The NMR, IMR and U5MR data for rural Guangxi from 2000 to 2024 used in this study were all obtained from the Guangxi Health Yearbook (2002–2025), officially published annually by the Health Commission of Guangxi Zhuang Autonomous Region. The maternal and child health data in the yearbook are collected through the National Maternal and Child Health Surveillance System (MCHSS) of China. The coverage sample size is determined by the design of the surveillance system, and no separate sample size estimation is conducted. This surveillance system employs stratified cluster random sampling to select surveillance sites and implements rigorous reporting and quality control procedures [7]. The MCHSS covers all 31 provinces, autonomous regions and municipalities directly under the Central Government of China, with data simultaneously stratified into urban and rural groups: urban areas comprise districts of municipalities directly under the Central Government and districts of prefecture-level cities, whereas rural areas include counties and county-level cities.

All data used in this study are publicly available aggregated statistics without personal identifiers; therefore, our analysis did not require additional ethical approval or informed consent.

Definitions

The three indicators follow the definitions of the World Health Organization [14]:

NMR

number of deaths of neonates (within the first 28 completed days of life) per 1000 live births.

IMR

number of deaths of infants (under 1 year of age) per 1000 live births.

U5MR

number of deaths of children under 5 years of age per 1000 live births.

In accordance with the Chinese MCHSS protocol, a live birth is defined as the complete expulsion or extraction from the mother of a product of conception of 28 weeks or more of gestation, which, after separation, shows any sign of life (heartbeat, breathing, umbilical cord pulsation, or definite movement of voluntary muscles). If gestational age is uncertain, a birth weight of ≥ 1000 g may be used as a reference.

Statistical analysis

Joinpoint regression was performed using Joinpoint version 6.0.1 [15] to analyse trends in NMR, IMR and U5MR in rural Guangxi from 2000 to 2024. A log-linear model was used, with the optimal number and locations of joinpoints determined through weighted Bayesian information criterion. The primary output indicators included the annual percent change (APC), average annual percent change (AAPC), joinpoint locations, and 95% confidence intervals (CIs) [16]. The APC reflects the trend within each time segment, whereas the AAPC represents the weighted average rate of change over the entire study period. An APC greater than 0 indicates an increasing trend in mortality within the corresponding segment, a value less than 0 indicates a decreasing trend, and a value equal to 0 indicates a stable trend. The t-test was employed to assess the statistical significance of the trends, with $P < 0.05$ considered statistically significant.

ARIMA modelling was conducted using R version 4.3.0 [17] for time series analysis and forecasting. The ARIMA(p, d, q) model comprises three parameters: p (autoregressive order), d (differencing order) and q (moving average order). To address heteroscedasticity as mortality rates decreased, we applied a Box-Cox transformation to the original mortality time series, with the optimal λ parameter automatically determined by the Guerrero method, to stabilise variance [18]. Model selection was based on the Bayesian Information Criterion (BIC) using the auto.arima function, allowing the inclusion of a drift term to capture long-term trends. We used data from 2000–2018 as the training set and 2019–2024 as the validation set to evaluate predictive performance. We also performed rolling forecasting with an initial training window of 2000–2005, advancing one year at a time, to further assess model stability. Finally, we refitted the optimal model using the full 2000–2024 dataset to generate forecasts for 2025–2030. Predicted values and their 95% CIs were truncated at zero to ensure biological plausibility.

Results

Descriptive analysis of NMR, IMR and U5MR in rural Guangxi

From 2000 to 2024, NMR, IMR and U5MR in rural Guangxi fell from 22.58‰, 31.39‰ and 37.08‰ to 1.35‰, 2.34‰ and 3.52‰, respectively, representing reductions of 94.02%, 92.55% and 90.51% (see Fig. 1).

Joinpoint regression results

Over the entire study period, the three mortality indicators showed sustained downward trends, with AAPCs of -10.97% (95% CI: -11.47% to -10.33% , $P < 0.001$) for NMR, -10.03% (95% CI: -10.65% to -9.61% , $P < 0.001$) for IMR, and -9.04% (95% CI: -9.61% to -8.64% , $P < 0.001$) for U5MR. For NMR, the Joinpoint regression identified four joinpoints at 2007 (95% CI: 2002–2008), 2011 (95% CI: 2009–2012), 2014 (95% CI: 2013–2016) and 2019 (95% CI: 2017–2022), dividing the study period into five segments. The most rapid decline occurred during 2007–2011 (APC = -17.79% , 95% CI: -23.14% to -12.10% , $P < 0.001$), while the APCs during 2011–2014 and 2019–2024 did not reach statistical significance. For IMR and U5MR, one joinpoint was identified at 2020 for each. IMR declined significantly during 2000–2020 (APC = -11.23% , 95% CI: -11.97% to -10.79% , $P < 0.001$), but the decline during 2020–2024 was not statistically significant (APC = -3.81% , 95% CI: -8.79% to 6.15% , $P = 0.256$). Similarly, U5MR declined significantly during 2000–2020

(APC = − 10.19%, 95% CI: −10.85% to − 9.79%, $P < 0.001$), with the 2020–2024 segment not reaching statistical significance (APC = − 3.08%, 95% CI: −7.73% to 6.38%, $P = 0.315$). Detailed results are presented in Table 1.

Table 1
Joinpoint regression results for NMR, IMR and U5MR in rural Guangxi, 2000–2024

Indicators	Years	APC (%)	95% CI	P value	AAPC (%)	95% CI	P value
NMR	2000–2007	-11.66	(-13.51, -6.80)	< 0.05	-10.97	(-11.47, -10.33)	< 0.001
	2007–2011	-17.79	(-23.14, -12.10)	< 0.05			
	2011–2014	-3.02	(-14.62, 1.82)	> 0.05			
	2014–2019	-14.49	(-20.32, -11.17)	< 0.05			
	2019–2024	-5.13	(-8.59, 3.77)	> 0.05			
IMR	2000–2020	-11.23	(-11.97, -10.79)	< 0.05	-10.03	(-10.65, -9.61)	< 0.001
	2020–2024	-3.81	(-8.79, 6.15)	> 0.05			
U5MR	2000–2020	-10.19	(-10.85, -9.79)	< 0.05	-9.04	(-9.61, -8.64)	< 0.001
	2020–2024	-3.08	(-7.73, 6.38)	> 0.05			

ARIMA model fitting

After variance stabilization using the Box-Cox transformation and automatic model selection based on the Bayesian Information Criterion (BIC), the optimal fitting models for NMR, IMR and U5MR in rural Guangxi were all ARIMA(0,1,0) with drift. All models achieved a coefficient of determination (R^2) exceeding 0.99, indicating a good fit. The mean absolute percentage error (MAPE) ranged from 6.37% to 6.92%, all below 10%, and the root mean square error (RMSE) was less than 1‰ for all models. The Ljung-Box test yielded P-values greater than 0.05 for all models, confirming that the residual series conformed to the white noise assumption and indicating that the models had adequately extracted the underlying information. Detailed fitting metrics are presented in Table 2. Residual analysis of the three models revealed that the residuals were randomly distributed, with no discernible trends or heteroscedasticity. The autocorrelation function (ACF) and partial autocorrelation function (PACF) plots showed no significant autocorrelation in the residuals. The quantile-quantile (Q-Q) plots indicated that the residuals were approximately normally distributed (see Figures S1–S3 in the Supplementary Materials).

Table 2
ARIMA model fitting results for NMR, IMR and U5MR in rural Guangxi, 2000–2024

Indicators	λ	ARIMA	AIC	BIC	R^2	RMSE (‰)	MAPE (%)	Ljung-Box Q	P value	White noise test
NMR	-0.379	(0,1,0) with drift	-70.419	-68.063	0.991	0.593	6.917	4.405	0.883	Passed
IMR	0.065	(0,1,0) with drift	-42.946	-40.590	0.991	0.840	6.371	13.144	0.156	Passed
U5MR	0.087	(0,1,0) with drift	-42.465	-40.109	0.994	0.813	6.550	15.401	0.081	Passed

Prediction results of the ARIMA models

The out-of-sample fixed-split validation results showed that the MAE values for rural Guangxi NMR, IMR and U5MR were 0.324‰, 0.526‰, and 0.775‰, respectively, and the RMSE were 0.391‰, 0.619‰, and 0.865‰, respectively. The absolute errors for all three indicators were at relatively low levels, indicating that the models possessed good short-term predictive capability for unobserved data (see Table S1 in the Supplementary Materials).

The rolling time series cross-validation results showed that the average MAE values for rural Guangxi NMR, IMR and U5MR were 0.621‰, 0.790‰, and 0.810‰, respectively, and the average RMSE were 1.228‰, 1.212‰, and 1.090‰, respectively. The predictive performance of the models remained relatively stable across different periods from 2005 to 2023 (see Table S2 in the Supplementary Materials).

Based on the ARIMA model results, NMR, IMR and U5MR in rural Guangxi are projected to exhibit a continued declining trend from 2025 to 2030, although the rate of decline will gradually decelerate. By 2030, NMR, IMR and U5MR in rural Guangxi are projected to decline to 0.90‰, 1.13‰, and 1.80‰, respectively (see Fig. 2 and Table 3).

Table 3
Forecasted NMR, IMR and U5MR in rural Guangxi, 2025–2030 (‰, with 95% CI)

Indicators	2025	2026	2027	2028	2029	2030	2030 planning target	Projected trend by 2030
NMR	1.26 (1.13, 1.41)	1.17 (1.01, 1.38)	1.10 (0.92, 1.33)	1.03 (0.84, 1.27)	0.96 (0.77, 1.22)	0.90 (0.72, 1.17)	≤ 3.0	decline
IMR	2.08 (1.75, 2.47)	1.85 (1.44, 2.36)	1.64 (1.20, 2.21)	1.45 (1.01, 2.06)	1.28 (0.85, 1.91)	1.13 (0.72, 1.75)	≤ 5.0	decline
U5MR	3.16 (2.67, 3.72)	2.83 (2.22, 3.57)	2.53 (1.88, 3.38)	2.26 (1.59, 3.16)	2.01 (1.36, 2.95)	1.80 (1.16, 2.73)	≤ 6.0	decline

Note: NMR, neonatal mortality rate; IMR, infant mortality rate; U5MR, under-five mortality rate. CI, confidence interval. The planning targets are sourced from the Program for the Development of Chinese Children (2021–2030).

Discussion

This study found that NMR, IMR and U5MR in rural Guangxi all declined substantially from 2000 to 2024, with reductions exceeding 90% for all three indicators. By 2024, all three indicators had already achieved the targets set by the Program for the Development of Chinese Children (2021–2030) ahead of schedule. Compared with the national level, the AAPCs for the three indicators in rural Guangxi were – 10.97%, – 10.03%, and – 9.04%, respectively, all representing steeper declines than the national rural averages of – 7.7%, – 7.5%, and – 7.0% [5], exhibiting a distinct "catch-up" decline pattern. The substantial decline in child mortality rates in rural Guangxi resulted from the synergistic effects of multiple factors, including socioeconomic development, maternal and child health policy interventions, and improvements in healthcare service capacity [7, 19]. As a key supported province in western China, Guangxi received priority allocation in central government transfer payments, enabling the rapid concentration of resources to improve rural maternal and child health. The joinpoints identified by Joinpoint regression were temporally highly concordant with major maternal and child health policy adjustments in Guangxi, suggesting that policy interventions may have played a key role in driving the phased changes in child mortality rates.

During 2000–2007, all three indicators declined rapidly. In 1998, Guangxi initiated the “Maternal and Child Safety Project” and, in 2004, launched the “Reducing Maternal Mortality and Eliminating Neonatal Tetanus” programme, which facilitated access to hospital delivery services for rural and impoverished pregnant women and contributed to reducing child mortality [11, 20]. After the 2003 SARS outbreak, the government increased investment in maternal and child health and strengthened the national surveillance system [21]. In 2004, the national “Neonatal Resuscitation Programme” was launched to reduce neonatal asphyxia-related deaths [22]. The convergence of these policies likely contributed to the rapid decline.

The NMR in rural Guangxi exhibited the most rapid decline during 2007–2011, with IMR and U5MR also decreasing sharply during the same period, which may be attributable to the comprehensive implementation of multiple maternal and child health programs. Although the fastest declining segment for IMR and U5MR spanned the broader 2000–2020 period, the 2007–2011 interval represented a particularly intensive phase of decline shared by all three indicators, coinciding with the concentrated rollout of major maternal and child health policies. In 2007, the third cycle of the “Guangxi Maternal and Child Safety Project” was launched, covering all counties across the region [20]. In 2009, the rural hospital delivery subsidy program for pregnant women was fully implemented, which alleviated the financial burden on rural pregnant women and improved the utilisation efficiency of maternal and child health service resources [12]. Also in 2009, the Program to Reduce Maternal Mortality and Eliminate Neonatal Tetanus achieved full coverage across all 111 counties in Guangxi; through the establishment of clinical training bases and the implementation of a county-stationed expert guidance model, the service capacity of grassroots obstetric and neonatal care was enhanced [23]. Furthermore, the National Essential Public Health Services Program was initiated in 2009, contributing to further reductions in rural child mortality through comprehensive interventions encompassing neonatal health management and folic acid supplementation for pregnant women [24]. The cumulative impact of multiple concurrent policies may have accelerated the decline in child mortality during this period.

The slowdown in NMR decline during 2011–2014, during which the APC did not reach statistical significance, may reflect a policy transition period. By 2012, the neonatal visit rate (the proportion of newborns receiving at least one postnatal visit) in Guangxi had reached 98.62% and the rural hospital delivery rate had reached 99.73% [25], indicating that basic service coverage was approaching saturation. In 2012, Hechi City in Guangxi passed the WHO on-site validation for elimination of neonatal tetanus on behalf of China [26], signifying that basic public health indicators for newborn health had reached international standards. However, this also meant that further reductions in child mortality would require a shift from basic coverage to quality improvement, which had not yet been fully established, possibly causing a temporary plateau.

The NMR decline re-accelerated during 2014–2019. During this period, Guangxi pioneered the “24 exemptions and 4 subsidies” maternal and child health benefit policy [27], creating a full-life-cycle service chain covering premarital check-ups, prenatal screening, newborn screening and child nutrition improvement, thereby further reducing child mortality in rural areas. In 2015, China adjusted its fertility policy, leading to an increase in the proportion of older and high-risk pregnant women [28], which increased demand for reproductive health services and prompted the government to optimise service resource allocation [29, 30], indirectly improving the accessibility and quality of neonatal care.

After 2019, the declining trend of NMR in rural Guangxi decelerated markedly, with the APC during 2019–2024 not reaching statistical significance. Similarly, IMR and U5MR entered a phase of slowed decline after 2020, with neither APC achieving statistical significance during 2020–2024 ($P = 0.256$ and $P = 0.315$, respectively). These patterns suggest that child mortality rates in rural Guangxi may have reached a plateau. This trend may be associated with the substantial reduction in avoidable child deaths and the consequent shift in the leading causes of child mortality toward more intractable conditions, such as complications of extreme prematurity and severe congenital anomalies [31, 32]. Concurrently, issues including the incomplete critical neonatal transport network [33], insufficient standardised

construction of county-level neonatal intensive care units (NICUs) [34], and inadequate primary healthcare resources [8, 35] may further compound the difficulty of reducing rural child mortality.

The "catch-up" decline in child mortality rates in rural Guangxi indicates that the phased implementation of health policies and continuous interventions have led to sustained improvements in regional child health equity. However, the overall improvement in indicators does not imply that complete health equity has been achieved within the region; structural inequalities in healthcare service quality and neonatal care capacity still persist among counties, which is consistent with the developmental pattern of maternal and child health nationwide [4].

This study employed the ARIMA model to forecast child mortality rates through 2030. To address the potential issue of negative predictions by the ARIMA model under extremely low mortality scenarios, this study adopted Box-Cox transformation, rigorous model training and validation, and post-prediction value correction to ensure the validity of the forecasts. The results indicated that all three child mortality rates in rural Guangxi will continue to decline from 2025 to 2030, although the rate of decline will further decelerate across all indicators. Previous studies have projected that by 2030, the national rural NMR, IMR and U5MR will decline to 0.64‰, 1.65‰, and 1.72‰, respectively [4]. The IMR and U5MR in rural Guangxi are already approaching or outperforming the national projected values, whereas the NMR still lags behind. Therefore, future efforts to reduce rural child mortality should prioritize neonatal care. It is noteworthy that as NMR, IMR and U5MR decline to low levels, the marginal difficulty of achieving further reductions increases. This phenomenon has been widely observed in countries such as Japan and Scotland, where child mortality rates have long remained at low levels [36, 37].

To further reduce rural NMR, IMR and U5MR, we recommend the following: (1) prioritise key difficult areas such as preterm/low birth weight, severe birth defects and neonatal critical care, and improve referral networks for critically ill children [32]; (2) increase investment in rural health resources and continue to expand the delivery of high-quality maternal and child services to primary levels; (3) given the internal regional disparities within rural Guangxi, regularly assess trends and differences in child health indicators at the county level and formulate targeted policies.

Limitations

This study has several limitations. First, the Joinpoint regression model is a trend analysis method rather than a causal inference tool; the correspondence between joinpoints and policies represents temporal association rather than causal inference, and further research is needed to explore the causal relationships between these joinpoints and various policies. Second, the long-term predictive reliability of the ARIMA model is limited, and it is necessary to dynamically update the model annually by incorporating new data. Third, the data used in this study were derived from a routine surveillance system. Information bias may arise from inaccurate classification of causes of death due to limited diagnostic capacity, and under-registration bias may occur in rural areas, particularly in remote mountainous regions, due to underreporting; these factors may have affected the study results. Furthermore, this study focused on the aggregate level of rural Guangxi without distinguishing internal differences among counties, border areas and ethnic minority concentrated areas, which may have masked health inequalities within the region. This represents an important direction for future research.

Conclusions

Between 2000 and 2024, rural Guangxi achieved remarkable reductions in NMR, IMR and U5MR, likely linked to the effective implementation of national and local maternal and child health policies. However, the mortality decline appears to be entering a plateau phase, with neonatal mortality remaining a key challenge. Future efforts should strengthen neonatal critical care systems and primary maternal and child health capacity building. Regular assessment of child health indicator trends is essential to promptly identify anomalies and adjust strategies and interventions.

Declarations

Ethics approval and consent to participate

This study was granted an exemption by the institutional review board, as it relied solely on publicly accessible data that did not include any confidential or personally identifiable patient information.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

CHL designed the study, performed data analysis and result interpretation, and drafted the manuscript. LCL and LYL contributed to data collection and analysis. JZ critically revised the manuscript. All authors read and approved the final manuscript.

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Data Availability

The data that support the findings of this study were obtained from the printed volumes of the Guangxi Health Yearbook (formerly Guangxi Health Statistics Yearbook) series (2002–2025 editions) held in the collection of the Guangxi Zhuang Autonomous Region Library (Nanning, China). The Yearbook is an official statistical compendium published annually by the Health Commission of Guangxi Zhuang Autonomous Region and its predecessor agencies; the inaugural 2002 edition retrospectively compiled statistics for 2000 and 2001. As these are printed publications without an online repository, accession numbers or direct web links are not applicable. Restrictions apply to the availability of the raw data, which were used under licence for the current study; de-identified, study-specific datasets are available from the corresponding author upon reasonable request.

References

1. World Health Organization. Targets of Sustainable Development Goal 3 [Internet]. [cited 2025 Aug 3]. Available from:<https://www.who.int/europe/about-us/our-work/sustainable-development-goals/targets-of-sustainable-development-goal-3>
2. State Council of the People's Republic of China. The Program for the Development of Chinese Women and the Program for the Development of Chinese Children (2021–2030) [Internet]. 2021 Sep 27 [cited 2025 Aug 3]. Available from:https://www.gov.cn/zhengce/content/2021-09/27/content_5639412.htm
3. Central Committee of the Communist Party of China, State Council of the People's Republic of China. The Healthy China 2030 Planning Outline [Internet]. 2016 Oct 25 [cited 2025 Aug 3]. Available from:https://www.gov.cn/gongbao/content/2016/content_5133024.htm
4. Rao Z, Liu B, Li D, et al. Reducing urban-rural disparities in maternal and child mortality in China: a 33-year analysis and projection to 2030. *J Glob Health*. 2026;16:04011.
5. Wang XY, Zhang BB, Cao YY, et al. Trends in maternal and child health in China and its urban and rural areas from 1991 to 2020: a joinpoint regression model. *Sci Rep*. 2024;14(1):13480.
6. Lv JM, Chen N, He XN, et al. Trends in under-five mortality rate in China, 1996–2020: a Joinpoint regression and correlation analysis. *BMJ Open*. 2024;14(9):e077461.
7. He C, Kang L, Liu Y, et al. Changes in the epidemiology of under-5 mortality in China from 2016 to 2022: an observational analysis of population-based surveillance data. *Lancet Public Health*. 2024;9(12):e1059–69.
8. Yu X, Wang Y, Kang L, et al. Geographical disparities in infant mortality in the rural areas of China: a descriptive study, 2010–2018. *BMC Pediatr*. 2022;22(1):264.
9. Tang Z, Hang R, Wang S, Liu J, Shi W. Evaluation and dynamic evolution of maternal and child health services in township health centers in ethnic minority areas of Guangxi, China. *Prim Health Care Res Dev*. 2025;26:e64.
10. Guangxi Bureau of Statistics. Guangxi Statistical Yearbook 2025 [Internet]. [cited 2025 Aug 3]. Available from:<http://tjj.gxzf.gov.cn/tjsj/tjnj/material/tjnj20200415/2025/indexch.htm>
11. Chen P, Li M, Zhu J, et al. Provincial-level outcomes of China's 'Reducing maternal mortality and eliminating neonatal tetanus' program. *Sci Rep*. 2020;10(1):13328.
12. Gao Y, Zhou H, Singh NS, et al. Progress and challenges in maternal health in western China: a Countdown to 2015 national case study. *Lancet Glob Health*. 2017;5(5):e523–36.
13. Guangxi Zhuang Autonomous Region Health Commission. Guangxi Health Yearbook 2025. Zhengzhou: Zhongzhou Ancient Books Publishing House; 2025.
14. World Health Organization. Under-five mortality rate [Internet]. [cited 2025 Aug 3]. Available from:<https://www.who.int/data/nutrition/nlis/info/under-five-mortality-rate>
15. National Cancer Institute. Joinpoint Trend Analysis Software [Internet]. [cited 2025 Aug 3]. Available from:<https://surveillance.cancer.gov/joinpoint/>
16. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med*. 2000;19(3):335–51.
17. Wagner B, Cleland K. Using autoregressive integrated moving average models for time series analysis of observational data. *BMJ*. 2023;383:p2739.
18. Petropoulos F, Apiletti D, Assimakopoulos V, et al. Forecasting: theory and practice. *Int J Forecast*. 2022;38(3):705–871.
19. Qiao J, Wang Y, Li X, Jiang F, Zhang Y, Ma J, Song Y, Ma J, Fu W, Pang R, et al. A Lancet Commission on 70 years of women's reproductive, maternal, newborn, child, and adolescent health in China. *Lancet*. 2021;397(10293):2497–536.

20. Li J, Chen LL, Chen SZ, Zhao NQ, Qin YM, Qian X. Evaluation of the implementation effect of the Guangxi Maternal and Child Safety Project using the TOPSIS method [in Chinese]. *Chin Health Resour.* 2007;(5):238–40.
21. Wang J, Wu H. Health shocks and unbalanced growth of medical resources: evidence from the SARS epidemic in China. *Int J Health Serv.* 2022;52(1):47–60.
22. Wang C, Yue Q, Xu T. Reducing neonatal mortality with a three-stage neonatal resuscitation training programme - China, 2004–2021. *China CDC Wkly.* 2022;4(36):807–10.
23. Yu H, Qin XX, Chen LL, Chen SZ, Duan ZB. Analysis of the effect of the obstetric expert extended-stay model in the Reducing Maternal Mortality and Eliminating Neonatal Tetanus project in Guangxi in 2012 [in Chinese]. *Chin J Women Child Health.* 2013;4(5):29–32.
24. State Council of the People's Republic of China. Notice of the State Council on issuing the recent key implementation plan for the reform of the medical and health system (2009–2011) (Guofa [2009] No. 12) [Internet]. 2009 Apr 6 [cited 2025 Aug 3]. Available from: https://www.gov.cn/gongbao/content/2009/content_1284376.htm
25. Guangxi Zhuang Autonomous Region Health Commission. Briefing on the development of health services in Guangxi, 2012 [in Chinese] [Internet]. [cited 2025 Aug 3]. Available from: https://wsjkw.gxzf.gov.cn/z tq_49630/sszt/jxkp/t5630697.shtml
26. Fan Z, Guan H, Luo S, et al. Validation on the elimination of neonatal tetanus programs through Lot Quality Assurance-Cluster Sample Survey in China [in Chinese]. *Zhonghua Liu Xing Bing Xue Za Zhi.* 2014;35(2):163–6.
27. Guangxi Zhuang Autonomous Region People's Government. The 14th Five-Year Plan for Health Development of Guangxi [Internet]. [cited 2025 Aug 3]. Available from: http://www.gxzf.gov.cn/html/zfgb/2022nzfgb/d16q_zfgb2022_142895/zzqrmzfwj20201231/t13109467.shtml
28. Li HT, Xue M, Hellerstein S, et al. Association of China's universal two child policy with changes in births and birth related health factors: national, descriptive comparative study. *BMJ.* 2019;366:l4680.
29. Zeng Y, Hesketh T. The effects of China's universal two-child policy. *Lancet.* 2016;388(10054):1930–8.
30. National Health and Family Planning Commission of the People's Republic of China. Notice on effectively strengthening medical care services and clinical management for pregnant women of advanced maternal age [Internet]. 2016 Apr 5 [cited 2025 Aug 3]. Available from: <https://www.nhc.gov.cn/fys/c100078/201604/bbcc4f128b8d4da999b6f0a20b9b959c.shtml>
31. Liu Y, Kang L, Zou Y, et al. Urban-rural disparity in preterm neonatal mortality in China: a retrospective study. *BMC Pediatr.* 2025;25(1):793.
32. Liu Y, Kang L, He C, et al. Neonatal mortality and leading causes of deaths: a descriptive study in China, 2014–2018. *BMJ Open.* 2021;11(2):e042654.
33. Subspecialty Group of Neonatology, Society of Pediatrics, Chinese Medical Association. Editorial Board, Chinese Journal of Contemporary Pediatrics. Guideline for the diagnosis and treatment of common neonatal diseases in primary healthcare institutions: neonatal transport (2025) [in Chinese]. *Chin J Contemp Pediatr.* 2025;27(7):759–69.
34. Peng JR, Huang T, Li QP, et al. Investigation of the status of 95 critical newborn treatment centers [in Chinese]. *J Dev Med (Electron Ed).* 2024;12(2):102–7.
35. Peng R, Zhong XL, He LB, et al. Research on the status quo of infrastructure, equipment, and human resources allocation in Guangxi primary medical and health institutions in 2022 [in Chinese]. *Intern Med.* 2023;18(4):309–15.
36. Liang FW, Chou CS, Chen HL, Jeng MJ, Chou HC, Chiang MC, Lien R, Chang HY, Peng CC, Lu TH. Trends in neonatal mortality on the first day of life in Japan, Korea, and Taiwan. *BMC Public Health.* 2025;25(1):3325.
37. Harpur A, Minton J, Ramsay J, McCartney G, Fenton L, Campbell H, Wood R. Trends in infant mortality and stillbirth rates in Scotland by socio-economic position, 2000–2018: a longitudinal ecological study. *BMC Public Health.* 2021;21(1):995.

Figures

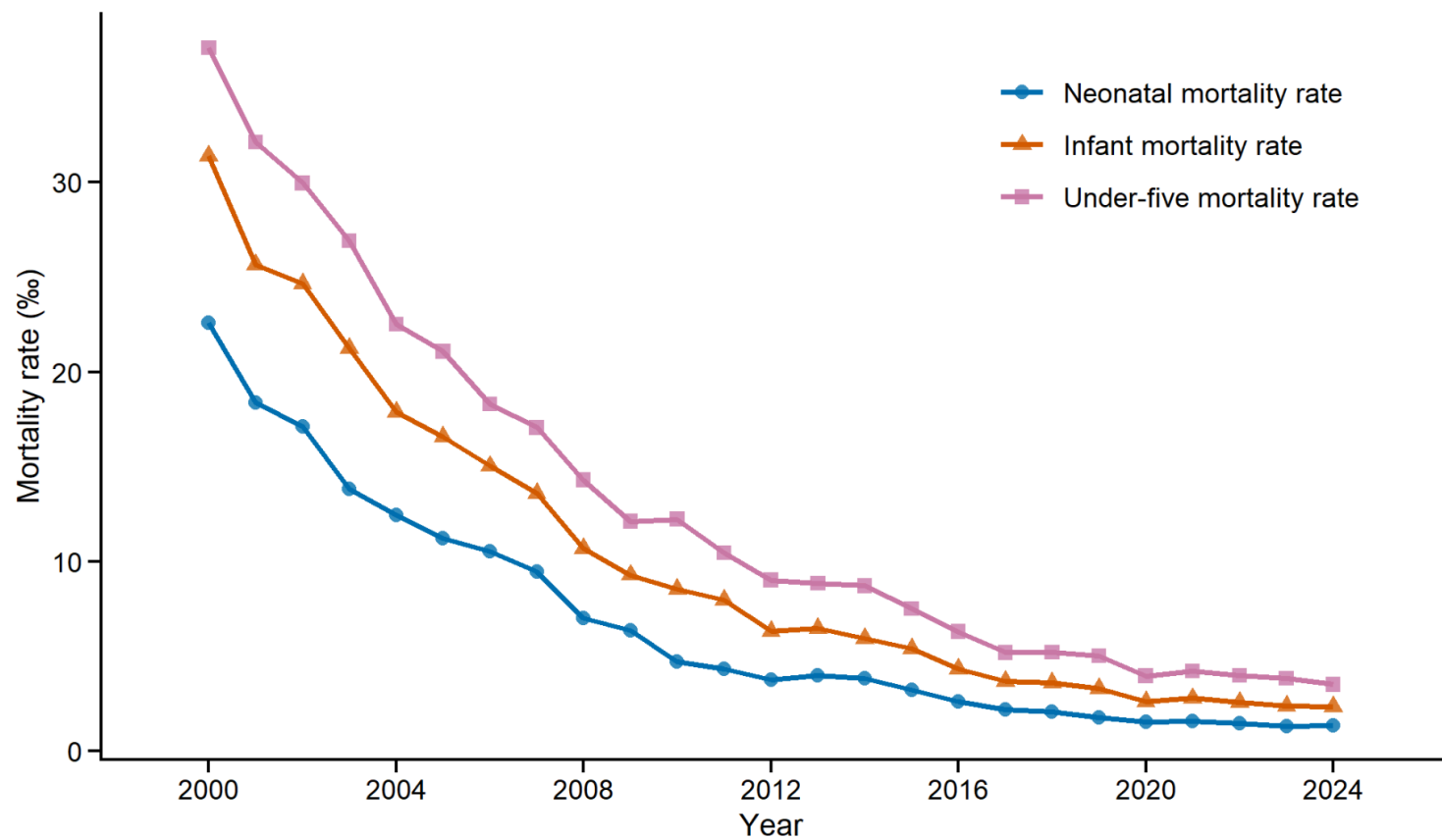


Figure 1

Trends in NMR, IMR and U5MR in rural Guangxi, 2000–2024.

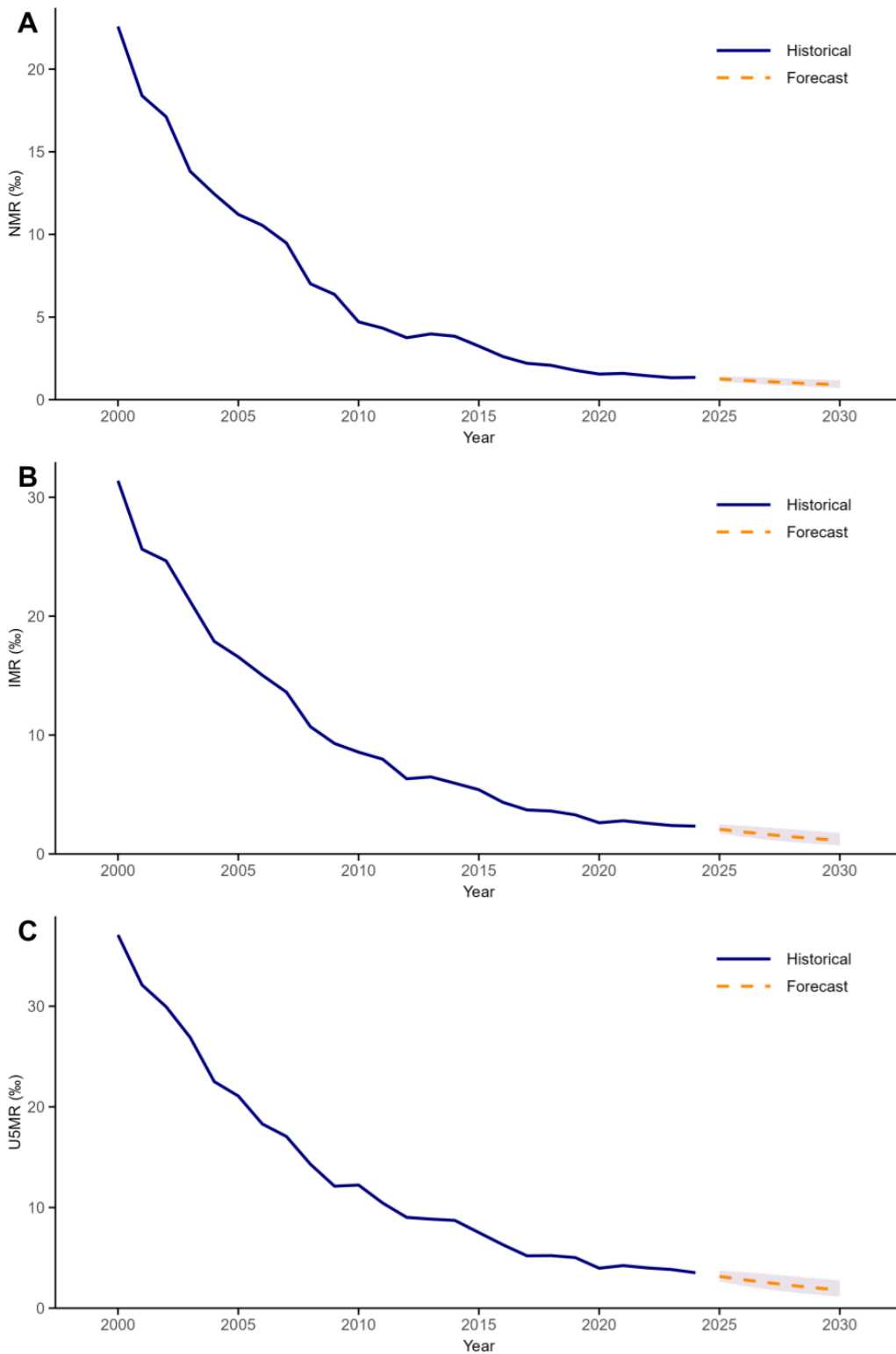


Figure 2

Projected trends in NMR, IMR and U5MR in rural Guangxi, 2025–2030. Panels A, B and C correspond to NMR, IMR and U5MR, respectively.

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