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Complete List of Authors:	Huang, Yuan; Kunming Medical University, School of Public Health Xiao, Xia; Kunming Medical University Wan, Ying; Yunnan Maternal and Child Health Care Hospital Ye, Qingyun; Kunming Medical University Yang, Zhongting; Kunming Medical University Xu, Lingling; Kunming Medical University Chen, Shuqi ; Kunming Medical University Li, Huifang ; Kunming Medical University Wang, Fangfang ; Kunming Medical University Chen, Yurong ; Kunming Medical University Zhao, Dandan ; Kunming Medical University Zhang, Qian ; Yunnan Maternal and Child Health Care Hospital Zheng, Jiarui; Yunnan Maternal and Child Health Care Hospital Guo, Guangping ; Yunnan Maternal and Child Health Care Hospital Li, Yan; Kunming Medical University
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Tracking progress towards equitable maternal and child health in Yunnan: a systematic assessment for the Health Programme for Poverty Alleviation in China during 2015-2020

Yuan Huang Ph.D.[a], Xia Xiao Ph.D.[a], Ying Wan B.Sc.[b], Qingyun Ye M.Sc.[a], Zhongting Yang M.Sc.[a], Lingling Xu M.Sc.[a], Shuqi Chen M.Sc.[a], Huifang Li M.Sc.[a], Fangfang Wang M.Sc.[a], Yurong Chen M.Sc.[a], Dandan Zhao M.Sc.[a], Qian Zhang B.Sc.[b], Jiarui Zheng M.Sc.[b], Guangping Guo B.M.[b]*, Yan Li Ph.D.[a]*

a.Kunming Medical University, Kunming, Yunnan Province, 650500 China

b.Yunnan Maternal and Child Health Care Hospital, Kunming, Yunnan Province, 650051 China

*Correspondence to Yan Li (email: yanli20021965@21cn.com) and Guangping Guo (email: guoguangping68@126.com).

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The reason why this manuscript is over 4000 words: It is a systematic assessment to measure the changes in disparities in maternal and child health system inputs, outputs, outcomes, and impacts across Yunnan, China, between 2015 and 2020, to inform the effect of health programmes on preventing women and children from being trapped in or returning to poverty because of illness.

Key points

What is not yet known about this subject?

How did health programmes help break the vicious cycle of poverty and illness among vulnerable populations?

What does this study add?

This systematic assessment in Yunnan, the main battlefield against poverty in China, indicated that remarkable progress in equitable maternal and child health outcome and health care financing has achieved by strengthening health system and implementing universal coverage with firm commitment, determined leadership, detailed blueprint, and social participation.

How might this impact on practice?

Health programme is an essential component of great success in poverty alleviation in China, which might provide a new reference for other countries and regions.

Abstract

Objective We present a systematic assessment in Yunnan, the main battlefield against poverty in China, to inform the impacts of health programmes which aimed at preventing women and children from being trapped in or returning to poverty because of illness.

Methods National and Yunnan policy documents related to maternal and child health programmes for poverty alleviation during 2015-2020 were analysed. The changes in disparities in maternal and child health system inputs, service coverage, and health outcomes between poor and non-poor areas, as well as out-of-pocket payments between poor and non-poor populations were assessed by using the longitudinal comparative evaluation design and difference-in-difference technique before and after 2017.

Findings In total 12 policies and 15 programmes related to poverty alleviation for poor women and children in Yunnan were summarised. As a result of health system strengthening in Yunnan, the densities of licenced doctors, nurses, obstetricians, midwives, township health workers, and female village doctors had been increased substantially in poor areas. Although disparities existed in some of service coverage between poor and non-poor areas, the health programmes had narrowed the gaps in utilisation of facility birth, caesarean section, prenatal screening, and newborn screening across Yunnan. The out-of-pocket payments for inpatient care for serious illnesses among women and children with poverty registration had been considerably decreased to 10.0%. Paralleling the universal coverage, maternal deaths per 100,000 livebirths and child deaths per 1,000 livebirths had further declined in both poor and non-poor areas, and the impacts of health programmes on closing the gaps in child survivals across Yunnan were significant.

Conclusion Remarkable progress in equitable maternal and child survival has been achieved in Yunnan. The practices in Yunnan have showed the Chinese model in ending poverty by strengthening health system and implementing universal coverage

with firm commitment, determined leadership, detailed blueprint, and social participation.

Keywords

Maternal and child survival; Health equity; Poverty alleviation; Health Programme; Western China

Introduction

Maternal and child health (MCH) affects economic growth and social development globally. Reducing maternal and child mortality is continually featured in the United Nations post-2015 Sustainable Development Goals (SDGs) and requires global supports.[1] China has made impressive progress in maternal and child survivals in recent decades. Between 1990 and 2015, maternal mortality rate fell from 89 to 22 deaths per 100,000 livebirths and same decrease trend was seen in under-5 mortality rate, falling from 54 to 11 deaths per 1000 livebirths in China.[2,3] However, disparities remained in western China where the maternal and child survivals were lagging behind in 2015, typically in rural and remote areas of Yunnan Province which is economically deprived and overwhelmingly concentrated by ethnic minorities.[4] Due to poor nutrition, little health knowledge, and lack of access to proper sanitation and healthcare services, poor and remote pregnant women and children were vulnerable populations at high risk of severe illness and death, which was the tough challenge facing in China.[4,5] Particularly, both of maternal mortality rate and under-5 mortality rate were twice as high for ethnic minorities than for their Han counterparts in western China according to a meta-analysis published in 2017.[6] Except for economic and educational disadvantages, traditional beliefs, mountainous topography, and poor quality of care were important barriers to seeking MCH care.[7] Maternal and child deaths not only decreased household income but also took a substantial share of national labour productivity loss.[8] Moreover, the treatment cost of disease or long-term complication might trap women and their families in poverty especially when large out-of-pocket expenditures were paid.[9]

To break the vicious cycle of poverty and illness, the China's Government has introduced the Health Programme for Poverty Alleviation Strategy which is an important measure to win the battle against poverty by targeting the poor and remote population precisely and reducing the heath disparities across regions and population groups[10]. In response to this, efforts have been made to ensure that the poor seldom fall ill, but can access and afford healthcare services when falling ill, as they can expect help from national public services, severe illness insurance, and government funds

which will cover the remaining cost after the relevant reimbursements to protect these people's right to health and prevent them from being trapped in or returning to poverty because of illness.[11,12] Promising to leave no one behind, as the main battlefield against extreme poverty in China, the Yunnan has launched the Thirty Health Actions for Poverty Alleviation in 2017 which includes a series of MCH programmes under Targeted Poverty Alleviation Strategy (hereinafter referred to as MCH-PA programmes) to address the specific challenges when seeking MCH healthcare services, reduce deaths of pregnant women, newborns and children under 5 years old, and avoid catastrophic health expenditures happened to those remote women and children as well as the ethnic minorities in poor rural Yunnan.[13] The MCH-PA programmes which include specific interventions in poor rural areas from strengthening emergency obstetric and newborn care to preventing birth defects, improving child nutrition, supplementing folic acid, breast and cervical cancer screening as well as affordable medical services, also echo the goal of guaranteeing the Healthy China 2030 and Healthy Yunnan 2030 Initiatives and the Strategy of Rural Revitalisation to achieve moderate prosperity in all respects after ending absolute poverty.[13]

We present a systematic assessment in Yunnan to inform the impacts of the MCH-PA programmes which aimed at preventing women and children from being trapped in or returning to poverty because of illness, moreover improving maternal and child heath equity across Yunnan. This article discussed the lessons learnt with regard to health-related poverty alleviation in Yunnan which may provide special reference to those still remaining impoverished by illness. These improvements may not only benefit Yunnan and people living there, but also serve as excellent demonstrations to other places and populations on how things can change, for the better.

Methods

Study Setting

Yunnan Province of China, a mountain and plateau region on the country's southwestern frontier, covers an area of 394,100 square kilometres with altitudes

varying from the mountain peaks to river valleys by as much as 6,000 metres. The total population of Yunnan was 47.2 million in 2020, which includes 11.3 million women of childbearing age (23.9%) and 3.1 million children under 5 years old (6.6%).[14] Yunnan is noted for a very high level of ethnic diversity and owns the highest number of ethnic groups and autonomous regions in China, accounting for 33.1% of its total population.[14] As one of the least developed provinces in China, more than 8.8 million rural residents in Yunnan were living in poverty in 2012, based on national poverty line 2,300 CNY (about 364.5 USD) per capita net income of rural residents.[15] Some of the most entrenched poverty in Yunnan was found in regions inhabited by 11 smaller ethnic groups who practiced relatively primitive ways of life.[15] In 2014, the China's Government released a list of 832 impoverished counties according to poverty headcount ratio. Yunnan had 88 such counties including 8,502 impoverished villages when the list was released, more than any other provinces of China.[16] After 6-year efforts under China's Targeted Poverty Alleviation Strategy, as the main battlefield in China's war against poverty, Yunnan announced that all 88 counties designated by the government as poverty-stricken (accumulatively 7.6 million population including 2.3 million women of childbearing age and 0.3 million children under 5 years old) have shrugged off absolute poverty and all of its impoverished rural residents have been lifted above the current poverty line by December, 2020.[17]

Overview of Study Designs

We applied the World Health Organization Health System Building Blocks as the evaluation framework which assesses the improved MCH outcomes through an analysis of MCH systems inputs, MCH services coverage and quality, and geographic disparity (see appendix figure 1).[4,18,19] We started by reviewing the National and Yunnan provincial policy documents since 2015 to summarise the key MCH programmes for poverty alleviation in Yunnan. The timeline of MCH-PA programmes disaggregated into 4 aspects by health system inputs was drawn by an iterative process during a series of workshops with a multidisciplinary team of maternal health and health systems experts. As the Yunnan intensively launched MCH-PA programmes in 2017 and aimed

at reaching women and children in poor rural areas, we described the variations in MCH system inputs, services coverage, and health outcomes between 88 poor rural counties and 41 non-poor rural counties/urban districts before (in 2015) and after (in 2020) MCH-PA programmes. The changes from 2015 to 2020 were calculated for areas with and without MCH-PA programmes. The ratios of poor to non-poor were used to show the differences between areas in 2015 and 2020. In order to assess the impact of MCH-PA programmes more precisely, the township-level data were adopted to estimate the changes in those MCH indicators brought about by MCH-PA programmes in poor areas after 2017, compared to non-poor areas. A total of 912 rural townships from 88 impoverished counties of Yunnan were categorised into the group "poor areas with MCH-PA programmes"; the remaining 295 rural townships and 109 urban streets from 41 non-poor counties/districts as well as 102 urban streets from impoverished counties were clustered into the group "non-poor areas without MCH-PA programmes" (506 rural townships/urban streets in total) (see appendix figure 2). The effects of MCH-PA programmes on out-of-pocket payments were assessed at individual level, between populations with and without poverty registration.

Data Sources

First, we extracted data on MCH outcomes (the number of live births, maternal deaths, neonatal deaths, infant deaths, under-5 deaths, birth defects, low-weight births, underweight children, stunted children, wasted children, overweight children, obese children, anaemic children, and anaemic pregnant women) and MCH services (the number of high-risk pregnancies, antenatal visits, prenatal screening, facility deliveries, caesarean sections, postnatal visits, newborn visits, and newborn diseases screening) between 2015 and 2020 at both county- and township-level, and data on MCH system inputs (the number of obstetricians, midwives, and facilities providing delivery services or caesarean sections) between 2017 and 2020 at county-level from Yunnan Maternal and Child Health Routine Reporting System. This system reports the annual number of MCH outcomes and service coverage for all 129 rural counties/urban districts including 1418 rural townships/urban streets of Yunnan and data are reliable because rigorous

quality control mechanisms including data quality audit process and standardisation of data collection were introduced from 1997 onward. But data on MCH system inputs were added from 2017 onward. Second, data on the number of licenced doctors, licenced nurses, public MCH programme personnel at township-level, female village doctors, and hospital beds for all health facilities and the number of beds in the Department of Gynaecology & Obstetrics and in the Department of Neonatology & Paediatrics in 129 rural counties/urban districts across Yunnan between 2015 and 2020 were extracted from Yunnan Health Statistical Yearbooks. Third, we obtained county-level data on total resident population, per capita gross domestic product (GDP), per capita disposable income of rural residents, and land area between 2015 and 2020 from Yunnan Statistical Yearbooks. The density of MCH health resources per 1,000 population or per 1,000 livebirths were calculated. Fourth, the individual data on total medical expenditures and out-of-pocket payments for the treatment of breast cancer and cervical cancer among women, and the treatment of congenital heart disease and pneumonia among children under 5 years old across Yunnan were extracted from Yunnan Social Medical Insurance Reimbursement Datasets. Medical expenditures of both outpatient care and inpatient care were collected. Finally, policy data related to MCH-PA programmes were provided by Office for Poverty Alleviation People's Government of Yunnan Province, Office for Women and Children Health Commission of Yunnan Province, and Yunnan Provincial Maternal and Child Health Care Hospital.

Statistical Analysis

We adapted the longitudinal comparative evaluation design and the difference-in-difference (DID) technique to assess the changes in disparities in MCH system inputs, service coverage, and health outcomes between poor and non-poor areas at township-level, and out-of-pocket payments between poor and non-poor populations before and after MCH-PA programmes.[20] We constructed two dummy variables $Treat_i$ and $Time_t$. If i is a poor area/person with MCH-PA programmes, the value of $Treat_i$ is 1 (the treatment group); opposite, the value of $Treat_i$ is 0, if i is a non-poor

area/person without MCH-PA programmes (the control group). $Time_t$ is a time dummy variable and it is assigned 1 after the implementation of MCH-PA programmes (2018-2020), 0 before the MCH-PA programmes (2015-2017). Based on the DID technique, the theoretical model to estimate the treatment effects comparing the pre- and post-treatment differences in the outcome of a treatment and a control group can be expressed as:

$$\text{Treatment Effect} = E\left(\Delta Y_i^1 \middle| Treat_i = 1\right) - E\left(\Delta Y_i^0 \middle| Treat_i = 0\right) \quad (1)$$

E is the mathematical expectation in the equation. Y_i^1 is the observations if i area/person participated MCH-PA programmes. Y_i^0 represents the area/person which did not participate in MCH-PA programmes. ΔY_i shows the difference before and after MCH-PA programmes implementation. To estimate the impact of MCH-PA programmes, the equation (1) could be designed as follow:

$$Y_{it} = \alpha + \beta Treat_i + \gamma Time_t + \delta Treat_i Time_t + \varepsilon_{it} \quad (2)$$

Then the coefficient of interaction δ in equation (2) measures the effects of MCH-PA programmes:

$$E\left(\Delta Y_i^1 - \Delta Y_i^0\right) = [(\alpha + \beta + \gamma + \delta) - (\alpha + \beta)] - [(\alpha + \gamma) - \alpha]$$

$$= (\gamma + \delta) - \gamma = \delta \quad (3)$$

So we used the following multivariate linear regression model to examine if MCH-PA programmes contributed to the changes in MCH indicators:

$$Y_{it} = \alpha + \beta Treat_i + \gamma Time_t + \delta Treat_i Time_t + \theta X_{it} + \varepsilon_{it} \quad (4)$$

Y_{it} is any of MCH indicators and data normalization will be adopted when necessary. $Treat_i$ is poor area dummy indicating poor rural townships where the MCH-PA programmes has implemented. $Time_t$ is time dummy indicating years after the implementation of MCH-PA programmes. X_{it} indicates the confounding variables including per capita GDP, the number of live births, or the density of maternal health personnel. α indicates intercept. ε_{it} is residual. In order to avoid heteroscedasticity and serial correlation of residual, we clustered residual to the county-level. All estimates were reported with 95% confidence intervals (CIs) where relevant.

Statistically significant change was defined as change for which the 95% CIs did not overlap zero. All analyses were done with STATA version 15.0.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

In total of 69 policy documents related to the national and provincial MCH-PA programmes had been reviewed. Finally, 6 national policies and another 6 policies and 15 MCH-PA programmes of Yunnan were list in Figure 1. The Chinese government has maintained a strong focus on maternal and child health through a series of national general and specific Plans of Actions for Women and Children. The Guidance on the Implementation of Health Programme for Poverty Alleviation provided a complete legal and policy framework for breaking the vicious cycle of poverty and illness among vulnerable populations, such as poor pregnant women and children, which echoed the Healthy China 2030 initiative. As shown, Yunnan provincial policies and plans of actions were made under the national guidance which specified clear targets and tasks. The Yunnan Thirty Health Actions for Poverty Alleviation and Yunnan Actions for Wining Tough Battle against Poverty which were formulated in 2017 and 2019 respectively, emphasised the main objectives to ensure that the maternal mortality rate and infant mortality rate in Yunnan are respectively lower than 20 per 10 thousand livebirths and 10 per thousand livebirths by the end of 2020. Specific strategies in 4 aspects of financing, infrastructure building/drugs/equipment/medical suppliers, services provision, and health human resources have been designed and realised through the implementations of a series of MCH-PA programmes.

A total amount of 1.3 billion CNY (about 201.8 million USD) was transferred from central and provincial governments to the specific MCH-PA programmes in Yunnan from 2017 to 2019. The government's expenses on social basic medical insurance

reimbursements for ill women and children were not included into the number mentioned above. Otherwise, another 449.1 million CNY (about 69.5 million USD) was especially invested in infrastructure building for MCH system strengthening in poor rural areas in Yunnan. A total of 128 Emergency Obstetric Care Centres and 112 Emergency Newborn Care Centres have been built until 2020, which nearly covered all the poor counties of Yunnan. For further improving level of and equity in maternal and child survivals in Yunnan, besides the regular free MCH services such as antenatal and postnatal care, the free services including pre-pregnancy checkup, prenatal screening, newborn diseases screening, child nutrition package, folic acid supplement, breast and cervical cancer screening, and female common disease screening had been provided which had expanded MCH health service coverage to woman and child in poor rural areas. Birth companion and waiting room services in the Department of Obstetrics had been available for pregnant women at high-risk in remote and poor areas since 2013. Meanwhile, counterpart assistance programmes and special training had been conducted. Specialists from Shanghai, Guangzhou, and Fujian (the most developed provinces from the Eastern China) and 9 tertiary hospitals of Yunnan were assigned to the poor counties or townships and had worked in the Department of Obstetrics or the Department of Pediatrics there for two years. The capacity building series training had been given to obstetricians and other medical staff at primary level. Otherwise, a three-tiered financial protection strategy has been made to ensure that medical services would be affordable (out-of-pocket payments at 10%) with basic medical insurance, serious illness insurance, and medical financial assistance schemes among the Households with Poverty Registration. For some extremely poor households, out-of-pocket health expenditure was completely covered by the governmental financial protection strategy.

Poor areas where the MCH-PA programmes have been implemented are home to the half of total population in Yunnan. But population densities in most poor areas were much lower than those in non-poor areas. Between 2015 and 2020, there was a sign that people moved from poor areas to non-poor areas. Although disparities persisted between areas, the per capita GDP and per capita disposable income of rural residents

in poor areas had increased at the annual rates of 19.8% and 11.5% respectively, which exceeded those in non-poor areas (14.9% and 11.4%). The decrease trend was seen in the number of live births across Yunnan, but which was not statistically significant (Table 1).

As a result of capacity strengthening of MCH system in Yunnan, health workforce and facilities had been growing steadily in poor areas. Not only the numbers of licensed doctors (from 1.1 to 1.9) and nurses (from 1.1 to 2.6) per 1,000 population, but also the numbers of obstetricians (from 10.1 to 15.7) and midwives (from 10.9 to 21.6) per 1,000 livebirths had been increased substantially in poor areas, with the annual rates of 14.3%, 22.5%, 21.8%, and 23.9% separately. Moreover, the numbers of township MCH workers and female village doctors in poor areas had been increased largely, who participated in MCH programme implementation and service provision at primary-level (the township- and village-levels). Disparities existed in most indicators of MCH human resources between poor and non-poor areas, but the gap in the density of obstetricians per 1,000 livebirths had become smaller (from 0.83 to 0.76) in 2020. Oppositely, the gaps in densities of township MCH workers and female village doctors per 1,000 livebirths had grown larger between areas at the same time period and there were more health staff working for MCH at both township- (P=0.04) and village-levels (P=0.05) in poor areas, compared to those in non-poor areas. Meanwhile, the percentages of township MCH workers with bachelor degree (3.7% vs 3.6%) and female village doctors with high school degree (2.7% vs 1.5%) had grown faster in poor areas than non-poor areas. Besides, the densities of hospital beds in the Department of Gynaecology & Obstetrics and the Department of Neonatology & Paediatrics per 1,000 livebirths and the densities of facilities providing delivery services and caesarean sections per 1,000 livebirths had increased in poor areas, with the annual rates of 10.2%, 18.5%, 10.9%, and 8.6%. (Table 1).

Table 1 Socio-economic Characteristics and Health System Inputs of Areas with and without MCH-PA programmes at County-level in Yunnan, China

	Poor areas with MCH-PA programmes			Non-poor areas without MCH-PA programmes			Ratio of poor to non-poor, 2015	Ratio of poor to non-poor, 2020
	2015	2020	Annual rate of change	2015	2020	Annual rate of change		
Socio-economic Characteristics								
Population (10 thousand)	30.8 (3.8 to 138.4)	27.3 (3.8 to 135)	-1.0% (-4.3 to 2.4)	33.2 (10.5 to 39.5)	40.5 (10.2 to 160.3)	2.1% (-2.3 to 6.5)	**0.93 (0.16)**	**0.67 (<0.01)**
Population per square kilometre	103.4 (8.8 to 550.7)	94.4 (7.5 to 414.5)	-1.8% (-4.9 to 1.2)	224.4 (68.0 to 2531.2)	202.6 (45.6 to 3293.3)	6.3% (-6.5 to 19.1)	0.46 (<0.01)	0.47 (<0.01)
Number of ethnic autonomous regions	25 (28.4%)	25 (28.4%)	--	5 (12.2%)	5 (12.2%)	--	--	--
Per capita GDP (CNY, 10 thousand)*	1.8 (0.7 to 5.6)	3.8 (1.6 to 8.7)	**19.8% (17.3 to 22.3)**	3.8 (1.8 to 12.2)	6.8 (3.8 to 15.2)	**14.9% (10.4 to 19.5)**	0.47 (<0.01)	0.56 (<0.01)
Per capita disposable income of rural residents (CNY, 10 thousand)*	0.8 (0.5 to 1.2)	1.2 (0.8 to 1.8)	**11.5% (10.6 to 12.5)**	1.1 (0.6 to 1.6)	1.7 (1.3 to 2.4)	**11.4% (9.8 to 13.1)**	0.73 (<0.01)	0.71 (<0.01)
Number of live births	3180 (391 to 22605)	2703 (418 to 20056)	-2.6% (-6.8 to 1.6)	2878 (1133 to 7918)	2864 (1003 to 13287)	2.7% (-3.2 to 8.7)	1.10 (0.17)	0.94 (0.90)
Health System Inputs								
Number of licensed doctors	289 (42 to 1513)	524 (75 to 2899)	**13.5% (8.4 to 18.7)**	612 (143 to 5900)	945 (253 to 8098)	9.2 (-1.0 to 19.3)	0.47 (<0.01)	0.55 (<0.01)
Density of licensed doctors per 1,000 population	1.1 (0.4-3.0)	1.9 (0.9 to 6.0)	**14.3% (11.7 to 16.8)**	1.9 (1.0 to 7.1)	2.8 (1.3 to 8.4)	**6.7% (2.1 to 11.3)**	0.58 (<0.01)	0.68 (<0.01)
Number of licensed nurses	322 (67 to 2343)	676 (81 to 4580)	**22.4% (15.5 to 29.4)**	653 (188 to 7775)	1242 (362 to 10834)	**13.7% (2.3 to 25.2)**	0.49 (<0.01)	0.54 (<0.01)
Density of licensed nurses per 1,000 population	1.1 (0.2 to 4.7)	2.6 (1.3 to 8.5)	**22.5% (19.1 to 25.8)**	2.1 (0.5 to 8.9)	3.7 (1.5 to 11.3)	**11.0% (5.5 to 16.6)**	0.52 (<0.01)	0.70 (<0.01)
Number of hospital beds	1017 (176 to 5286)	1574 (184 to 9073)	**10.2% (5.1 to 15.4)**	1754 (548 to 12480)	2167 (647 to 14374)	5.2% (-3.2 to 13.6)	0.58 (<0.01)	0.73 (<0.01)
Density of hospital beds per 1,000 population	3.5 (1.5 to 9.7)	5.8 (3.4 to 17.0)	**10.7% (8.7 to 12.8)**	5.8 (1.4 to 16.0)	7.2 (1.2 to 14.8)	2.5% (-1.2 to 6.2)	0.60 (<0.01)	0.81 (0.01)
Number of hospital beds in G&O	112 (22 to 463)	170 (25 to 810)	**8.3% (4.5 to 12.2)**	168 (34 to 825)	227 (42 to 1021)	1.8% (-4.7 to 8.2)	0.67 (<0.01)	0.75 (0.02)
Density of hospital beds in G&O per 1,000 livebirths	36.5 (10.6 to 84.7)	55.7 (23.0 to 139.8)	**10.2% (7.7 to 12.8)**	66.2 (4.6 to 297.8)	67.2 (12.9 to 184.7)	-1.1% (-4.6 to 2.5)	0.55 (<0.01)	0.83 (0.03)
Number of hospital beds in N&P	55 (0 to 371)	99 (4 to 580)	**14.4% (9.1 to 19.7)**	88 (17 to 1303)	136 (18 to 1687)	7.2% (-4.1 to 18.6)	0.63 (<0.01)	0.73 (<0.03)
Density of hospital beds in N&P per 1,000 livebirths	17.0 (0 to 55.7)	34.1 (6.6 to 125.8)	**18.5% (14.8 to 22.3)**	31.5 (8.8 to 244.5)	48.8 (10.3 to 248.1)	3.7% (-2.1 to 9.6)	0.54 (<0.01)	0.70 (<0.01)

Number of obstetricians**	38 (5 to 153)	43 (5 to 187)	**7.4% (0.2 to 14.5)**	50 (12 to 257)	55 (15 to 242)	3.1% (-8.0 to 14.2)	0.76 (<0.01)	0.78 (<0.01)
Density of obstetricians per 1,000 livebirths**	10.1 (1.7 to 24.5)	15.7 (3.3 to 53.2)	**21.8% (15.3 to 28.3)**	12.1 (3.4 to 23.6)	20.6 (4.7 to 35.2)	**19.3% (12.1 to 26.5)**	0.83 (<0.01)	0.76 (0.02)
Number of midwives**	42 (3 to 230)	52 (2 to 331)	8.3% (0.1 to 16.6)	69 (10 to 330)	78 (18 to 372)	4.2% (-7.0 to 15.3)	0.61 (<0.01)	0.67 (0.02)
Density of midwives per 1,000 livebirths**	10.9 (1.2 to 41.9)	21.6 (1.0 to 55.0)	**23.9% (15.8 to 32.0)**	15.7 (3.8 to 43.5)	27.7 (5.3 to 75.3)	**20.6% (11.1 to 30.1)**	0.69 (0.02)	0.78 (0.01)
Number of facilities providing delivery services**	13 (2 to 36)	14 (1 to 36)	-0.2% (-4.7 to 4.3)	11 (1 to 31)	10 (1 to 28)	-2.5% (-11.9 to 6.8)	**1.2 (0.18)**	**1.4 (0.04)**
Density of facilities providing delivery services per 1,000 livebirths**	3.0 (0.5 to 12.3)	4.4 (0.7 to 24.5)	**10.9% (4.6 to 17.2)**	2.4 (0.3 to 5.4)	3.6 (0.4 to 7.4)	**9.7% (0.6 to 18.8)**	1.25 (<0.01)	1.22 (<0.01)
Number of facilities providing caesarean sections**	3 (1 to 13)	3 (1 to 9)	-3.2% (-9.1 to 2.7)	4 (1 to 23)	3 (1 to 19)	-4.4% (-15.4 to 6.6)	0.75 (<0.01)	1.00 (<0.01)
Density of facilities providing caesarean sections per 1,000 livebirths**	0.7 (0.1 to 2.6)	0.9 (0.2 to 2.5)	**8.6% (2.7 to 14.5)**	0.8 (0.3 to 2.6)	1.1 (0.2 to 3.5)	7.1% (-1.2 to 15.3)	0.88 (0.13)	0.82 (0.15)
Number of township MCH workers	15 (4 to 97)	21 (6 to 153)	**12.0% (6.7 to 17.3)**	15 (4 to 47)	19 (6 to 62)	**6.2% (1.2 to 11.1)**	1.00 (0.98)	1.11 (0.17)
Percent of township MCH workers with bachelor degree and above	13.6% (0 to 44.4)	30.0% (0 to 90.0)	**3.7% (2.9 to 4.4)**	23.4% (0 to 53.6)	42.3% (13.6 to 62.5)	**3.6% (2.6 to 4.6)**	0.58 (<0.01)	0.71 (0.01)
Density of township MCH workers per 1,000 livebirths	4.9 (0.6 to 17.6)	8.2 (1.7 to 31.1)	**14.1% (10.8 to 17.4)**	5.3 (2.0 to 13.8)	5.9 (2.7 to 17.8)	**4.0% (0.3 to 7.8)**	**0.92 (0.16)**	**1.39 (0.04)**
Number of female village doctors	126 (24 to 565)	162 (26 to 661)	**5.3% (2.3 to 8.4)**	127 (28 to 428)	142 (28 to 480)	2.7% (-1.0 to 10.0)	0.99 (0.67)	1.14 (0.17)
Percent of female village doctors with high school degree and above	82.9% (34.1 to 99.4)	95.2% (64.3 to 100.0)	**2.7% (2.1 to 3.3)**	94.2% (46.7 to 100.0)	97.9% (73.4 to 100.0)	**1.5% (0.7 to 2.2)**	0.88 (<0.01)	0.97 (0.03)
Density of female village doctors per 1,000 livebirths	34.5 (15.7 to 92.5)	55.6 (25.5 to 132.4)	**7.1% (5.4 to 8.7)**	45.7 (12.3 to 96.2)	46.8 (11.0 to 116.2)	2.2% (-0.6 to 5.0)	**0.75 (0.12)**	**1.19 (0.05)**

Note: Data are median (range), rate (95% CI), or ratio ($P>|t|$). *6.15 CNY=1 USD in year 2014. **Data stated in 2017. MCH-PA programmes indicate the maternal and child health programmes for poverty alleviation in Yunnan. Township MCH workers indicate health staff in township health centre who manage MCH programmes, collect and report data, and help MCH service provision at township-level. MCH= maternal and child health. GDP= gross domestic product. G&O= the Department of Gynaecology & Obstetrics. N&P= the Department of Neonatology & Paediatrics.

Although more than 99% of pregnant women gave birth in health facilities across Yunnan in 2015, the determined efforts to expanding MCH services to every woman and child had resulted in a continuous rise in proportions of births in health facilities in 2020 (from 99.2% to 99.9% in poor areas and from 99.9% to 100.0% in non-poor areas). Both crude (0.49, $P<0.01$) and adjusted (0.55, $P<0.01$) DID estimators showed the MCH-PA programmes had effectively encouraged facility births in Yunnan. Paralleling the universal coverage in health facility births, the median caesarean section rates had been increased to 24.5% in poor areas and 34.8% in non-poor areas, with the annual rates of 1.6% and 1.1% respectively. The adjusted (1.84, $P=0.02$) DID estimator showed the MCH-PA programmes had narrowed the gaps in proportions of caesarean section between areas in Yunnan. Proportions of antenatal visits, postnatal visits, and newborn visits had showed decrease trend between 2015 and 2020 in poor areas, however those in non-poor areas followed similar trends. In order to prevent and control birth defects, prenatal screening for fetal abnormalities and newborn screening for hearing, phenylketonuria (PKU), and congenital hypothyroidism (CH) had been provided free of charge to pregnant women and newborns in poor areas. The annual rates of increase in attendances of fetal abnormalities (12.9% vs 9.6%) and hearing (2.7% vs 1.5%) screening were all faster in poor areas than those in non-poor areas. Ratios of poor to non-poor in newborn screening for PKU & CH were 1 in both 2015 and 2020 and there were no significant difference between areas ($P>0.05$). Compared to non-poor areas, the MCH-PA programmes had promoted the attendances of prenatal screening (crude DID estimator 9.08, $P<0.05$; adjusted DID estimator 13.87, $P<0.01$) and newborn hearing screening (crude DID estimator 4.68, $P<0.01$; adjusted DID estimator 4.78, $P<0.01$) in poor rural areas of Yunnan (Table 2).

Table 2 The Impact of MCH-PA Programmes on Service Coverage and Health Outcomes across Yunnan, China

	Poor areas with MCH-PA programmes			Non-poor areas without MCH-PA programmes			Crude DID estimator (*P*>|*t*|)	Adjusted DID estimator (*P*>|*t*|)*
	2015	2020	Annual rate of change	2015	2020	Annual rate of change		
MCH Service Coverage								
Births in health facility	99.2% (91.6 to 100.0)	99.9% (94.0 to 100.0)	**0.2% (0.1 to 0.3)**	99.9% (98.3 to 100.0)	100.0% (99.6 to 100.0)	**<0.1% (0.0 to 0.1)**	**0.49 (<0.01)**	**0.55 (<0.01)**
Caesarean sections	16.6% (3.7 to 35.7)	24.5% (7.1 to 46.8)	**1.6% (1.2 to 2.0)**	29.4% (13.4 to 42.0)	34.8% (19.1 to 45.6)	**1.1% (0.6 to 1.6)**	1.37 (0.29)	**1.84 (0.02)**
Five and more antenatal visits	96.2% (50.1 to 100.0)	93.5% (80.0 to 95.9)	**-1.9% (-2.6 to -1.3)**	98.3% (83.5 to 99.3)	93.7% (92.4 to 98.4)	**-2.1% (-3.0 to -1.3)**	0.69 (0.73)	0.83 (0.56)
First trimester antenatal visits	94.4% (43.5 to 99.9)	93.6% (80.1 to 97.0)	-0.6% (-1.2 to 0.0)	96.5% (75.6 to 99.3)	94.5% (92.4 to 98.9)	-0.7% (-1.5 to 0.1)	0.52 (0.78)	0.87 (0.46)
High-risk pregnancy management	100.0% (97.2 to 100.0)	100.0% (98.7 to 100.0)	<0.1% (-0.0 to 0.0)	100.0% (99.8 to 100.0)	100.0% (99.9 to 100.0)	<0.1% (0.0 to 0.0)	0.02 (0.76)	0.02 (0.59)
Any postnatal visits	98.3% (83.5 to 100.0)	97.7 (84.4 to 99.9)	-0.4% (-0.7 to 0.0)	98.9% (83.9 to 99.5)	98.4 (94.9 to 99.8)	-0.2% (-0.6 to 0.1)	-0.61 (0.45)	-0.66 (0.32)
Prenatal screening for fetal abnormalities	0.0% (0.0 to 46.7)	68.1% (6.3 to 99.5)	**12.9% (11.9 to 13.9)**	41.1% (0.0 to 97.7)	90.2% (64.5 to 99.9)	**9.6% (7.3 to 11.8)**	**9.08 (<0.05)**	**13.87 (<0.01)**
Newborn visits	98.6% (80.1 to 99.9)	97.9 (83.7 to 100.0)	-0.4% (-0.6 to 0.0)	99.5% (83.9 to 100.0)	99.6% (95.3 to 100.0)	-0.2% (-0.6 to 0.3)	0.42 (0.63)	0.41 (0.55)
Newborn hearing screening	86.7% (27.3 to 99.7)	98.7% (86.6 to 100.0)	**2.7% (2.3 to 3.1)**	95.6% (57.4 to 99.8)	98.9% (84.4 to 99.9)	**1.5% (1.0 to 2.1)**	**4.68 (<0.01)**	**4.78 (<0.01)**
Newborn screening for PKU & CH**	91.1% (58.0 to 100.0)	98.9% (75.8 to 100.0)	**2.2% (1.7 to 2.7)**	89.4% (67.2 to 100.0)	98.9% (84.5 to 100.0)	**2.4% (1.6 to 3.3)**	-0.75 (0.66)	-1.28 (0.31)
MCH Outcomes								
Maternal deaths per 100,000 livebirths	17.8 (0.0 to 127.7)	0.0 (0.0 to 193.8)	**-10.1% (-17.4 to -2.7)**	16.3 (0.0 to 173.3)	0.0 (0.0 to 125.2)	**-12.4% (-20.3 to-4.5)**	0.14 (0.98)	-1.14 (0.80)
Neonatal deaths per 1,000 livebirths	6.2 (2.6 to 17.6)	3.0 (0.0 to 7.9)	**-11.1% (-12.8 to -9.3)**	3.9 (0.8 to 10.5)	2.1 (0.6 to 5.7)	**-10.8% (-13.5 to -8.2)**	**-0.81 (0.02)**	**-1.03 (<0.01)**
Infant deaths per 1,000 livebirths	9.3 (4.9 to 25.1)	5.4 (0.5 to 14.2)	**-9.4% (-11.0 to -7.9)**	6.2 (1.7 to 11.5)	3.5 (0.8 to 8.9)	**-9.3% (-11.5 to -7.2)**	**-1.08 (0.02)**	**-1.41 (<0.01)**

Under-5 deaths per 1,000 livebirths	11.9 (7.7 to 31.6)	7.4 (2.5 to 20.8)	**-7.8% (-9.4 to -6.3)**	7.8 (2.1 to 14.5)	5.4 (1.7 to 11.3)	**-7.7% (-9.0 to -5.4)**	-0.98 (<0.10)	**-1.39 (<0.01)**
Born at low birthweight	3.9% (1.7 to 7.3)	3.9% (2.2 to 6.6)	0.1% (-0.0 to 0.1)	3.9% (2.2 to 5.7)	4.0% (1.3 to 7.2)	**0.1% (0.1 to 0.2)**	-0.26 (0.12)	**-0.29 (0.04)**
Underweight children	1.8% (0.5 to 9.0)	1.3% (0.2 to 5.2)	**-0.1% (-0.2 to -0.1)**	2.0% (0.6 to 4.8)	1.5% (0.4 to 3.1)	**-0.1% (-0.2 to -0.0)**	-0.08 (0.71)	-0.19 (0.20)
Stunted children	0.9% (0.1 to 6.4)	0.9% (0.0 to 4.7)	<-0.0% (-0.1 to 0.0)	1.9% (0.3 to 7.7)	1.4% (0.3 to 4.3)	**-0.1% (-0.2 to -0.0)**	0.38 (0.06)	0.27 (0.15)
Wasted children***	0.7% (0.0 to 3.1)	0.5% (0.0 to 3.0)	<-0.1% (-0.1 to 0.1)	0.8% (0.0 to 3.4)	0.8% (0.1 to 2.2)	<-0.1% (-0.2 to 0.1)	--	--
Overweight children	0.4% (0.0 to 5.4)	0.5% (0.0 to 5.1)	**0.1% (0.0 to 0.1)**	0.9% (0.1 to 19.9)	1.4% (0.0 to 12.8)	-0.1% (-0.4 to 0.2)	0.32 (0.46)	0.67 (0.09)
Obese children	0.2% (0.0 to 2.1)	0.3% (0.0 to 6.0)	**0.1% (0.0 to 0.1)**	0.5% (0.0 to 4.4)	0.7% (0.1 to 2.9)	<-0.1% (-0.1 to 0.0)	0.22 (0.08)	**0.24 (0.02)**
Anaemic children****	25.3% (1.5 to 30.5)	18.0% (1.3 to 21.3)	**-1.2% (-2.6 to -0.3)**	--	--	--	--	--

Note: Data are median (range) or rate (95% CI). *DID estimators were adjusted by per capita GDP, the number of live births, or the density of maternal health personnel. **Data stated in 2016. ***Data stated in 2018. ****Haemoglobin values adjusted by altitude. MCH-PA programmes indicate the maternal and child health programmes for poverty alleviation in Yunnan. MCH= maternal and child health. GDP= gross domestic product. DID= difference-in-difference. PKU= phenylketonuria. CH= congenital hypothyroidism.

In addition, the out-of-pocket payments for serious illnesses among women and children with poverty registration had been considerably decreased by the three-tiered financial protection strategy. After MCH-PA programmes had launched, the registered poor women only paid 10.0% of total medical expenses for inpatient care for both cervical cancer and breast cancer, which was much less than those (30.0% and 27.2%) paid by populations without poverty registration (P<0.01). Except for inpatient care, the registered poor women paid for outpatient care much less from their own pockets compared to the non-poor women for treating cervical cancer (50.0% vs 60.0%) and breast cancer (50.0% vs 62.7%) (P<0.01). Same trend had been seen among children under 5 years old and the households with registered registration paid less for both inpatient and outpatient care for children with congenital heart disease (10.0% vs 43.1%, 65.0% vs 75.0%) or pneumonia (10.0% vs 46.0%, 50.0% vs 60.0%), compared to their counterparts (P<0.01). Moreover, for those without poverty registration, the out-of-pocket payments for inpatient care for cervical cancer (from 35.0% to 30.0%), breast cancer (from 30.0% to 27.2%), and pneumonia (from 48.0% to 46.0%) had declined after the MCH-PA programmes had launched, whereas the out-of-pocket payments for outpatient care had only declined in the treatment of pneumonia (from 77.2% to 60.0%) among children under 5 years old (P<0.01) (Table 3).

Table 3 The Impact of MCH-PA Programmes on Out-of-pocket Payments by Specific Medical Treatments in Yunnan, China

	All populations before MCH-PA programmes (2015-2017)		Populations without PR after MCH-PA programmes (2018-2020)		Populations with PR after MCH-PA programmes (2018-2020)		Ratio of oop% for before and after MCH-PA programmes	Ratio of oop% for populations with PR to those without PR
	TME per time (CNY)	OOP per time (%)	TME per time (CNY)	OOP per time (%)	TME per time (CNY)	OOP per time (%)		
Inpatient care for cervical cancer of women	7712.4 (626.4 to 69233.2)	35.0% (10.0 to 83.1)	6580.9 (844.0 to 51800.2)	30.0% (4.1% to 74.2)	5870.0 (514.5 to 51670.1)	10.0% (0.0 to 51.9)	**0.86 (<0.01)**	**0.33 (<0.01)**
Outpatient care for cervical cancer of women	198.1 (15.8 to 12471.8)	30.0% (15.0 to 98.6)	65.0 (3.8 to 18305.7)	60.0% (12.0 to 100.0)	56.4 (5.0 to 1465.8)	50.0% (13.2 to 100.0)	**2.00 (<0.01)**	**0.83 (<0.01)**
Inpatient care for breast cancer of women	6418.0 (645.9 to 35273.2)	30.0% (10.0 to 73.9)	5472.6 (954.2 to 33121.9)	27.2% (3.6 to 73.9)	5448.8 (617.6 to 36847.7)	10.0% (0.0 to 47.2)	**0.91 (<0.01)**	**0.37 (<0.01)**
Outpatient care for breast cancer of women	111.4 (3.4 to 3242.9)	45.0% (18.4 to 100.0)	83.1 (3.4 to 10023.0)	62.7% (9.0 to 100.0)	51.5 (5.0 to 2390.5)	50.0% (16.6 to 100.0)	**1.39 (<0.01)**	**0.80 (<0.01)**
Inpatient care for Congenital heart disease of children under-5	11451.4 (969.5 to 152605.8)	47.1% (10.0 to 81.3)	21352.3 (1169.1 to 219126.7)	43.1% (20.8 to 79.8)	10354.5 (217.2 to 97009.6)	10.0% (9.5 to 46.7)	0.92 (0.12)	**0.23 (<0.01)**
Outpatient care for Congenital heart disease of children under-5	230.0 (9.0 to 4384.0)	75.1% (22.2 to 94.0)	223.0 (0.7 to 18776.7)	75.0% (27.3 to 93.9)	172.0 (14.7 to 285.0)	65.0% (35.6 to 100.0)	1.00 (0.76)	**0.87 (<0.01)**
Inpatient care for Pneumonia of children under-5	2358.1 (573.2 to 9147.2)	48.0% (20.2 to 81.7)	2240.1 (410.5 to 12073.3)	46.0% (20.4 to 77.8)	1933.7 (0.0 to 8627.2)	10.0% (0.0 to 35.3)	**0.96 (<0.01)**	**0.22 (<0.01)**
Outpatient care for Pneumonia of children under-5	63.9 (0.3 to 223.0)	77.2% (28.6 to 99.4)	60.4 (8.8 to 215.2)	60.0% (30.8 to 100.0)	50.1 (6.3 to 196.3)	50.0% (15.1 to 100.0)	**0.78 (<0.01)**	**0.83 (<0.01)**

Note: Data are median (range) or ratio ($P>|t|$). MCH-PA programmes indicate the maternal and child health programmes for poverty alleviation in Yunnan. TME= Total medical expenses. CNY= Chinese Yuan. OOP= Out-of-pocket payments. PR= Poverty registration.

As a result, maternal deaths per 100,000 livebirths and child deaths (including neonatal, infant, and under-5 deaths) per 1,000 livebirths had declined substantially between 2015 and 2020 in both poor and non-poor areas. The median MMR per 100,000 livebirths declined from 17.8 to no death in poor areas and from 16.3 to no death in non-poor areas. Difference in MMR between areas had not been found, however, the impact of MCH-PA programmes on maternal survivals was not significant and the gap between poor and non-poor areas had not gone closer with the estimated change trend of MMR from 2015 to 2020 (Table 2, Figure 2A).

The median NMR varied 1.59 times (P<0.01) between poor and non-poor areas of Yunnan in 2015 and 1.43 times (P<0.01) in 2020, whereas the median IMR varied 1.50 times (P<0.01) and 1.54 times (P<0.01), and the median U5MR varied 1.53 times (P<0.01) and 1.37 times (P<0.01), respectively. All the NMR (-11.1% vs -10.8%), IMR (-9.4% vs -9.3%), and U5MR (-7.8% vs -7.7%) per 1,000 livebirths had decreased faster in poor areas than those in non-poor areas. Although disparities remained between areas, the impacts of MCH-PA programmes on closing the gaps in child survivals across Yunnan were significant (P<0.01) (Table 2) which were showed obviously with the estimated change trend of NMR, IMR, and U5MR from 2015 to 2020 (Figure 2B-D).

Between 2015 and 2020, the prevalence rate of child underweight had significantly decreased in both poor areas (from 1.8% to 1.3%) and non-poor areas (from 2.0% to 1.5%), however, the prevalence rate of child stunted had only decreased in non-poor areas (from 1.9% to 1.4%). Oppositely, the percentages of children who were either overweight (from 0.4% to 0.5%) or obese (from 0.2% to 0.3%) had increased in poor areas at an annual rate of 0.1%, whereas there was no significant changes in non-poor areas. But children in non-poor areas were more likely to be stunted, overweight, or obese, compared to their counterparts in poor areas (P<0.01). Moreover, the proportions of anaemic children had decreased from 25.3% to 18.2% (annual rate of decline -1.2%) in poor areas of Yunnan during the same time period (Table 2).

Discussions

Ending poverty in all its forms is the first goal of UN SDGs.[1] Nearly 20 million people in China were victims of poverty or had returned to poverty because of illness in 2015, which accounted for 44.1% of the total number of poor population.[11] The poverty headcount ratio in rural China was 5.7% in 2015,[21] whereas the prevalence rates of poverty among women of childbearing age (15-59 years old) and children under 5 years old in rural Yunnan in the same year were 7.83% and 5.92%. The poverty headcount ratios among women and child being higher than the national average level indicated a greater impact of poverty on women and children in Yunnan. Our systematic assessment in Yunnan provides evidence of the positive effects of launching health programmes on preventing households from being trapped in or returning to poverty by decreasing maternal and child mortality and morbidity, as well as avoiding the catastrophic medical expenses because of illness, which is an important feature of China's poverty alleviation efforts and an useful measure to win the battle against poverty for whole China.

Remarkable progress in equitable maternal and child survival has been achieved in Yunnan, which is not only an outcome, but an essential component of poverty reduction. The maternal mortality rate fell to 12.42 deaths per 100,000 livebirths and under-5 mortality rate fell to 6.89 deaths per 1000 livebirths in 2020 in Yunnan, which had been below the national average for three consecutive years.[22] While the inequality in maternal mortality between poor areas and non-poor areas has disappeared, the gaps in child mortalities (including neonatal, infant, and under-5 child) across Yunnan have also been closing. The proportions of maternal deaths due to obstetric haemorrhage, neonatal and infant deaths due to preterm birth and low birth weight, and the preventable maternal deaths had decreased in poor areas between 2015 and 2020. China's efforts to improve maternal and child survival have been extraordinary and coherent. The progress presented by this research is not only past-depended but also boosted by China's Targeted Poverty Alleviation Strategy. Yunnan, as one of the most underdeveloped provinces in China, owned the most impoverished counties in 2014.[16]

The mountainous environment, cultural diversity, and weak service delivery at primary-level of Yunnan made people living in poor areas face a range of interrelated cultural, financial, geographical, and institutional barriers in seeking formal healthcare.[7] To defeat the vicious cycle of poverty and illness, especially among vulnerable populations like poor women and children, a series of MCH-PA programmes have been introduced in Yunnan to strengthen MCH system in poor rural areas by building infrastructures, improving human resources, expanding service coverage, and providing financial protection.[13]

The huge investments in the constructions of Emergency Obstetric Care Centre and Emergency Newborn Care Centre with the referral pathway across provincial-, prefecture-, and county- levels in Yunnan have guaranteed the timely rescue service providing to the pregnant and newborn in risk. To identify the high-risk pregnancy as early as possible, counterpart assistance programmes and special training had been conducted at primary-level for MCH human resource capacity building in rural Yunnan.[23] Hence, the densities of licenced doctors, nurses, obstetricians, and midwives, as well as township MCH workers and female village doctors had been increased substantially in poor areas between 2015 and 2020. The gaps had been narrowed not only in the quantity of health staff but also in the quality of them. There are now more township MCH workers with bachelor degree and female village doctors with high school degree in poor areas than those in non-poor areas. Township MCH workers and female village doctors play very important roles in MCH system who mainly participate in MCH programme implementation and service provision at township- and village-levels.[24] With the increase of both quantity and quality of MCH human resources, our DID statistical models showed the positive effect of MCH-PA programmes on expanding MCH service coverage in poor areas. Except for the proportions of facility birth, caesarean section, antenatal visit, and postnatal visit which had achieved the national average,[22] the proportions of prenatal screening and newborn diseases screening had increased in both poor and non-poor areas to prevent birth defects, but much faster in poor areas. Otherwise, MCH-PA programme such as nutrition

improvement for poor children, folic acid supplementation for poor pregnant women, and cervical and breast cancer screening for rural women at childbearing age had been delivered and enlarged in poor areas to prevent diseases or identify diseases at an early-stage, thus improving health among targeted populations.[25,26] The percentages of underweight children and anaemic children in poor areas of Yunnan had been decreased significantly between 2015 and 2020. Accessibility to essential health services are also improved by providing health insurance and financial assistance schemes.[27] With supports from MCH-PA programmes, all registered poor women and children are covered by a three-tiered financial protection strategy. The out-of-pocket payments for inpatient care for poor women and children with cancer or heart disease had been considerably decreased to 10% of total medical expenses which may greatly help them access high-quality treatments and avoid catastrophic medical expenses.[28]

Despite impressive progress in maternal and child survival has been made in Yunnan, the current research points out that insufficient MCH system inputs, unmet needs, and poor health outcomes still remain in small parts of poor areas in Yunnan. To maintain what have been achieved, the current MCH-PA programmes should be continued and enhanced for a sustainable improvement in accessibility to and affordability of high-quality MCH services, which may be one of the main focus areas of rural revitalisation after Chines government announced that all 98.99 million impoverished rural residents have been lifted from absolute poverty according to the current poverty line by February 25th, 2021.[29] In the present study, we found while the proportion of underweight children had decreased, the proportions of overweight (0.5%) and obese (0.3%) children had increased in poor areas in Yunnan. Although there was not a change, the proportions of overweight (1.4%) and obese (0.7%) children in non-poor areas were much higher than those in poor areas. Childhood obesity often start children on the path to health problems like diabetes, high blood pressure and high cholesterol.[30] Living in a healthy lifestyle including enough activity and limited calories from food and drinks is what parents and children should be told through health education campaigns to prevent childhood obesity.[31]

Some interesting facts were found in the present study. While the numbers of live births increased in some areas mainly because of the universal two-child policy after 2015, there was a slight decrease trend in the numbers of live births in more areas between 2015 and 2020. To earn a living and shrug off poverty, there were more and more young rural-urban migrants in Yunnan, which could be an explanation of less babies born during the same period.[32] The next step towards rural revitalisation will involve upgrading economic activities and creating new jobs for young people in rural areas, which will be a long-term mechanism for stable poverty elimination.[33] Otherwise, we found the decrease trends in the numbers of facilities providing delivery services and caesarean sections in non-poor areas between 2015 and 2020. The Amended MCH Services Policy of Yunnan Province issued July 31st, 2019 re-emphasise that only the qualified health facility and staff can provide MCH services, with a legal permit.[34] To ensure the safeties of pregnant women and newborns, some of health facilities at primary-level had to strengthen their capacities to provide obstetric services.[4]

Our assessment was comprehensive and systematic, but the study design might have some limitations. First, mortality estimates were mainly based on the data from Yunnan Maternal and Child Health Routine Reporting System, which was possible for under-reporting of maternal and child deaths.[4] Especially, the deaths which had been missed were more likely to occur in the poor areas far away from health facilities, where people might die at home without recording. Second, the statistical standards had been changed in some of indicators of MCH service coverage in 2018, such as the proportions of five and more antenatal visits, first trimester antenatal visits, postnatal visits, and newborn visits. The updated statistical standards strictly require the timely full coverage, which means that only the MCH service provided in a specific time period can be counted.[35] Third, due to lack of some key variables at county- or township-level such as maternal illiteracy rates which are related with both poverty and health,[36,37] some potential confounders were not controlled to adjust for DID estimations of MCH-PA programmes. Thus caution is needed in the interpretation of the differences in MCH

indicators mentioned above across Yunnan between 2015 and 2020 provided by the present study.

Yunnan Province, as the main battlefield against poverty in China, has achieved remarkable progress in equitable maternal and child health, which is an essential component of great success in poverty alleviation in China. The practices in Yunnan have showed the Chinese model in ending poverty with health programmes, which may be summarised as firm commitment and determined leadership from the government at all levels, people-centred and problem-oriented health system strengthening, detailed and long-term health strategy blueprint, and social mobilisation and participation. China has its own poverty alleviation policies, derived from theory and practice and based on its own national conditions, can provide new perspectives and useful references for other countries and regions in their battle against poverty.[33]

Funding and Data Sharing Statement

This study was not funded. Data used in this study are available in Yunnan Maternal and Child Health Annual Report System, Yunnan Health Statistical Yearbooks, and Yunnan Statistical Yearbooks.

Contributors

HY designed the research protocol, constructed the database, developed the DID statistical model, interpreted the results, and drafted the article. XX and WY assisted with protocol design and development, data extraction and synthesis, results interpretation, and article revision. YQY, YZT, XLL, CSQ, LHF, WFF, CYY and ZDD were involved in compiling database, doing data analysis, and producing tables and graphs. ZQ, ZJR and GGP assessed the database, reviewed results, and revised article. LY proposed the study and oversaw database construction, models establishment, results interpretation, and article revision. All authors reviewed and approved the final submitted version.

Declaration of interests

We declare no competing interests.

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Ethics Approval Statement

This study does not involve human participants and ethical approval was not required.

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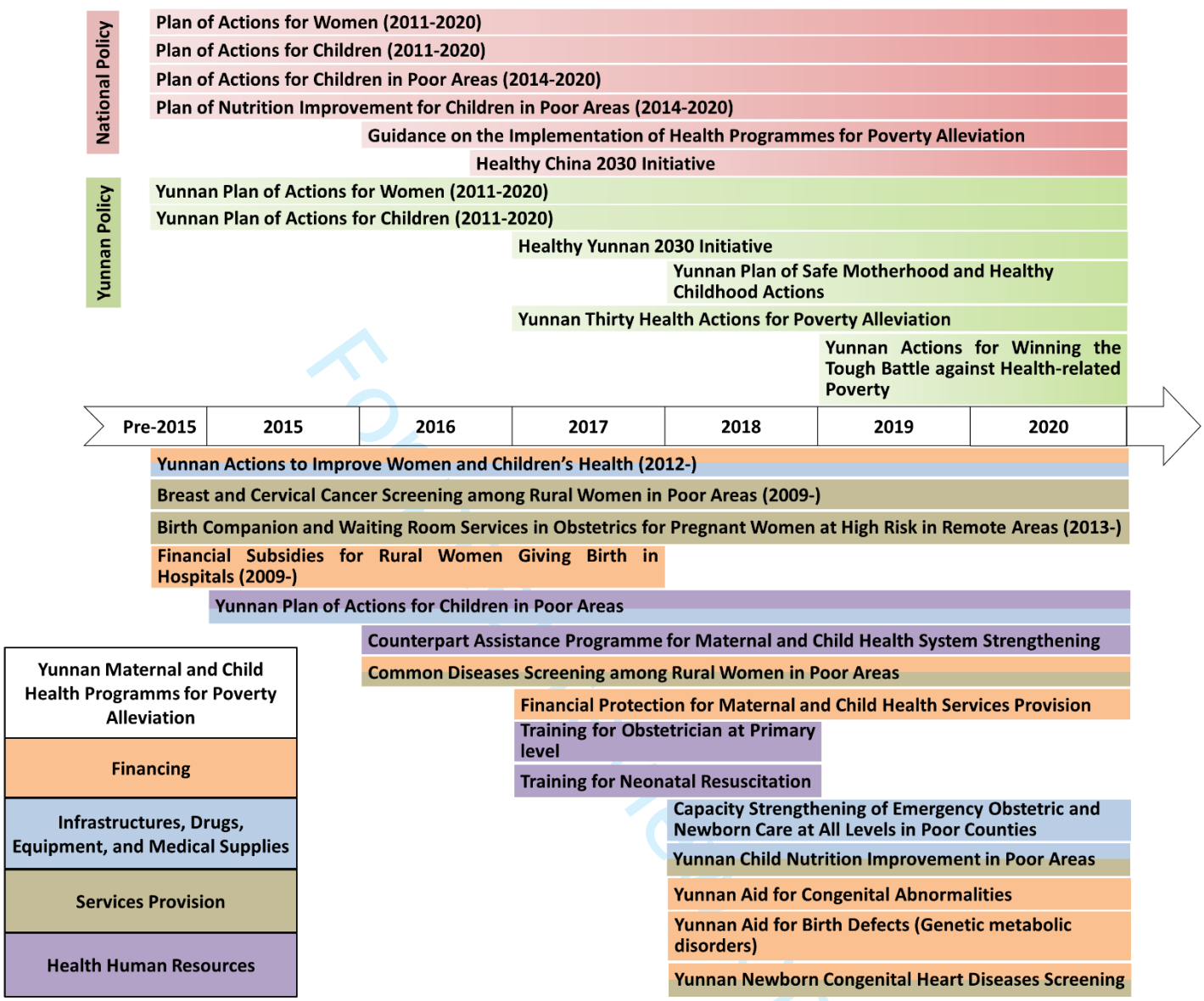


Figure 1 Timeline of Maternal and Child Health Policies and Programmes for Poverty Alleviation during 2015-2020 in Yunnan, China

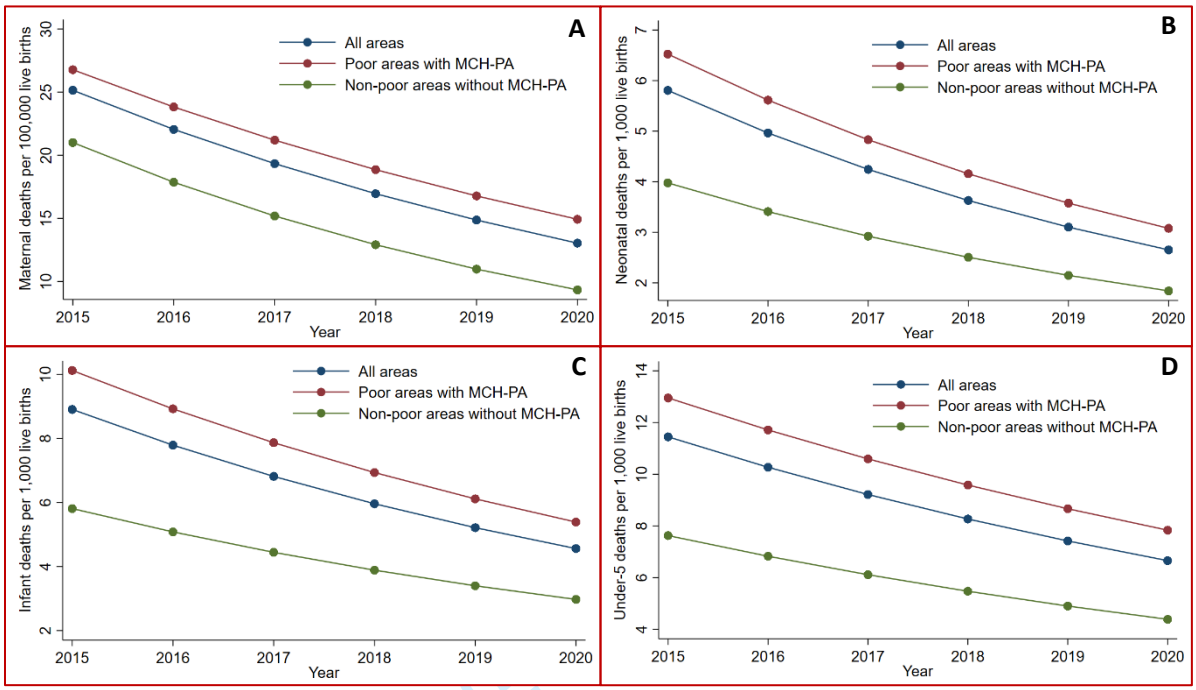
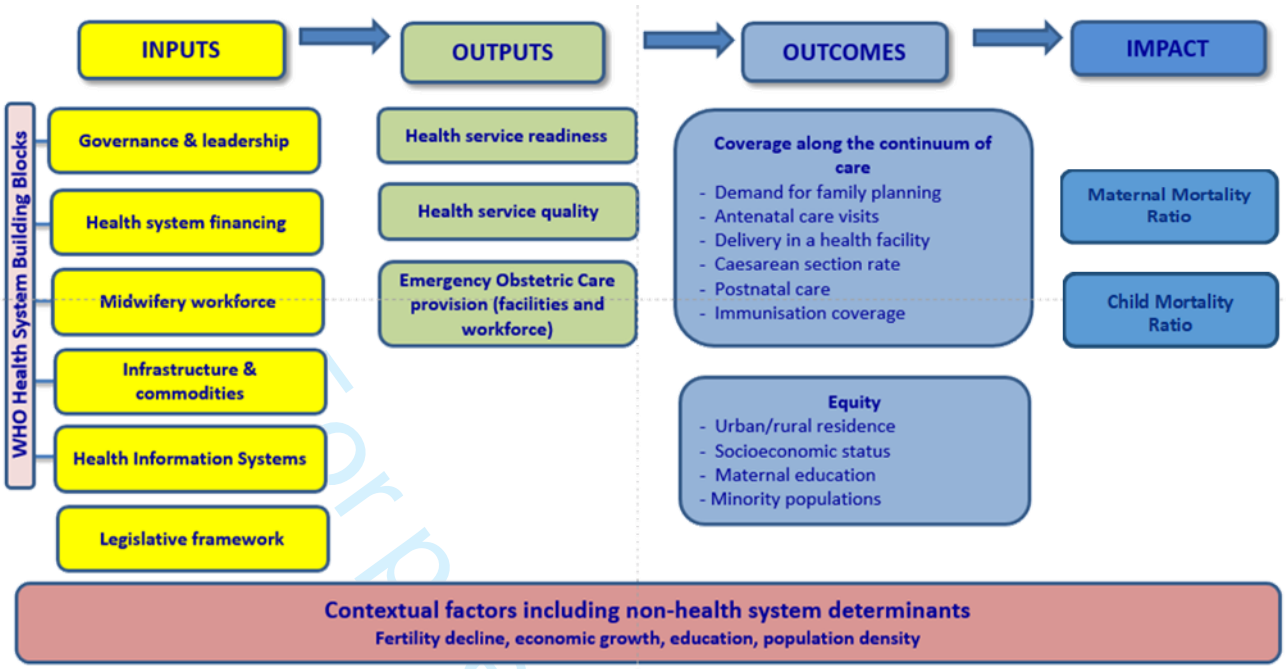


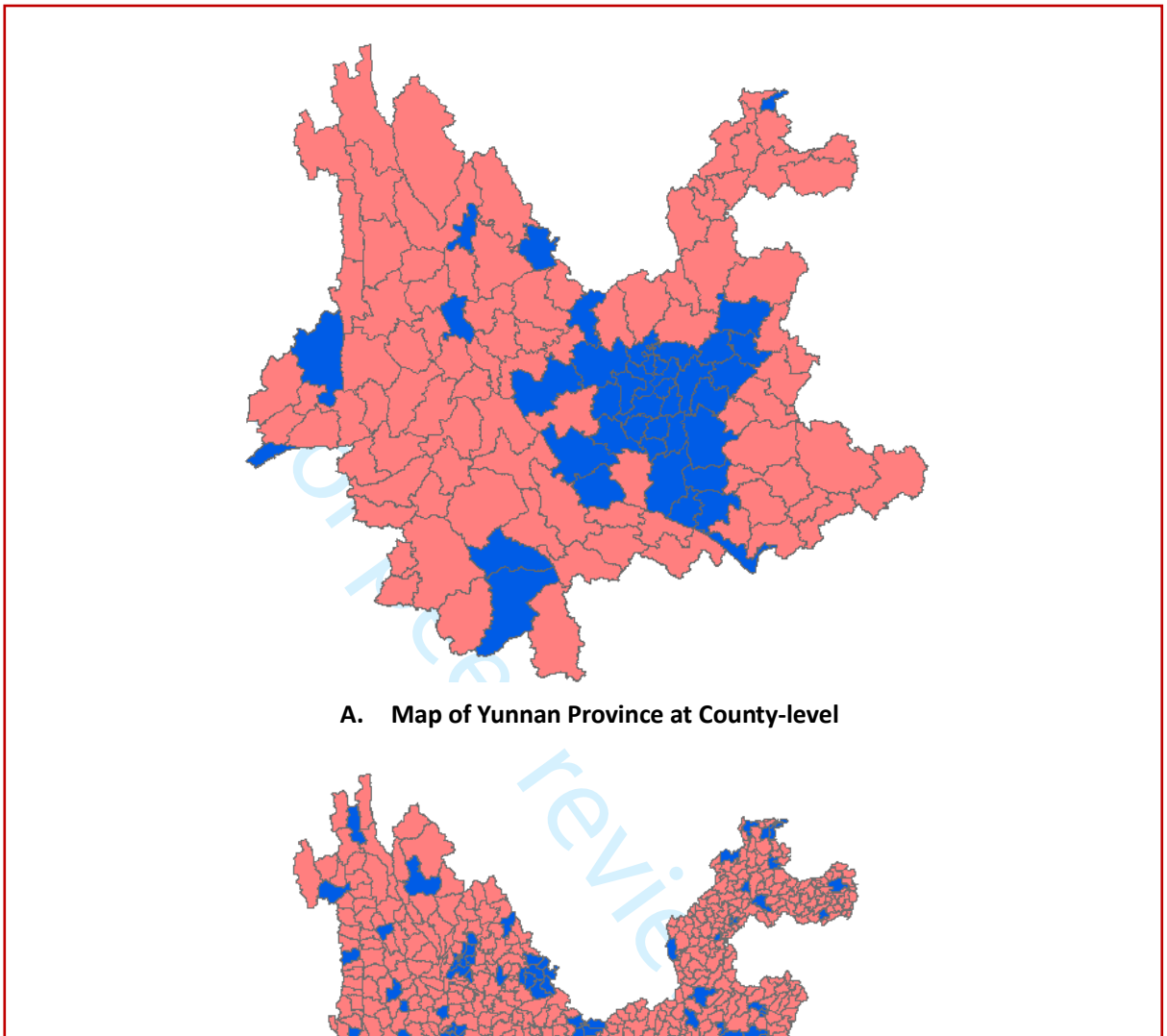
Figure 2 Estimated change trend of MMR (A), NMR (B), IMR (C), and U5MR (D) among all areas and areas with and without MCH-PA programmes from 2015 to 2020 in Yunnan, China

Note: MCH-PA indicates the maternal and child health programmes for poverty alleviation in Yunnan. MMR=maternal mortality rate. NMR=neonatal mortality rate. IMR=infant mortality rate. U5MR=under-5 mortality rate.

Appendix



Appendix Figure 1 Evaluation Framework Developed by Bryce et al (2013)



Appendix Figure 2 Map of Areas with and without MCH-PA Programmes at County- and Township-level in Yunnan Province

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Reported on page No/ line No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1, line 2-3 Page 3, line 11-12
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 3, line 7-26
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5, line 2-30 Page 6, line 1-16
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 6, line 18-25
Methods			
Study design	4	Present key elements of study design early in the paper	Page 7, line 22-30 Page 8, line 1-16
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6, line 29-30 Page 7, line 1-19
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Page 8, line 7-16
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 8, line 19-30 Page 9, line 1-20
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 8, line 19-30 Page 9, line 1-30 Page 10, line 1-28
Bias	9	Describe any efforts to address potential sources of bias	Page 10, line 17-28
Study size	10	Explain how the study size was arrived at	Page 8, line 7-16
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 9, line 23-30 Page 10, line 1-28
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 9, line 23-30 Page 10, line 1-28
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 8, line 1-16
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 12, line 28-30 Page 13, line 1-5
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Page 14-15, 17-18, and 20
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates	Page 16, line 1-24

		and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 17-18
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 22, line 9-30 Page 21, line 1-8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 25, line 17-30
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 24, line 14-30 Page 25 line 17-30
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 26, line 4-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 27, line 2

*Give information separately for exposed and unexposed groups.

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

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Tracking progress towards equitable maternal and child health in Yunnan: a systematic assessment for the Health Programme for Poverty Alleviation in China during 2015-2020

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Primary Subject Heading:	Health policy
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Tracking progress towards equitable maternal and child health in Yunnan: a systematic assessment for the Health Programme for Poverty Alleviation in China during 2015-2020

Yuan Huang Ph.D.[a], Xia Xiao Ph.D.[a], Ying Wan B.Sc.[b], Qingyun Ye M.Sc.[a], Zhongting Yang M.Sc.[a], Lingling Xu M.Sc.[a], Shuqi Chen M.Sc.[a], Huifang Li M.Sc.[a], Fangfang Wang M.Sc.[a], Yurong Chen M.Sc.[a], Dandan Zhao M.Sc.[a], Qian Zhang B.Sc.[b], Jiarui Zheng M.Sc.[b], Guangping Guo B.M.[b]*, Yan Li Ph.D.[a]*

a.Kunming Medical University, Kunming, Yunnan Province, 650500 China

b.Yunnan Maternal and Child Health Care Hospital, Kunming, Yunnan Province, 650051 China

*Correspondence to Yan Li (email: yanli20021965@21cn.com) and Guangping Guo (email: guoguangping68@126.com).

Word count of the manuscript text: 5369

Number of tables: 3

Number of figures: 2

The reason why this manuscript is over 4000 words: It is a systematic assessment to measure the changes in disparities in maternal and child health system inputs, outputs, outcomes, and impacts across Yunnan, China, between 2015 and 2020, to inform the effect of health programmes on preventing women and children from being trapped in or returning to poverty because of illness.

Abstract

Objectives To inform the impacts of health programmes which aimed at preventing women and children from being trapped in or returning to poverty because of illness in Yunnan, the main battlefield against poverty in China.

Design The longitudinal comparative evaluation design.

Data collection and analysis National and Yunnan policy documents related to maternal and child health programmes for poverty alleviation during 2015-2020 were analysed. The changes in disparities in maternal and child health system inputs, service coverage, and health outcomes between poor and non-poor areas, as well as out-of-pocket payments between poor and non-poor populations were assessed before and after 2017.

Results In total 12 policies and 15 programmes related to poverty alleviation for poor women and children in Yunnan were summarised. As a result of health system strengthening in Yunnan, the densities of licenced doctors, nurses, obstetricians, midwives, township health workers, and female village doctors had been increased substantially in poor areas, with the annual rates of 14.3%, 22.5%, 21.8%, 23.9%, 14.1%, and 7.1% separately. Although disparities existed in some of service coverage between poor and non-poor areas, the health programmes had narrowed the gaps in utilisation of facility birth, caesarean section, prenatal screening, and newborn screening across Yunnan (P<0.01). The out-of-pocket payments for inpatient care for serious illnesses among women and children with poverty registration had been considerably decreased to 10.0%. Paralleling the universal coverage, maternal deaths per 100,000 livebirths and child deaths per 1,000 livebirths had further declined in both poor and non-poor areas, and the impacts of health programmes on closing the gaps in child survivals across Yunnan were significant (P<0.01).

Conclusions Remarkable progress in equitable maternal and child survival has been achieved in Yunnan. The practices in Yunnan have showed the Chinese model in ending poverty by strengthening health system and implementing universal coverage with firm commitment, determined leadership, detailed blueprint, and social participation.

Keywords

Maternal and child survival; Health equity; Poverty alleviation; Health Programme; Western China

Strengths and limitations of this study

- This study examined the impacts of implementing maternal and child health (MCH) programmes on various outcomes, including health system inputs, service coverage, health outcomes, and out-of-pocket payments in Yunnan Province, China, to provide empirical evidence supporting the importance of health programmes in breaking the vicious cycle of poverty and illness among vulnerable populations.
- This study employed a difference-in-differences (DID) design, which compared outcomes in poor and non-poor areas before and after the intensive implementation of MCH programs in 2017, and found significant improvements in many indicators of service coverage and health outcome following the interventions.
- The effects of MCH programmes were mainly estimated with secondary data at county/township level in this study, which lacked the considerations of some key variables such as maternal literacy and household income and veiled the differences at individual level.

Introduction

Maternal and child health (MCH) affects economic growth and social development globally. Reducing maternal and child mortality is continually featured in the United Nations post-2015 Sustainable Development Goals (SDGs) and requires global supports.[1] China has made impressive progress in maternal and child survivals in recent decades. Between 1990 and 2015, maternal mortality rate fell from 89 to 22 deaths per 100,000 livebirths and same decrease trend was seen in under-5 mortality rate, falling from 54 to 11 deaths per 1000 livebirths in China.[2,3] However, disparities remained in western China where the maternal and child survivals were lagging behind in 2015, typically in rural and remote areas of Yunnan Province which is economically deprived and overwhelmingly concentrated by ethnic minorities.[4] Due to poor nutrition, little health knowledge, and lack of access to proper sanitation and healthcare services, poor and remote pregnant women and children were vulnerable populations at high risk of severe illness and death, which was the tough challenge facing in China.[4,5] Particularly, both of maternal mortality rate and under-5 mortality rate were twice as high for ethnic minorities than for their Han counterparts in western China according to a meta-analysis published in 2017.[6] Except for economic and educational disadvantages, traditional beliefs, mountainous topography, and poor quality of care were important barriers to seeking MCH care.[7] Maternal and child deaths not only decreased household income but also took a substantial share of national labour productivity loss.[8] Moreover, the treatment cost of disease or long-term complication might trap women and their families in poverty especially when large out-of-pocket expenditures were paid.[9]

To break the vicious cycle of poverty and illness, the China's Government has introduced the Health Programme for Poverty Alleviation Strategy which is an important measure to win the battle against poverty by targeting the poor and remote population precisely and reducing the heath disparities across regions and population groups.[10] In response to this, efforts have been made to ensure that the poor seldom fall ill, but can access and afford healthcare services when falling ill, as they can expect

help from national public services, severe illness insurance, and government funds which will cover the remaining cost after the relevant reimbursements to protect these people's right to health and prevent them from being trapped in or returning to poverty because of illness.[11,12] Promising to leave no one behind, as the main battlefield against extreme poverty in China, the Yunnan has launched the Thirty Health Actions for Poverty Alleviation in 2017 which includes a series of MCH programmes under Targeted Poverty Alleviation Strategy (hereinafter referred to as MCH-PA programmes) to address the specific challenges when seeking MCH healthcare services, reduce deaths of pregnant women, newborns and children under 5 years old, and avoid catastrophic health expenditures happened to those remote women and children as well as the ethnic minorities in poor rural Yunnan.[13] The MCH-PA programmes which include specific interventions in poor rural areas from strengthening emergency obstetric and newborn care to preventing birth defects, improving child nutrition, supplementing folic acid, breast and cervical cancer screening as well as affordable medical services, also echo the goal of guaranteeing the Healthy China 2030 and Healthy Yunnan 2030 Initiatives and the Strategy of Rural Revitalisation to achieve moderate prosperity in all respects after ending absolute poverty.[13]

We present a systematic assessment in Yunnan to inform the impacts of the MCH-PA programmes which aimed at preventing women and children from being trapped in or returning to poverty because of illness, moreover improving maternal and child heath equity across Yunnan. This article discussed the lessons learnt with regard to health-related poverty alleviation in Yunnan which may provide special reference to those still remaining impoverished by illness. These improvements may not only benefit Yunnan and people living there, but also serve as excellent demonstrations to other places and populations on how things can change, for the better.

Methods

Study Setting

Yunnan Province of China, a mountain and plateau region on the country's southwestern frontier, covers an area of 394,100 square kilometres with altitudes varying from the mountain peaks to river valleys by as much as 6,000 metres. The total population of Yunnan was 47.2 million in 2020, which includes 11.3 million women of childbearing age (23.9%) and 3.1 million children under 5 years old (6.6%).[14] Yunnan is noted for a very high level of ethnic diversity and owns the highest number of ethnic groups and autonomous regions in China, accounting for 33.1% of its total population.[14] As one of the least developed provinces in China, more than 8.8 million rural residents in Yunnan were living in poverty in 2012, based on national poverty line 2,300 CNY (about 364.5 USD) per capita net income of rural residents.[15] Some of the most entrenched poverty in Yunnan was found in regions inhabited by 11 smaller ethnic groups who practiced relatively primitive ways of life.[15] In 2014, the China's Government released a list of 832 impoverished counties according to poverty headcount ratio. Yunnan had 88 such counties including 8,502 impoverished villages when the list was released, more than any other provinces of China.[16] After 6-year efforts under China's Targeted Poverty Alleviation Strategy, as the main battlefield in China's war against poverty, Yunnan announced that all 88 counties designated by the government as poverty-stricken (accumulatively 7.6 million population including 2.3 million women of childbearing age and 0.3 million children under 5 years old) have shrugged off absolute poverty and all of its impoverished rural residents have been lifted above the current poverty line by December, 2020.[17]

Overview of Study Designs

We applied the World Health Organization Health System Building Blocks as the evaluation framework which assesses the improved MCH outcomes through an analysis of MCH systems inputs, MCH services coverage and quality, and geographic disparity (see appendix figure 1).[4,18,19] We started by reviewing the National and Yunnan provincial policy documents since 2015 to summarise the key MCH programmes for poverty alleviation in Yunnan. The timeline of MCH-PA programmes disaggregated into 4 aspects by health system inputs was drawn by an iterative process during a series

of workshops with a multidisciplinary team of maternal health and health systems experts. As the Yunnan intensively launched MCH-PA programmes in 2017 and aimed at reaching women and children in poor rural areas, we described the variations in MCH system inputs, services coverage, and health outcomes between 88 poor rural counties and 41 non-poor rural counties/urban districts before (in 2015) and after (in 2020) MCH-PA programmes. The changes from 2015 to 2020 were calculated for areas with and without MCH-PA programmes. The ratios of poor to non-poor were used to show the differences between areas in 2015 and 2020. In order to assess the impact of MCH-PA programmes more precisely, the township-level data were adopted to estimate the changes in those MCH indicators brought about by MCH-PA programmes in poor areas after 2017, compared to non-poor areas. A total of 912 rural townships from 88 impoverished counties of Yunnan were categorised into the group "poor areas with MCH-PA programmes"; the remaining 295 rural townships and 109 urban streets from 41 non-poor counties/districts as well as 102 urban streets from impoverished counties were clustered into the group "non-poor areas without MCH-PA programmes" (506 rural townships/urban streets in total) (see appendix figure 2). The effects of MCH-PA programmes on out-of-pocket payments were assessed at individual level, between populations with and without poverty registration.

Data Sources

First, we extracted data on MCH outcomes (the number of live births, maternal deaths, neonatal deaths, infant deaths, under-5 deaths, birth defects, low-weight births, underweight children, stunted children, wasted children, overweight children, obese children, anaemic children, and anaemic pregnant women) and MCH services (the number of high-risk pregnancies, antenatal visits, prenatal screening, facility deliveries, caesarean sections, postnatal visits, newborn visits, and newborn diseases screening) between 2015 and 2020 at both county- and township-level, and data on MCH system inputs (the number of obstetricians, midwives, and facilities providing delivery services or caesarean sections) between 2017 and 2020 at county-level from Yunnan Maternal and Child Health Routine Reporting System. This system reports the annual number of

MCH outcomes and service coverage for all 129 rural counties/urban districts including 1418 rural townships/urban streets of Yunnan and data are reliable because rigorous quality control mechanisms including data quality audit process and standardisation of data collection were introduced from 1997 onward. But data on MCH system inputs were added from 2017 onward. Second, data on the number of licenced doctors, licenced nurses, public MCH programme personnel at township-level, female village doctors, and hospital beds for all health facilities and the number of beds in the Department of Gynaecology & Obstetrics and in the Department of Neonatology & Paediatrics in 129 rural counties/urban districts across Yunnan between 2015 and 2020 were extracted from Yunnan Health Statistical Yearbooks. Third, we obtained county-level data on total resident population, per capita gross domestic product (GDP), per capita disposable income of rural residents, and land area between 2015 and 2020 from Yunnan Statistical Yearbooks. The density of MCH health resources per 1,000 population or per 1,000 livebirths were calculated. Fourth, the individual data on total medical expenditures and out-of-pocket payments for the treatment of breast cancer and cervical cancer among women, and the treatment of congenital heart disease and pneumonia among children under 5 years old across Yunnan were extracted from Yunnan Social Medical Insurance Reimbursement Datasets. Medical expenditures of both outpatient care and inpatient care were collected. Finally, policy data related to MCH-PA programmes were provided by Office for Poverty Alleviation People's Government of Yunnan Province, Office for Women and Children Health Commission of Yunnan Province, and Yunnan Provincial Maternal and Child Health Care Hospital.

Statistical Analysis

We adapted the longitudinal comparative evaluation design and the difference-in-difference (DID) technique to assess the changes in disparities in MCH service coverage and health outcomes between poor and non-poor areas at township-level before and after MCH-PA programmes.[20] We constructed two dummy variables $Treat_i$ and $Time_t$. If i is a poor area/person with MCH-PA programmes, the value

of $Treat_i$ is 1 (the treatment group); opposite, the value of $Treat_i$ is 0, if i is a non-poor area/person without MCH-PA programmes (the control group). $Time_t$ is a time dummy variable and it is assigned 1 after the implementation of MCH-PA programmes (2018-2020), 0 before the MCH-PA programmes (2015-2017). Based on the DID technique, the theoretical model to estimate the treatment effects comparing the pre- and post-treatment differences in the outcome of a treatment and a control group can be expressed as:

$$\text{Treatment Effect} = E\left(\Delta Y_i^1 \,\middle|\, Treat_i = 1\right) - E\left(\Delta Y_i^0 \,\middle|\, Treat_i = 0\right) \quad (1)$$

E is the mathematical expectation in the equation. Y_i^1 is the observations if i area/person participated MCH-PA programmes. Y_i^0 represents the area/person which did not participate in MCH-PA programmes. ΔY_i shows the difference before and after MCH-PA programmes implementation. To estimate the impact of MCH-PA programmes, the equation (1) could be designed as follow:

$$Y_{it} = \alpha + \beta Treat_i + \gamma Time_t + \delta Treat_i Time_t + \varepsilon_{it} \quad (2)$$

Then the coefficient of interaction δ in equation (2) measures the effects of MCH-PA programmes:

$$E\left(\Delta Y_i^1 - \Delta Y_i^0\right) = [(\alpha + \beta + \gamma + \delta) - (\alpha + \beta)] - [(\alpha + \gamma) - \alpha]$$

$$= (\gamma + \delta) - \gamma = \delta \quad (3)$$

So we used the following multivariate linear regression model to examine if MCH-PA programmes contributed to the changes in MCH indicators:

$$Y_{it} = \alpha + \beta Treat_i + \gamma Time_t + \delta Treat_i Time_t + \theta X_{it} + \varepsilon_{it} \quad (4)$$

Y_{it} is any of MCH indicators and data normalization will be adopted when necessary. $Treat_i$ is poor area dummy indicating poor rural townships where the MCH-PA programmes has implemented. $Time_t$ is time dummy indicating years after the implementation of MCH-PA programmes. X_{it} indicates the confounding variables including per capita GDP, the number of live births, or the density of maternal health personnel. α indicates intercept. ε_{it} is residual. The fixed effect of year, which could account for all time-invariant unobserved confounding for two groups, was also

included as a covariate. The parallel trends assumption for DID analysis that pre-treatment trends in outcomes were same between two groups was verified by regressing each MCH indicator on an interaction term between the binary treatment status and a continuous variable representing years before 2017. The models for continuous outcomes used Ordinary Least Squares, categorical outcomes used Logistic, and binary outcomes (such as incidence or mortality) used Poisson. No significant coefficients on the interaction terms were detected, which suggested that the parallel trends assumption was not be violated and the DID estimators were unbiased. In order to avoid heteroscedasticity and serial correlation of residual, we clustered residual to the county-level. All estimates were reported with 95% confidence intervals (CIs) where relevant. Statistically significant change was defined as change for which the 95% CIs did not overlap zero. All analyses were done with STATA version 15.0.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

In total of 69 policy documents related to the national and provincial MCH-PA programmes had been reviewed. Finally, 6 national policies and another 6 policies and 15 MCH-PA programmes of Yunnan were list in Figure 1. The Chinese government has maintained a strong focus on maternal and child health through a series of national general and specific Plans of Actions for Women and Children. The Guidance on the Implementation of Health Programme for Poverty Alleviation provided a complete legal and policy framework for breaking the vicious cycle of poverty and illness among vulnerable populations, such as poor pregnant women and children, which echoed the Healthy China 2030 initiative. As shown, Yunnan provincial policies and plans of actions were made under the national guidance which specified clear targets and tasks. The Yunnan Thirty Health Actions for Poverty Alleviation and Yunnan Actions for Wining Tough Battle against Poverty which were formulated in 2017 and 2019

respectively, emphasised the main objectives to ensure that the maternal mortality rate and infant mortality rate in Yunnan are respectively lower than 20 per 10 thousand livebirths and 10 per thousand livebirths by the end of 2020. Specific strategies in 4 aspects of financing, infrastructure building/drugs/equipment/medical suppliers, services provision, and health human resources have been designed and realised through the implementations of a series of MCH-PA programmes.

A total amount of 1.3 billion CNY (about 201.8 million USD) was transferred from central and provincial governments to the specific MCH-PA programmes in Yunnan from 2017 to 2019. The government's expenses on social basic medical insurance reimbursements for ill women and children were not included into the number mentioned above. Otherwise, another 449.1 million CNY (about 69.5 million USD) was especially invested in infrastructure building for MCH system strengthening in poor rural areas in Yunnan. A total of 128 Emergency Obstetric Care Centres and 112 Emergency Newborn Care Centres have been built until 2020, which nearly covered all the poor counties of Yunnan. For further improving level of and equity in maternal and child survivals in Yunnan, besides the regular free MCH services such as antenatal and postnatal care, the free services including pre-pregnancy checkup, prenatal screening, newborn diseases screening, child nutrition package, folic acid supplement, breast and cervical cancer screening, and female common disease screening had been provided which had expanded MCH health service coverage to woman and child in poor rural areas. Birth companion and waiting room services in the Department of Obstetrics had been available for pregnant women at high-risk in remote and poor areas since 2013. Meanwhile, counterpart assistance programmes and special training had been conducted. Specialists from Shanghai, Guangzhou, and Fujian (the most developed provinces from the Eastern China) and 9 tertiary hospitals of Yunnan were assigned to the poor counties or townships and had worked in the Department of Obstetrics or the Department of Pediatrics there for two years. The capacity building series training had been given to obstetricians and other medical staff at primary level. Otherwise, a three-tiered financial protection strategy has been made to ensure that medical services would

be affordable (out-of-pocket payments at 10%) with basic medical insurance, serious illness insurance, and medical financial assistance schemes among the Households with Poverty Registration. For some extremely poor households, out-of-pocket health expenditure was completely covered by the governmental financial protection strategy.

Poor areas where the MCH-PA programmes have been implemented are home to the half of total population in Yunnan. But population densities in most poor areas were much lower than those in non-poor areas. Between 2015 and 2020, there was a sign that people moved from poor areas to non-poor areas. Although disparities persisted between areas, the per capita GDP and per capita disposable income of rural residents in poor areas had increased at the annual rates of 19.8% and 11.5% respectively, which exceeded those in non-poor areas (14.9% and 11.4%). The decrease trend was seen in the number of live births across Yunnan, but which was not statistically significant (Table 1).

As a result of capacity strengthening of MCH system in Yunnan, health workforce and facilities had been growing steadily in poor areas. Not only the numbers of licensed doctors (from 1.1 to 1.9) and nurses (from 1.1 to 2.6) per 1,000 population, but also the numbers of obstetricians (from 10.1 to 15.7) and midwives (from 10.9 to 21.6) per 1,000 livebirths had been increased substantially in poor areas, with the annual rates of 14.3%, 22.5%, 21.8%, and 23.9% separately. Moreover, the numbers of township MCH workers and female village doctors in poor areas had been increased largely, who participated in MCH programme implementation and service provision at primary-level (the township- and village-levels). Disparities existed in most indicators of MCH human resources between poor and non-poor areas, but the gap in the density of obstetricians per 1,000 livebirths had become smaller (from 0.83 to 0.76) in 2020. Oppositely, the gaps in densities of township MCH workers and female village doctors per 1,000 livebirths had grown larger between areas at the same time period and there were more health staff working for MCH at both township- (P=0.04) and village-levels (P=0.05) in poor areas, compared to those in non-poor areas. Meanwhile, the

percentages of township MCH workers with bachelor degree (3.7% vs 3.6%) and female village doctors with high school degree (2.7% vs 1.5%) had grown faster in poor areas than non-poor areas. Besides, the densities of hospital beds in the Department of Gynaecology & Obstetrics and the Department of Neonatology & Paediatrics per 1,000 livebirths and the densities of facilities providing delivery services and caesarean sections per 1,000 livebirths had increased in poor areas, with the annual rates of 10.2%, 18.5%, 10.9%, and 8.6%. (Table 1).

Table 1 Socio-economic Characteristics and Health System Inputs of Areas with and without MCH-PA programmes at County-level in Yunnan, China

	Poor areas with MCH-PA programmes			Non-poor areas without MCH-PA programmes			Ratio of poor to non-poor, 2015	Ratio of poor to non-poor, 2020
	2015	2020	Annual rate of change	2015	2020	Annual rate of change		
Socio-economic Characteristics								
Population (10 thousand)	30.8 (3.8 to 138.4)	27.3 (3.8 to 135)	-1.0% (-4.3 to 2.4)	33.2 (10.5 to 39.5)	40.5 (10.2 to 160.3)	2.1% (-2.3 to 6.5)	**0.93 (0.16)**	**0.67 (<0.01)**
Population per square kilometre	103.4 (8.8 to 550.7)	94.4 (7.5 to 414.5)	-1.8% (-4.9 to 1.2)	224.4 (68.0 to 2531.2)	202.6 (45.6 to 3293.3)	6.3% (-6.5 to 19.1)	0.46 (<0.01)	0.47 (<0.01)
Number of ethnic autonomous regions	25 (28.4%)	25 (28.4%)	--	5 (12.2%)	5 (12.2%)	--	--	--
Per capita GDP (CNY, 10 thousand)*	1.8 (0.7 to 5.6)	3.8 (1.6 to 8.7)	**19.8% (17.3 to 22.3)**	3.8 (1.8 to 12.2)	6.8 (3.8 to 15.2)	**14.9% (10.4 to 19.5)**	0.47 (<0.01)	0.56 (<0.01)
Per capita disposable income of rural residents (CNY, 10 thousand)*	0.8 (0.5 to 1.2)	1.2 (0.8 to 1.8)	**11.5% (10.6 to 12.5)**	1.1 (0.6 to 1.6)	1.7 (1.3 to 2.4)	**11.4% (9.8 to 13.1)**	0.73 (<0.01)	0.71 (<0.01)
Number of live births	3180 (391 to 22605)	2703 (418 to 20056)	-2.6% (-6.8 to 1.6)	2878 (1133 to 7918)	2864 (1003 to 13287)	2.7% (-3.2 to 8.7)	1.10 (0.17)	0.94 (0.90)
Health System Inputs								
Number of licensed doctors	289 (42 to 1513)	524 (75 to 2899)	**13.5% (8.4 to 18.7)**	612 (143 to 5900)	945 (253 to 8098)	9.2 (-1.0 to 19.3)	0.47 (<0.01)	0.55 (<0.01)
Density of licensed doctors per 1,000 population	1.1 (0.4-3.0)	1.9 (0.9 to 6.0)	**14.3% (11.7 to 16.8)**	1.9 (1.0 to 7.1)	2.8 (1.3 to 8.4)	**6.7% (2.1 to 11.3)**	0.58 (<0.01)	0.68 (<0.01)
Number of licensed nurses	322 (67 to 2343)	676 (81 to 4580)	**22.4% (15.5 to 29.4)**	653 (188 to 7775)	1242 (362 to 10834)	**13.7% (2.3 to 25.2)**	0.49 (<0.01)	0.54 (<0.01)
Density of licensed nurses per 1,000 population	1.1 (0.2 to 4.7)	2.6 (1.3 to 8.5)	**22.5% (19.1 to 25.8)**	2.1 (0.5 to 8.9)	3.7 (1.5 to 11.3)	**11.0% (5.5 to 16.6)**	0.52 (<0.01)	0.70 (<0.01)
Number of hospital beds	1017 (176 to 5286)	1574 (184 to 9073)	**10.2% (5.1 to 15.4)**	1754 (548 to 12480)	2167 (647 to 14374)	5.2% (-3.2 to 13.6)	0.58 (<0.01)	0.73 (<0.01)
Density of hospital beds per 1,000 population	3.5 (1.5 to 9.7)	5.8 (3.4 to 17.0)	**10.7% (8.7 to 12.8)**	5.8 (1.4 to 16.0)	7.2 (1.2 to 14.8)	2.5% (-1.2 to 6.2)	0.60 (<0.01)	0.81 (0.01)
Number of hospital beds in G&O	112 (22 to 463)	170 (25 to 810)	**8.3% (4.5 to 12.2)**	168 (34 to 825)	227 (42 to 1021)	1.8% (-4.7 to 8.2)	0.67 (<0.01)	0.75 (0.02)
Density of hospital beds in G&O per 1,000 livebirths	36.5 (10.6 to 84.7)	55.7 (23.0 to 139.8)	**10.2% (7.7 to 12.8)**	66.2 (4.6 to 297.8)	67.2 (12.9 to 184.7)	-1.1% (-4.6 to 2.5)	0.55 (<0.01)	0.83 (0.03)
Number of hospital beds in N&P	55 (0 to 371)	99 (4 to 580)	**14.4% (9.1 to 19.7)**	88 (17 to 1303)	136 (18 to 1687)	7.2% (-4.1 to 18.6)	0.63 (<0.01)	0.73 (<0.03)
Density of hospital beds in	17.0	34.1	**18.5%**	31.5	48.8	3.7%	0.54	0.70

N&P per 1,000 livebirths	(0 to 55.7)	(6.6 to 125.8)	**(14.8 to 22.3)**	(8.8 to 244.5)	(10.3 to 248.1)	(2.1 to 9.6)	(<0.01)	(<0.01)
Number of obstetricians**	38 (5 to 153)	43 (5 to 187)	**7.4% (0.2 to 14.5)**	50 (12 to 257)	55 (15 to 242)	3.1% (-8.0 to 14.2)	0.76 (<0.01)	0.78 (<0.01)
Density of obstetricians per 1,000 livebirths**	10.1 (1.7 to 24.5)	15.7 (3.3 to 53.2)	**21.8% (15.3 to 28.3)**	12.1 (3.4 to 23.6)	20.6 (4.7 to 35.2)	**19.3% (12.1 to 26.5)**	0.83 (<0.01)	0.76 (0.02)
Number of midwives**	42 (3 to 230)	52 (2 to 331)	8.3% (0.1 to 16.6)	69 (10 to 330)	78 (18 to 372)	4.2% (-7.0 to 15.3)	0.61 (<0.01)	0.67 (0.02)
Density of midwives per 1,000 livebirths**	10.9 (1.2 to 41.9)	21.6 (1.0 to 55.0)	**23.9% (15.8 to 32.0)**	15.7 (3.8 to 43.5)	27.7 (5.3 to 75.3)	**20.6% (11.1 to 30.1)**	0.69 (0.02)	0.78 (0.01)
Number of facilities providing delivery services**	13 (2 to 36)	14 (1 to 36)	-0.2% (-4.7 to 4.3)	11 (1 to 31)	10 (1 to 28)	-2.5% (-11.9 to 6.8)	**1.2 (0.18)**	**1.4 (0.04)**
Density of facilities providing delivery services per 1,000 livebirths**	3.0 (0.5 to 12.3)	4.4 (0.7 to 24.5)	**10.9% (4.6 to 17.2)**	2.4 (0.3 to 5.4)	3.6 (0.4 to 7.4)	**9.7% (0.6 to 18.8)**	1.25 (<0.01)	1.22 (<0.01)
Number of facilities providing caesarean sections**	3 (1 to 13)	3 (1 to 9)	-3.2% (-9.1 to 2.7)	4 (1 to 23)	3 (1 to 19)	-4.4% (-15.4 to 6.6)	0.75 (<0.01)	1.00 (<0.01)
Density of facilities providing caesarean sections per 1,000 livebirths**	0.7 (0.1 to 2.6)	0.9 (0.2 to 2.5)	**8.6% (2.7 to 14.5)**	0.8 (0.3 to 2.6)	1.1 (0.2 to 3.5)	7.1% (-1.2 to 15.3)	0.88 (0.13)	0.82 (0.15)
Number of township MCH workers	15 (4 to 97)	21 (6 to 153)	**12.0% (6.7 to 17.3)**	15 (4 to 47)	19 (6 to 62)	**6.2% (1.2 to 11.1)**	1.00 (0.98)	1.11 (0.17)
Percent of township MCH workers with bachelor degree and above	13.6% (0 to 44.4)	30.0% (0 to 90.0)	**3.7% (2.9 to 4.4)**	23.4% (0 to 53.6)	42.3% (13.6 to 62.5)	**3.6% (2.6 to 4.6)**	0.58 (<0.01)	0.71 (0.01)
Density of township MCH workers per 1,000 livebirths	4.9 (0.6 to 17.6)	8.2 (1.7 to 31.1)	**14.1% (10.8 to 17.4)**	5.3 (2.0 to 13.8)	5.9 (2.7 to 17.8)	**4.0% (0.3 to 7.8)**	**0.92 (0.16)**	**1.39 (0.04)**
Number of female village doctors	126 (24 to 565)	162 (26 to 661)	**5.3% (2.3 to 8.4)**	127 (28 to 428)	142 (28 to 480)	2.7% (-1.0 to 10.0)	0.99 (0.67)	1.14 (0.17)
Percent of female village doctors with high school degree and above	82.9% (34.1 to 99.4)	95.2% (64.3 to 100.0)	**2.7% (2.1 to 3.3)**	94.2% (46.7 to 100.0)	97.9% (73.4 to 100.0)	**1.5% (0.7 to 2.2)**	0.88 (<0.01)	0.97 (0.03)
Density of female village doctors per 1,000 livebirths	34.5 (15.7 to 92.5)	55.6 (25.5 to 132.4)	**7.1% (5.4 to 8.7)**	45.7 (12.3 to 96.2)	46.8 (11.0 to 116.2)	2.2% (-0.6 to 5.0)	**0.75 (0.12)**	**1.19 (0.05)**

Note: Data are median (range), rate (95% CI), or ratio ($P>|t|$). *6.15 CNY=1 USD in year 2014. **Data stated in 2017. MCH-PA programmes indicate the maternal and child health programmes for poverty alleviation in Yunnan. Township MCH workers indicate health staff in township health centre who manage MCH programmes, collect and report data, and help MCH service provision at township-level. MCH= maternal and child health. GDP= gross domestic product. G&O= the Department of Gynaecology & Obstetrics. N&P= the Department of Neonatology & Paediatrics.

Although more than 99% of pregnant women gave birth in health facilities across Yunnan in 2015, the determined efforts to expanding MCH services to every woman and child had resulted in a continuous rise in proportions of births in health facilities in 2020 (from 99.2% to 99.9% in poor areas and from 99.9% to 100.0% in non-poor areas). Both crude (0.49, $P<0.01$) and adjusted (0.52, $P<0.01$) DID estimators showed the MCH-PA programmes had effectively encouraged facility births in Yunnan. Paralleling the universal coverage in health facility births, the median caesarean section rates had been increased to 24.5% in poor areas and 34.8% in non-poor areas, with the annual rates of 1.6% and 1.1% respectively. The adjusted (1.62, $P=0.04$) DID estimator showed the MCH-PA programmes had narrowed the gaps in proportions of caesarean section between areas in Yunnan. Proportions of antenatal visits, postnatal visits, and newborn visits had showed decrease trend between 2015 and 2020 in poor areas, however those in non-poor areas followed similar trends. In order to prevent and control birth defects, prenatal screening for fetal abnormalities and newborn screening for hearing, phenylketonuria (PKU), and congenital hypothyroidism (CH) had been provided free of charge to pregnant women and newborns in poor areas. The annual rates of increase in attendances of fetal abnormalities (12.9% vs 9.6%) and hearing (2.7% vs 1.5%) screening were all faster in poor areas than those in non-poor areas. Ratios of poor to non-poor in newborn screening for PKU & CH were around 1 in both 2015 and 2020 and there were no significant difference between areas ($P>0.05$). Compared to non-poor areas, the MCH-PA programmes had promoted the attendances of prenatal screening (crude DID estimator 9.08, $P<0.05$; adjusted DID estimator 13.46, $P<0.01$) and newborn hearing screening (crude DID estimator 4.68, $P<0.01$; adjusted DID estimator 4.74, $P<0.01$) in poor rural areas of Yunnan (Table 2).

Table 2 The Impact of MCH-PA Programmes on Service Coverage and Health Outcomes across Yunnan, China

	Poor areas with MCH-PA programmes			Non-poor areas without MCH-PA programmes			Crude DID estimator ($P>\|t\|$)	Adjusted DID estimator ($P>\|t\|$)*
	2015	2020	Annual rate of change	2015	2020	Annual rate of change		
MCH Service Coverage								
Births in health facility	99.2% (91.6 to 100.0)	99.9% (94.0 to 100.0)	**0.2% (0.1 to 0.3)**	99.9% (98.3 to 100.0)	100.0% (99.6 to 100.0)	**<0.1% (0.0 to 0.1)**	**0.49 (<0.01)**	**0.52 (<0.01)**
Caesarean sections	16.6% (3.7 to 35.7)	24.5% (7.1 to 46.8)	**1.6% (1.2 to 2.0)**	29.4% (13.4 to 42.0)	34.8% (19.1 to 45.6)	**1.1% (0.6 to 1.6)**	1.37 (0.29)	**1.62 (0.04)**
Five and more antenatal visits	96.2% (50.1 to 100.0)	93.5% (80.0 to 95.9)	**-1.9% (-2.6 to -1.3)**	98.3% (83.5 to 99.3)	93.7% (92.4 to 98.4)	**-2.1% (-3.0 to -1.3)**	0.69 (0.73)	0.83 (0.53)
First trimester antenatal visits	94.4% (43.5 to 99.9)	93.6% (80.1 to 97.0)	-0.6% (-1.2 to 0.0)	96.5% (75.6 to 99.3)	94.5% (92.4 to 98.9)	-0.7% (-1.5 to 0.1)	0.52 (0.78)	0.80 (0.46)
High-risk pregnancy management	100.0% (97.2 to 100.0)	100.0% (98.7 to 100.0)	<0.1% (-0.0 to 0.0)	100.0% (99.8 to 100.0)	100.0% (99.9 to 100.0)	<0.1% (0.0 to 0.0)	0.02 (0.76)	0.05 (0.39)
Any postnatal visits	98.3% (83.5 to 100.0)	97.7 (84.4 to 99.9)	-0.4% (-0.7 to 0.0)	98.9% (83.9 to 99.5)	98.4 (94.9 to 99.8)	-0.2% (-0.6 to 0.1)	-0.61 (0.45)	-0.67 (0.32)
Prenatal screening for fetal abnormalities	0.0% (0.0 to 46.7)	68.1% (6.3 to 99.5)	**12.9% (11.9 to 13.9)**	41.1% (0.0 to 97.7)	90.2% (64.5 to 99.9)	**9.6% (7.3 to 11.8)**	**9.08 (<0.05)**	**13.46 (<0.01)**
Newborn visits	98.6% (80.1 to 99.9)	97.9 (83.7 to 100.0)	-0.4% (-0.6 to 0.0)	99.5% (83.9 to 100.0)	99.6% (95.3 to 100.0)	-0.2% (-0.6 to 0.3)	0.42 (0.63)	0.23 (0.70)
Newborn hearing screening	86.7% (27.3 to 99.7)	98.7% (86.6 to 100.0)	**2.7% (2.3 to 3.1)**	95.6% (57.4 to 99.8)	98.9% (84.4 to 99.9)	**1.5% (1.0 to 2.1)**	**4.68 (<0.01)**	**4.74 (<0.01)**
Newborn screening for PKU & CH**	91.1% (58.0 to 100.0)	98.9% (75.8 to 100.0)	**2.2% (1.7 to 2.7)**	89.4% (67.2 to 100.0)	98.9% (84.5 to 100.0)	**2.4% (1.6 to 3.3)**	-0.75 (0.66)	-1.25 (0.33)
MCH Outcomes								
Maternal deaths per 100,000 livebirths	17.8 (0.0 to 127.7)	0.0 (0.0 to 193.8)	**-10.1% (-17.4 to -2.7)**	16.3 (0.0 to 173.3)	0.0 (0.0 to 125.2)	**-12.4% (-20.3 to-4.5)**	0.14 (0.98)	-1.15 (0.80)
Neonatal deaths per 1,000 livebirths	6.2 (2.6 to 17.6)	3.0 (0.0 to 7.9)	**-11.1% (-12.8 to -9.3)**	3.9 (0.8 to 10.5)	2.1 (0.6 to 5.7)	**-10.8% (-13.5 to -8.2)**	**-0.81 (0.02)**	**-1.21 (<0.01)**
Infant deaths per 1,000	9.3	5.4	**-9.4%**	6.2	3.5	**-9.3%**	**-1.08**	**-1.70**

livebirths	(4.9 to 25.1)	(0.5 to 14.2)	**(-11.0 to -7.9)**		(1.7 to 11.5)	(0.8 to 8.9)	**(-11.5 to -7.2)**	**(0.02)**	**(<0.01)**
Under-5 deaths per 1,000 livebirths	11.9 (7.7 to 31.6)	7.4 (2.5 to 20.8)	**-7.8% (-9.4 to -6.3)**		7.8 (2.1 to 14.5)	5.4 (1.7 to 11.3)	**-7.7% (-10.0 to -5.4)**	-0.98 (<0.10)	**-1.82 (<0.01)**
Born at low birthweight	3.9% (1.7 to 7.3)	3.9% (2.2 to 6.6)	0.1% (-0.0 to 0.1)		3.9% (2.2 to 5.7)	4.0% (1.3 to 7.2)	**0.1% (0.1 to 0.2)**	-0.26 (0.12)	**-0.30 (0.04)**
Underweight children	1.8% (0.5 to 9.0)	1.3% (0.2 to 5.2)	**-0.1% (-0.2 to -0.1)**		2.0% (0.6 to 4.8)	1.5% (0.4 to 3.1)	**-0.1% (-0.2 to -0.0)**	-0.08 (0.71)	-0.10 (0.50)
Stunted children	0.9% (0.1 to 6.4)	0.9% (0.0 to 4.7)	<-0.0% (-0.1 to 0.0)		1.9% (0.3 to 7.7)	1.4% (0.3 to 4.3)	**-0.1% (-0.2 to -0.0)**	0.38 (0.06)	0.27 (0.11)
Wasted children***	0.7% (0.0 to 3.1)	0.5% (0.0 to 3.0)	<-0.1% (-0.1 to 0.1)		0.8% (0.0 to 3.4)	0.8% (0.1 to 2.2)	<-0.1% (-0.2 to 0.1)	--	--
Overweight children	0.4% (0.0 to 5.4)	0.5% (0.0 to 5.1)	**0.1% (0.0 to 0.1)**		0.9% (0.1 to 19.9)	1.4% (0.0 to 12.8)	-0.1% (-0.4 to 0.2)	0.32 (0.46)	**0.74 (0.02)**
Obese children	0.2% (0.0 to 2.1)	0.3% (0.0 to 6.0)	**0.1% (0.0 to 0.1)**		0.5% (0.0 to 4.4)	0.7% (0.1 to 2.9)	<-0.1% (-0.1 to 0.0)	0.22 (0.08)	**0.27 (0.01)**
Anaemic children****	25.3% (1.5 to 30.5)	18.0% (1.3 to 21.3)	**-1.2% (-2.6 to -0.3)**		--	--	--	--	--

Note: Data are median (range) or rate (95% CI). *DID estimators were adjusted by year, per capita GDP, the number of livebirths, or the density of maternal health personnel. **Data stated in 2016. ***Data stated in 2018. ****Haemoglobin values adjusted by altitude. MCH-PA programmes indicate the maternal and child health programmes for poverty alleviation in Yunnan. MCH= maternal and child health. GDP= gross domestic product. DID= difference-in-difference. PKU= phenylketonuria. CH= congenital hypothyroidism.

In addition, the out-of-pocket payments for serious illnesses among women and children with poverty registration had been considerably decreased by the three-tiered financial protection strategy. After MCH-PA programmes had launched, the registered poor women only paid 10.0% of total medical expenses for inpatient care for both cervical cancer and breast cancer, which was much less than those (30.0% and 27.2%) paid by populations without poverty registration (P<0.01). Except for inpatient care, the registered poor women paid for outpatient care much less from their own pockets compared to the non-poor women for treating cervical cancer (50.0% vs 60.0%) and breast cancer (50.0% vs 62.7%) (P<0.01). Same trend had been seen among children under 5 years old and the households with registered registration paid less for both inpatient and outpatient care for children with congenital heart disease (10.0% vs 43.1%, 65.0% vs 75.0%) or pneumonia (10.0% vs 46.0%, 50.0% vs 60.0%), compared to their counterparts (P<0.01). Moreover, for those without poverty registration, the out-of-pocket payments for inpatient care for cervical cancer (from 35.0% to 30.0%), breast cancer (from 30.0% to 27.2%), and pneumonia (from 48.0% to 46.0%) had declined after the MCH-PA programmes had launched, whereas the out-of-pocket payments for outpatient care had only declined in the treatment of pneumonia (from 77.2% to 60.0%) among children under 5 years old (P<0.01) (Table 3).

Table 3 The Impact of MCH-PA Programmes on Out-of-pocket Payments by Specific Medical Treatments in Yunnan, China

	All populations before MCH-PA programmes (2015-2017)		Populations without PR after MCH-PA programmes (2018-2020)		Populations with PR after MCH-PA programmes (2018-2020)		Ratio of oop% for before and after MCH-PA programmes	Ratio of oop% for populations with PR to those without PR
	TME per time (CNY)	OOP per time (%)	TME per time (CNY)	OOP per time (%)	TME per time (CNY)	OOP per time (%)		
Inpatient care for cervical cancer of women	7712.4 (626.4 to 69233.2)	35.0% (10.0 to 83.1)	6580.9 (844.0 to 51800.2)	30.0% (4.1% to 74.2)	5870.0 (514.5 to 51670.6)	10.0% (0.0 to 51.9)	**0.86 (<0.01)**	**0.33 (<0.01)**
Outpatient care for cervical cancer of women	198.1 (15.8 to 12471.8)	30.0% (15.0 to 98.6)	65.0 (3.8 to 18305.7)	60.0% (12.0 to 100.0)	56.4 (5.0 to 1465.6)	50.0% (13.2 to 100.0)	**2.00 (<0.01)**	**0.83 (<0.01)**
Inpatient care for breast cancer of women	6418.0 (645.9 to 35273.2)	30.0% (10.0 to 73.9)	5472.6 (954.2 to 33121.9)	27.2% (3.6 to 73.9)	5448.8 (617.6 to 36848.6)	10.0% (0.0 to 47.2)	**0.91 (<0.01)**	**0.37 (<0.01)**
Outpatient care for breast cancer of women	111.4 (3.4 to 3242.9)	45.0% (18.4 to 100.0)	83.1 (3.4 to 10023.0)	62.7% (9.0 to 100.0)	51.5 (5.0 to 2390.5)	50.0% (16.6 to 100.0)	**1.39 (<0.01)**	**0.80 (<0.01)**
Inpatient care for Congenital heart disease of children under-5	11451.4 (969.5 to 152605.8)	47.1% (10.0 to 81.3)	21352.3 (1169.1 to 219126.7)	43.1% (20.8 to 79.8)	10354.5 (217.2 to 97006.6)	10.0% (9.5 to 46.7)	0.92 (0.12)	**0.23 (<0.01)**
Outpatient care for Congenital heart disease of children under-5	230.0 (9.0 to 4384.0)	75.1% (22.2 to 94.0)	223.0 (0.7 to 18776.7)	75.0% (27.3 to 93.9)	172.0 (14.7 to 285.8)	65.0% (35.6 to 100.0)	1.00 (0.76)	**0.87 (<0.01)**
Inpatient care for Pneumonia of children under-5	2358.1 (573.2 to 9147.2)	48.0% (20.2 to 81.7)	2240.1 (410.5 to 12073.3)	46.0% (20.4 to 77.8)	1933.7 (0.0 to 8627.1)	10.0% (0.0 to 35.3)	**0.96 (<0.01)**	**0.22 (<0.01)**
Outpatient care for Pneumonia of children under-5	63.9 (0.3 to 223.0)	77.2% (28.6 to 99.4)	60.4 (8.8 to 215.2)	60.0% (30.8 to 100.0)	50.1 (6.3 to 196.3)	50.0% (15.1 to 100.0)	**0.78 (<0.01)**	**0.83 (<0.01)**

Note: Data are median (range) or ratio ($P>|t|$). MCH-PA programmes indicate the maternal and child health programmes for poverty alleviation in Yunnan. TME= Total medical expenses. CNY= Chinese Yuan. OOP= Out-of-pocket payments. PR= Poverty registration.

As a result, maternal deaths per 100,000 livebirths and child deaths (including neonatal, infant, and under-5 deaths) per 1,000 livebirths had declined substantially between 2015 and 2020 in both poor and non-poor areas. The median MMR per 100,000 livebirths declined from 17.8 to no death in poor areas and from 16.3 to no death in non-poor areas. Difference in MMR between areas had not been found, however, the impact of MCH-PA programmes on maternal survivals was not significant and the gap between poor and non-poor areas had not gone closer with the estimated change trend of MMR from 2015 to 2020 (Table 2, Figure 2A).

The median NMR varied 1.59 times (P<0.01) between poor and non-poor areas of Yunnan in 2015 and 1.43 times (P<0.01) in 2020, whereas the median IMR varied 1.50 times (P<0.01) and 1.54 times (P<0.01), and the median U5MR varied 1.53 times (P<0.01) and 1.37 times (P<0.01), respectively. All the NMR (-11.1% vs -10.8%), IMR (-9.4% vs -9.3%), and U5MR (-7.8% vs -7.7%) per 1,000 livebirths had decreased faster in poor areas than those in non-poor areas. Although disparities remained between areas, the impacts of MCH-PA programmes on closing the gaps in child survivals across Yunnan were significant (P<0.01) (Table 2) which were showed obviously with the estimated change trend of NMR, IMR, and U5MR from 2015 to 2020 (Figure 2B-D).

Between 2015 and 2020, the prevalence rate of child underweight had significantly decreased in both poor areas (from 1.8% to 1.3%) and non-poor areas (from 2.0% to 1.5%), however, the prevalence rate of child stunted had only decreased in non-poor areas (from 1.9% to 1.4%). Oppositely, the percentages of children who were either overweight (from 0.4% to 0.5%) or obese (from 0.2% to 0.3%) had increased in poor areas at an annual rate of 0.1%, whereas there was no significant changes in non-poor areas. But children in non-poor areas were more likely to be stunted, overweight, or obese, compared to their counterparts in poor areas (P<0.01). Moreover, the proportions of anaemic children had decreased from 25.3% to 18.2% (annual rate of decline -1.2%) in poor areas of Yunnan during the same time period (Table 2).

Discussions

Ending poverty in all its forms is the first goal of UN SDGs.[1] Nearly 20 million people in China were victims of poverty or had returned to poverty because of illness in 2015, which accounted for 44.1% of the total number of poor population.[11] The poverty headcount ratio in rural China was 5.7% in 2015,[21] whereas the prevalence rates of poverty among women of childbearing age (15-59 years old) and children under 5 years old in rural Yunnan in the same year were 7.83% and 5.92%. The poverty headcount ratios among women and child being higher than the national average level indicated a greater impact of poverty on women and children in Yunnan. Our systematic assessment in Yunnan provides evidence of the positive effects of launching health programmes on preventing households from being trapped in or returning to poverty by decreasing maternal and child mortality and morbidity, as well as avoiding the catastrophic medical expenses because of illness, which is an important feature of China's poverty alleviation efforts and an useful measure to win the battle against poverty for whole China.

Remarkable progress in equitable maternal and child survival has been achieved in Yunnan, which is not only an outcome, but an essential component of poverty reduction. The maternal mortality rate fell to 12.42 deaths per 100,000 livebirths and under-5 mortality rate fell to 6.89 deaths per 1000 livebirths in 2020 in Yunnan, which had been below the national average for three consecutive years.[22] While the inequality in maternal mortality between poor areas and non-poor areas has disappeared, the gaps in child mortalities (including neonatal, infant, and under-5 child) across Yunnan have also been closing. The proportions of maternal deaths due to obstetric haemorrhage, neonatal and infant deaths due to preterm birth and low birth weight, and the preventable maternal deaths had decreased in poor areas between 2015 and 2020. China's efforts to improve maternal and child survival have been extraordinary and coherent. The progress presented by this research is not only past-depended but also boosted by China's Targeted Poverty Alleviation Strategy. Yunnan, as one of the most underdeveloped provinces in China, owned the most impoverished counties in 2014.[16]

The mountainous environment, cultural diversity, and weak service delivery at primary-level of Yunnan made people living in poor areas face a range of interrelated cultural, financial, geographical, and institutional barriers in seeking formal healthcare.[7] To defeat the vicious cycle of poverty and illness, especially among vulnerable populations like poor women and children, a series of MCH-PA programmes have been introduced in Yunnan to strengthen MCH system in poor rural areas by building infrastructures, improving human resources, expanding service coverage, and providing financial protection.[13]

The huge investments in the constructions of Emergency Obstetric Care Centre and Emergency Newborn Care Centre with the referral pathway across provincial-, prefecture-, and county- levels in Yunnan have guaranteed the timely rescue service providing to the pregnant and newborn in risk. To identify the high-risk pregnancy as early as possible, counterpart assistance programmes and special training had been conducted at primary-level for MCH human resource capacity building in rural Yunnan.[23] Hence, the densities of licenced doctors, nurses, obstetricians, and midwives, as well as township MCH workers and female village doctors had been increased substantially in poor areas between 2015 and 2020. The gaps had been narrowed not only in the quantity of health staff but also in the quality of them. There are now more township MCH workers with bachelor degree and female village doctors with high school degree in poor areas than those in non-poor areas. Township MCH workers and female village doctors play very important roles in MCH system who mainly participate in MCH programme implementation at primary level and special service provision such as birth companion and waiting room services for pregnant women at high-risk in remote and poor areas.[24] With the increase of both quantity and quality of MCH human resources, our DID statistical models showed the positive effect of MCH-PA programmes on expanding MCH service coverage in poor areas. Except for the proportions of facility birth, caesarean section, antenatal visit, and postnatal visit which had achieved the national average,[22] the proportions of prenatal screening and newborn diseases screening had increased in both poor and non-poor

areas to prevent birth defects, but much faster in poor areas. Otherwise, MCH-PA programme such as nutrition improvement for poor children, folic acid supplementation for poor pregnant women, and cervical and breast cancer screening for rural women at childbearing age had been delivered and enlarged in poor areas to prevent diseases or identify diseases at an early-stage, thus improving health among targeted populations.[25,26] The percentages of underweight children and anaemic children in poor areas of Yunnan had been decreased significantly between 2015 and 2020. Accessibility to essential health services are also improved by providing health insurance and financial assistance schemes.[27] With supports from MCH-PA programmes, all registered poor women and children are covered by a three-tiered financial protection strategy. The out-of-pocket payments for inpatient care for poor women and children with cancer or heart disease had been considerably decreased to 10% of total medical expenses which may greatly help them access high-quality treatments and avoid catastrophic medical expenses.[28]

Despite impressive progress in maternal and child survival has been made in Yunnan, the current research points out that insufficient MCH system inputs, unmet needs, and poor health outcomes still remain in small parts of poor areas in Yunnan. To maintain what have been achieved, the current MCH-PA programmes should be continued and enhanced for a sustainable improvement in accessibility to and affordability of high-quality MCH services, which may be one of the main focus areas of rural revitalisation after Chines government announced that all 98.99 million impoverished rural residents have been lifted from absolute poverty according to the current poverty line by February 25th, 2021.[29] In the present study, we found while the proportion of underweight children had decreased, the proportions of overweight (0.5%) and obese (0.3%) children had increased in poor areas in Yunnan. Although there was not a change, the proportions of overweight (1.4%) and obese (0.7%) children in non-poor areas were much higher than those in poor areas. Childhood obesity often start children on the path to health problems like diabetes, high blood pressure and high cholesterol.[30] Living in a healthy lifestyle including enough activity and limited calories from food and

drinks is what parents and children should be told through health education campaigns to prevent childhood obesity.[31]

Some interesting facts were found in the present study. While the numbers of live births increased in some areas mainly because of the universal two-child policy after 2015, there was a slight decrease trend in the numbers of live births in more areas between 2015 and 2020. To earn a living and shrug off poverty, there were more and more young rural-urban migrants in Yunnan, which could be an explanation of less babies born during the same period.[32] The next step towards rural revitalisation will involve upgrading economic activities and creating new jobs for young people in rural areas, which will be a long-term mechanism for stable poverty elimination.[33] Otherwise, we found the decrease trends in the numbers of facilities providing delivery services and caesarean sections in non-poor areas between 2015 and 2020. The Amended MCH Services Policy of Yunnan Province issued July 31st, 2019 re-emphasise that only the qualified health facility and staff can provide MCH services, with a legal permit.[34] To ensure the safeties of pregnant women and newborns, some of health facilities at primary-level had to strengthen their capacities to provide obstetric services.[4]

Our assessment was comprehensive and systematic, but the study design might have some limitations. First, mortality estimates were mainly based on the data from Yunnan Maternal and Child Health Routine Reporting System, which was possible for under-reporting of maternal and child deaths.[4] Especially, the deaths which had been missed were more likely to occur in the poor areas far away from health facilities, where people might die at home without recording. Second, the statistical standards had been changed in some of indicators of MCH service coverage in 2018, such as the proportions of five and more antenatal visits, first trimester antenatal visits, postnatal visits, and newborn visits. The updated statistical standards strictly require the timely full coverage, which means that only the MCH service provided in a specific time period can be counted.[35] Third, due to lack of some key variables at county- or township-level such as maternal illiteracy rates which are related with both poverty and health,[36,37] some potential

confounders were not controlled to adjust for DID estimations of MCH-PA programmes. Otherwise, MCH programmes which were ended before 2017 could have underscored the effect of the MCH-PA programmes implemented after 2017. Thus caution is needed in the interpretation of the effects of MCH-PA programmes on MCH indicators mentioned above across Yunnan between 2015 and 2020 provided by the present study.

Yunnan Province, as the main battlefield against poverty in China, has achieved remarkable progress in equitable maternal and child health, which is an essential component of great success in poverty alleviation in China. The practices in Yunnan have showed the Chinese model in ending poverty with health programmes, which may be summarised as firm commitment and determined leadership from the government at all levels, people-centred and problem-oriented health system strengthening, detailed and long-term health strategy blueprint, and social mobilisation and participation. China has its own poverty alleviation policies, derived from theory to practice and based on its own national conditions, which can provide new perspectives and useful references for other countries and regions in their battle against poverty.[33]

Funding and Data Sharing Statement

This study was not funded. Data used in this study are available in Yunnan Maternal and Child Health Routine Reporting System, Yunnan Health Statistical Yearbooks, Yunnan Statistical Yearbooks, and Yunnan Social Medical Insurance Reimbursement Datasets.

Contributors

HY designed the research protocol, constructed the database, developed the DID statistical model, interpreted the results, and drafted the article. XX and WY assisted with protocol design and development, data extraction and synthesis, results interpretation, and article revision. YQY, YZT, XLL, CSQ, LHF, WFF, CYY and ZDD were involved in compiling database, doing data analysis, and producing tables and graphs. ZQ, ZJR and GGP assessed the database, reviewed results, and revised article. LY proposed the study and oversaw database construction, models establishment, results interpretation, and article revision. All authors reviewed and approved the final submitted version.

Declaration of interests

We declare no competing interests.

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Ethics Approval Statement

This study does not involve human participants and ethical approval was not required.

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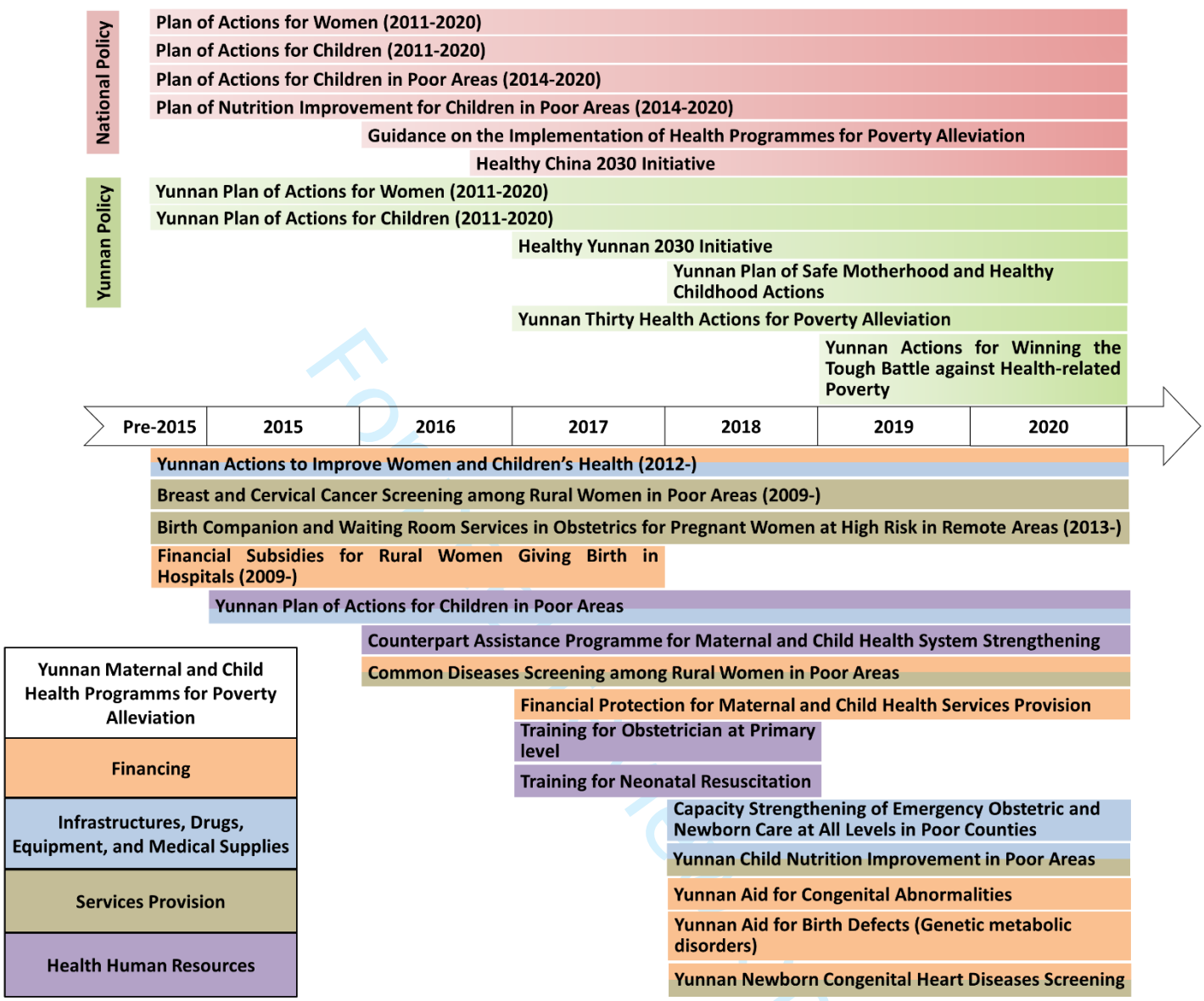


Figure 1 Timeline of Maternal and Child Health Policies and Programmes for Poverty Alleviation during 2015-2020 in Yunnan, China

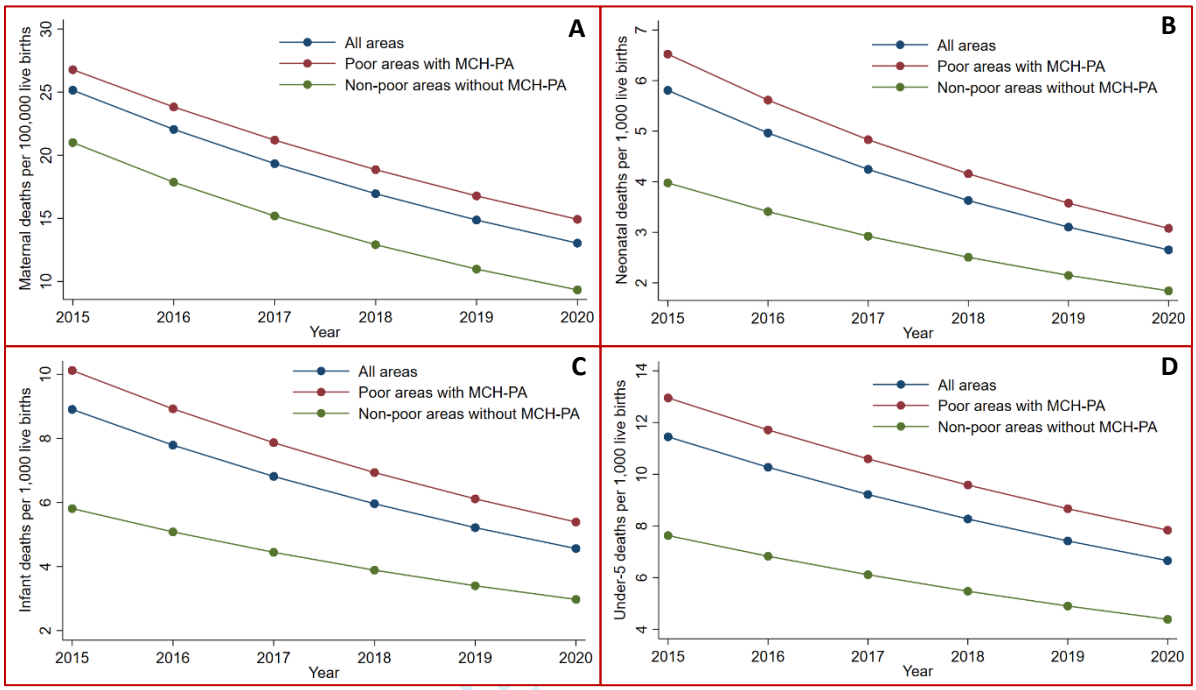
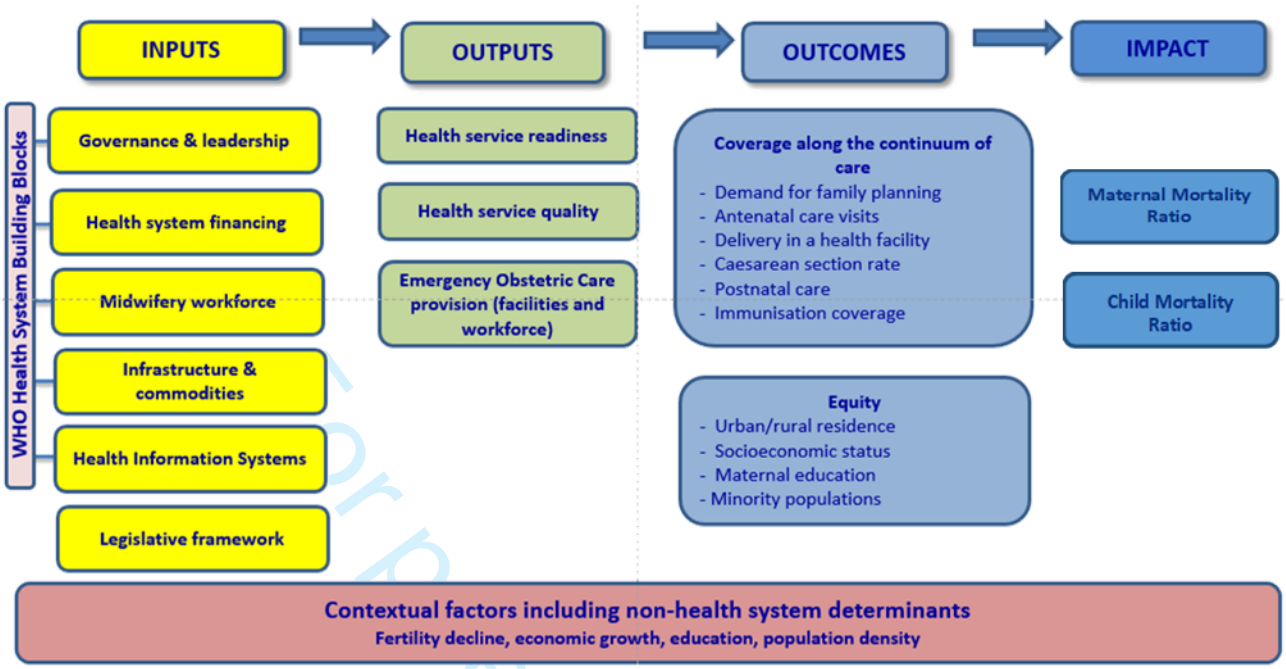


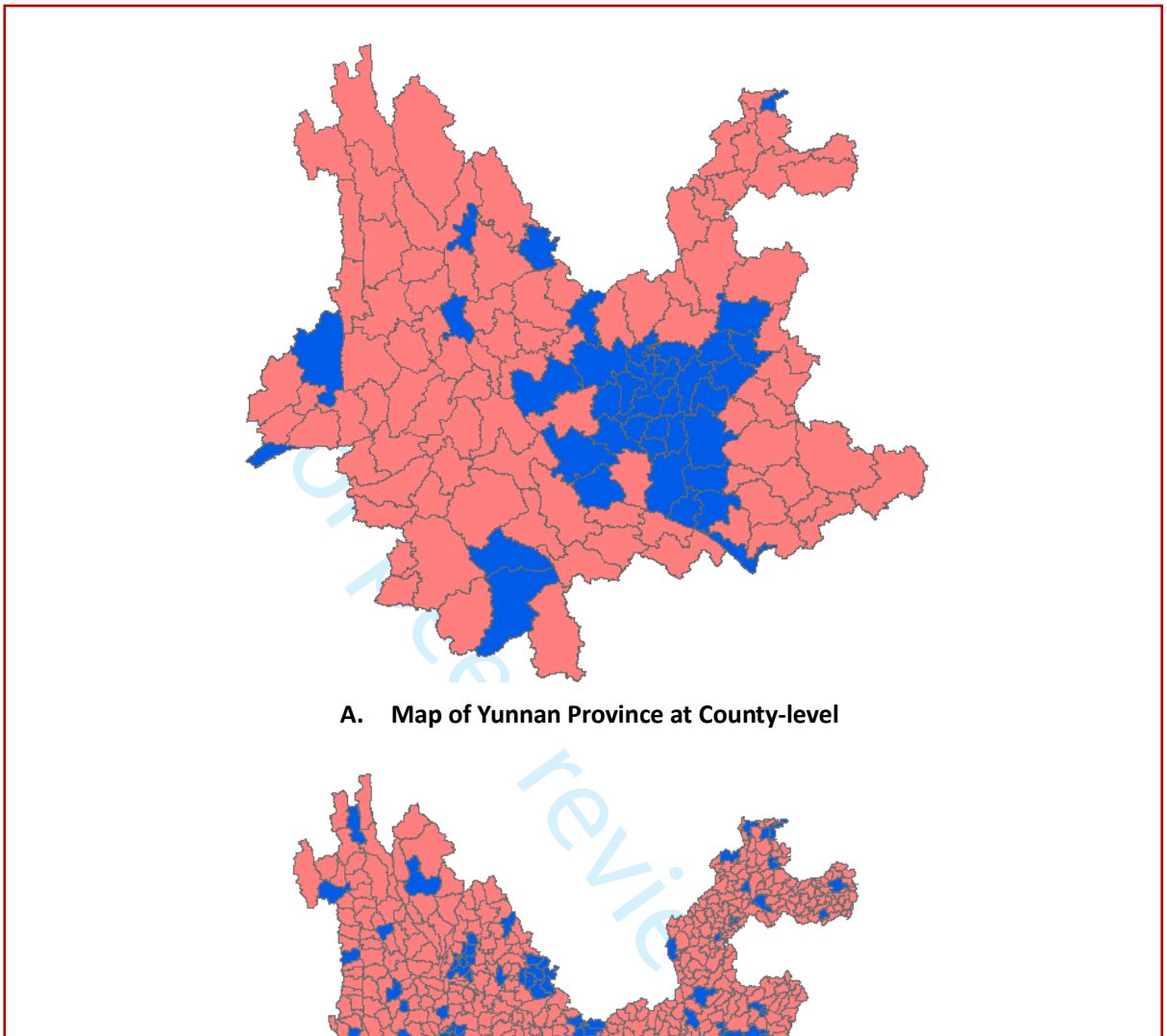
Figure 2 Estimated change trend of MMR (A), NMR (B), IMR (C), and U5MR (D) among all areas and areas with and without MCH-PA programmes from 2015 to 2020 in Yunnan, China

Note: MCH-PA indicates the maternal and child health programmes for poverty alleviation in Yunnan. MMR=maternal mortality rate. NMR=neonatal mortality rate. IMR=infant mortality rate. U5MR=under-5 mortality rate.

Appendix



Appendix Figure 1 Evaluation Framework Developed by Bryce et al (2013)



Appendix Figure 2 Map of Areas with and without MCH-PA Programmes at County- and Township-level in Yunnan Province

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Reported on page No/ line No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1, line 2-3 Page 3, line 11-12
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 3, line 7-26
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5, line 2-30 Page 6, line 1-16
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 6, line 18-25
Methods			
Study design	4	Present key elements of study design early in the paper	Page 7, line 22-30 Page 8, line 1-16
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6, line 29-30 Page 7, line 1-19
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Page 8, line 7-16
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 8, line 19-30 Page 9, line 1-20
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 8, line 19-30 Page 9, line 1-30 Page 10, line 1-28
Bias	9	Describe any efforts to address potential sources of bias	Page 10, line 17-28
Study size	10	Explain how the study size was arrived at	Page 8, line 7-16
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 9, line 23-30 Page 10, line 1-28
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 9, line 23-30 Page 10, line 1-28
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 8, line 1-16
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 12, line 28-30 Page 13, line 1-5
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Page 14-15, 17-18, and 20
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates	Page 16, line 1-24

		and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 17-18
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 22, line 9-30 Page 21, line 1-8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 25, line 17-30
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 24, line 14-30 Page 25 line 17-30
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 26, line 4-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 27, line 2

*Give information separately for exposed and unexposed groups.

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