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ORIGINAL ARTICLE

Has the Rate of Reduction in Infant Mortality Increased in India Since the Launch of National Rural Health Mission? Analysis of Time Trends 2000-2009 with Projection to 2015

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ABSTRACT

Objectives: National Rural Health Mission (NRHM) - India was launched in 2005 to tackle urban-rural health inequalities, especially in maternal and child health. We examined national and state level trends in Infant Mortality Rates (IMR) from 2000 through 2009 to: 1) assess whether the NRHM had increased the average annual reduction rate (AARR) of IMR 2) evaluate state-wise progress towards Millennium Development Goals (MDG4) and estimate required AARRs for 'off track' states.

Methods: Log-linear regression models were applied to national and state IMR data collated from the Sample Registration System (SRS)-India to estimate average annual reduction rates and compare AAARs before and after introduction of NRHM. The log-linear trend of infant mortality rates was also projected forward to 2015.

Results: The infant mortality rate in rural India declined from 74 to 55/1000 live births between 2000 and 2009, with AARR of 3.0% (95% CI=2.6%-3.4%) and the urban-rural gap in infant mortality narrowed (p =0.036). However there was no evidence (p=0.49) that AARR in rural India increased post NRHM (3.4%, 95% CI 2.0-4.7%) compared to pre NRHM (2.8%, 95% CI 2.1%-3.5%). States varied widely in rates of infant mortality reduction. Projections of infant mortality rates suggested that only eight states might be on track to help India achieve MDG4 by 2015.

Conclusions and Public Health Implications: Despite a narrowing urban-rural gap and high AARRs in some states, there was no evidence that the rate of reduction in infant mortality has increased in rural India post NRHM introduction. India appears unlikely to achieve child survival-related NRHM and millennium development goals. Government should revisit the child survival related NRHM strategies and ensure equitable access to health services. More robust monitoring and evaluation mechanisms must be inbuilt for following years.

Key Words: India • National Rural Health Mission • Infant Mortality Rate • Millennium Development Goals • Health Systems

Introduction

India's under-five mortality rate (U5MR) has declined by 32%; from 116 in 1990 to 66 per 1000 live births in 2009, placing it 48th globally[1]. However, the highest number (1.69 million) of under-five deaths globally continue to occur in India[2]. Nearly two thirds of these deaths are preventable with available interventions that can be implemented in low-income countries[3, 4]. India's progress has huge strategic importance in the global quest for Millennium Development Goals (MDG4). This largely depends on tackling infant mortality (forming >70% of all under five deaths[5-7]) in rural areas where >70% population lives and where the infant mortality rate (IMR) historically has stayed twice as high as urban areas (Figure 1).

National Rural Health Mission (2005-2012)

To address the striking urban-rural health inequalities[8], National Rural Health Mission (NRHM) was launched by the Government of India in April 2005.

Eighteen states with weak health infrastructure and indicators were categorized as High Focus states[9] (Fig 2). The key aim of NRHM is to reduce India's IMR from 58 in 2005 to 30/1000 live births by 2012, in order to reach MDG4[10].

Since the launch of NRHM, government reports[9, 11] and independent reviews[12-14] show a visible increase in the supply (increased 24 x 7 functioning health facilities-3- to 6-fold, drugs, consumables and flexible finances, additional 9,000 doctors, 60,000 nurses/ANMs and 690,000 ASHAs) and demand side (increased attendance to in-door and out-patients' departments and institutional deliveries) of health services. Going by the components of the health program (Figure 3), these NRHM reports and reviews provide useful insight into the input & pocess, output and outcome measures. However, despite the approaching NRHM deadline (2012), and considerable resource mobilization for improving childs, little is known about the extent to which these interventions have had an impact on infant mortality rates. The objectives of our study were to 1) describe time trends in infant mortality at national and state level between 2000 and 2009, 2) establish whether there was an increase in the annual average reduction rate (AARR) of IMR in rural areas, after the launch of NRHM and 3) to assess whether India and its states are likely to achieve the NRHM goal (national IMR of 30/1000 live births by 2012) or MDG4 (2/3rd reduction in baseline U5MR of 1990, by 2015). Since there is insufficient state-level U5MR information, we used IMR as an indicator.

Methods

NRHM was implemented in all states of India, so we were limited to performing a before- and after-comparison due to the lack of control areas. Infant mortality rate (IMR) was the dependent variable defined as number of deaths in children under one year of age per 1000 live births in that year.

Data

National and state level IMR data was derived from the Sample Registration System (SRS)[15]. Under SRS, panel household surveys are conducted for 1.5 million households with 7.1 million people living in 7,597 (as of year 2004) randomly selected villages (60%) and urban blocks (40%) spread across all states. The data collection involves continuous enumeration of births and deaths, which is cross verified and matched biannually (for detailed methods refer to: http://censusindia.gov.in/Vital_Statistics/SRS/Sample_Registration_System.aspx). The figures obtained from SRS are widely used by national and international development agencies and its U5MR data has been found particularly reliable[16]. Besides, SRS became an obvious choice since it is the only source providing yearly IMR estimates at the state level; including separate urban-rural figures. All of the data was compiled from online sources in the public domain. Please note, throughout this article we refer to aggregate urban and rural IMR figures as total IMR.

Analysis

Our analysis focused on average annual reduction rates (AARRs) which measure the average percent reduction in IMR per year. A positive value of AARR suggests average annual decrease in IMR and conversely negative AARR suggests an average annual increase. At both the national and state level, the analyses involved:

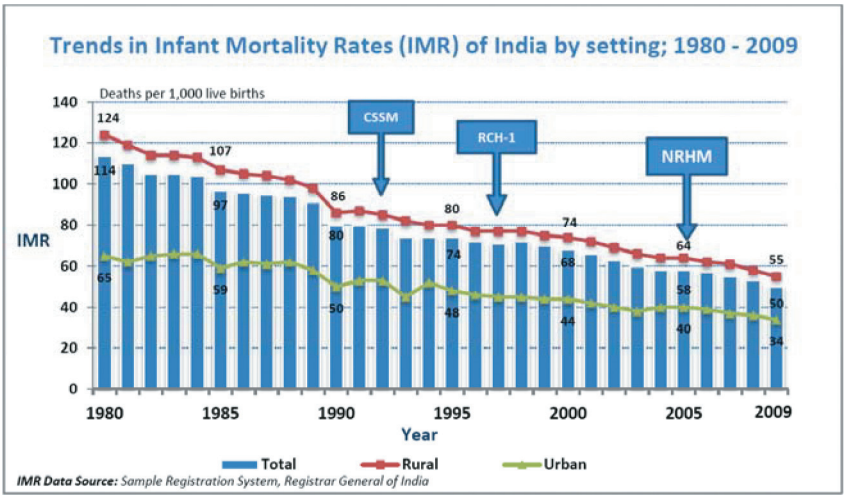

Figure 1. Spatial IMR Trends and Various Health Programs in India: 1980-2009. CSSM=Child Survival and Safe Motherhood; RCH-1=Reproductive and Child Health phase 1; NRHM=National Rural Health Mission.

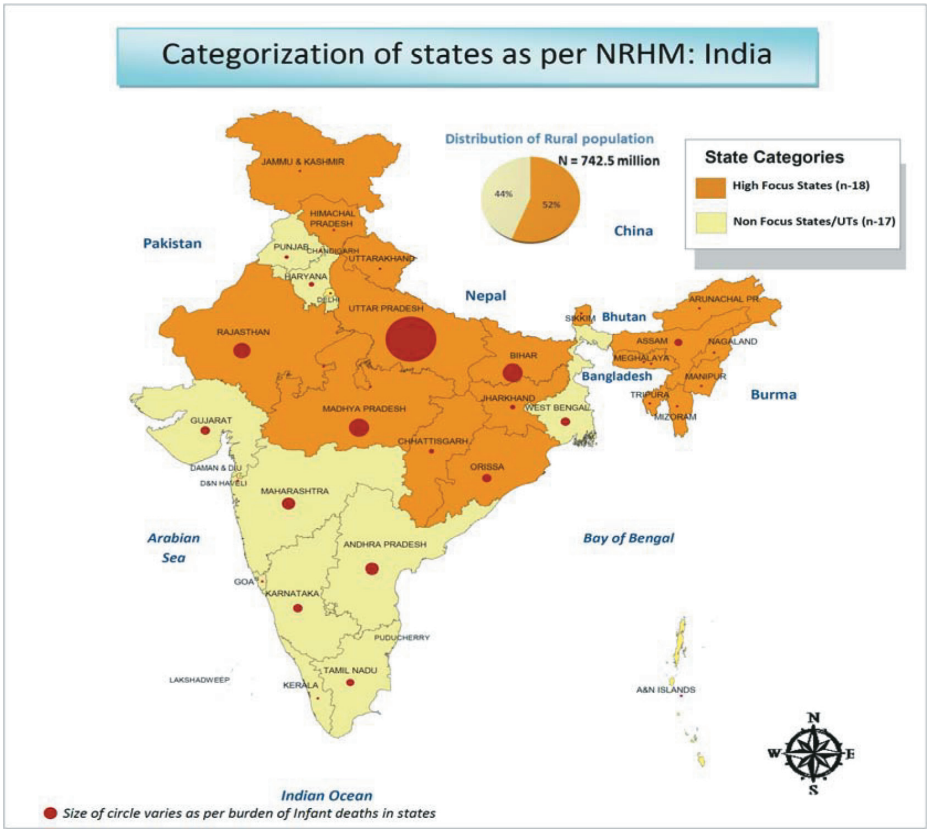

Figure 2. Categorization of States as per National Rural Health Mission (NRHM) and state-wise burden of infant deaths.

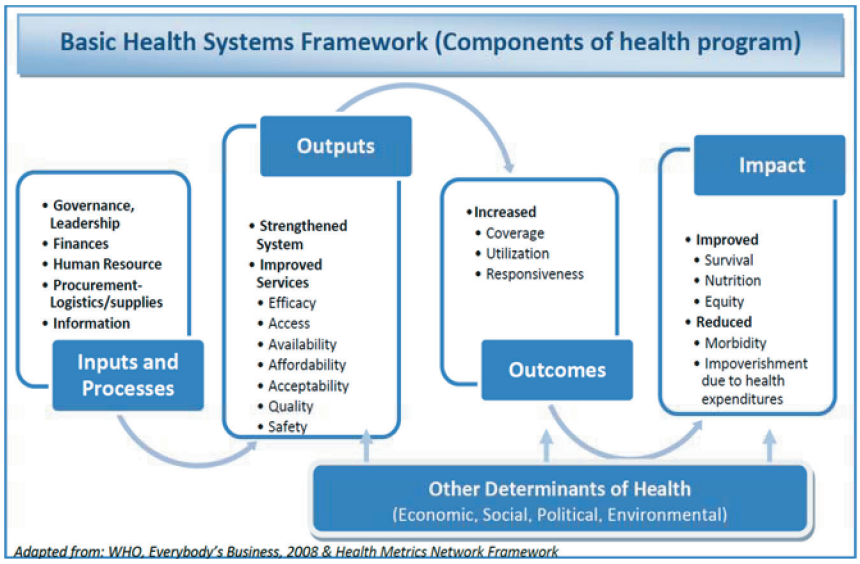

Figure 3. Basic Health Systems Framework

1) Descriptive analysis of AARRs for the period 2000-2009 using urban, rural and total IMRs;
2) Estimates of the absolute change in rate of IMR reduction in rural India using the separate AARRs for pre- and post-NRHM;
3) Forecasting total IMR up until 2015; estimating the required AARR in order to reach MDG4.

To compare IMR trends before and after NRHM, we used piecewise linear regression on log IMRs. This model assumes a single underlying linear trend during the pre-NRHM era up until the cut-off point followed by a different trend during the post-NRHM era. For pragmatic reasons, we pre-specified the cut-off point as exactly 6 months after the initiation date of NRHM for each state. For nation-wide analyses, we chose the launch date for NRHM as a whole, April 2005. 95% CIs for absolute differences and tests for no difference between AARRs before and after NRHM were calculated using the delta method[17]. Overall AARRs for the whole period from 2000 to 2009 were computed using simple linear regression on the log (rural) IMRs. Similar methods have been used earlier in Brazil and US[18-20]. We considered interrupted time series analysis and generalized linear mixed models (GLMM) as alternative analysis methods. However, it is difficult to estimate autocorrelation accurately with 9 observations per state and a Box-Ljung Q test[21] for auto-correlated errors indicated no reason for detailed time series modeling. The GLMM methods provided unacceptably large shrinkage in preliminary results wiping out between-state differences completely.

For forecasting we used simple instead of piecewise linear regression in order to limit the number of parameters. The extrapolated IMRs assume constant proportionate changes in trend for the annual IMRs from 2000 through to 2015. Since the actual IMR in 2015 is a random variable rather than a parameter, we obtain 95% reference ranges (RRs) in place of 95% CIs. We then assessed whether or not that state was 'on track'; i.e. likely to achieve 2/3 reduction in its 1990's baseline IMR, by 2015. Where the upper end of the projected RR fell below the 2015 target IMR, we took it as a clear evidence for that state being 'on track'. Where the lower end excluded the target IMR, we had clear evidence for the state being 'off track'. Where the RR included the target IMR, the state was 'potentially on track'.

Our projections were based purely on the assumption that the current IMR trends continue

Average Annual Reduction Rate of IMR
in Rural Areas of Indian States; 2000- 2009

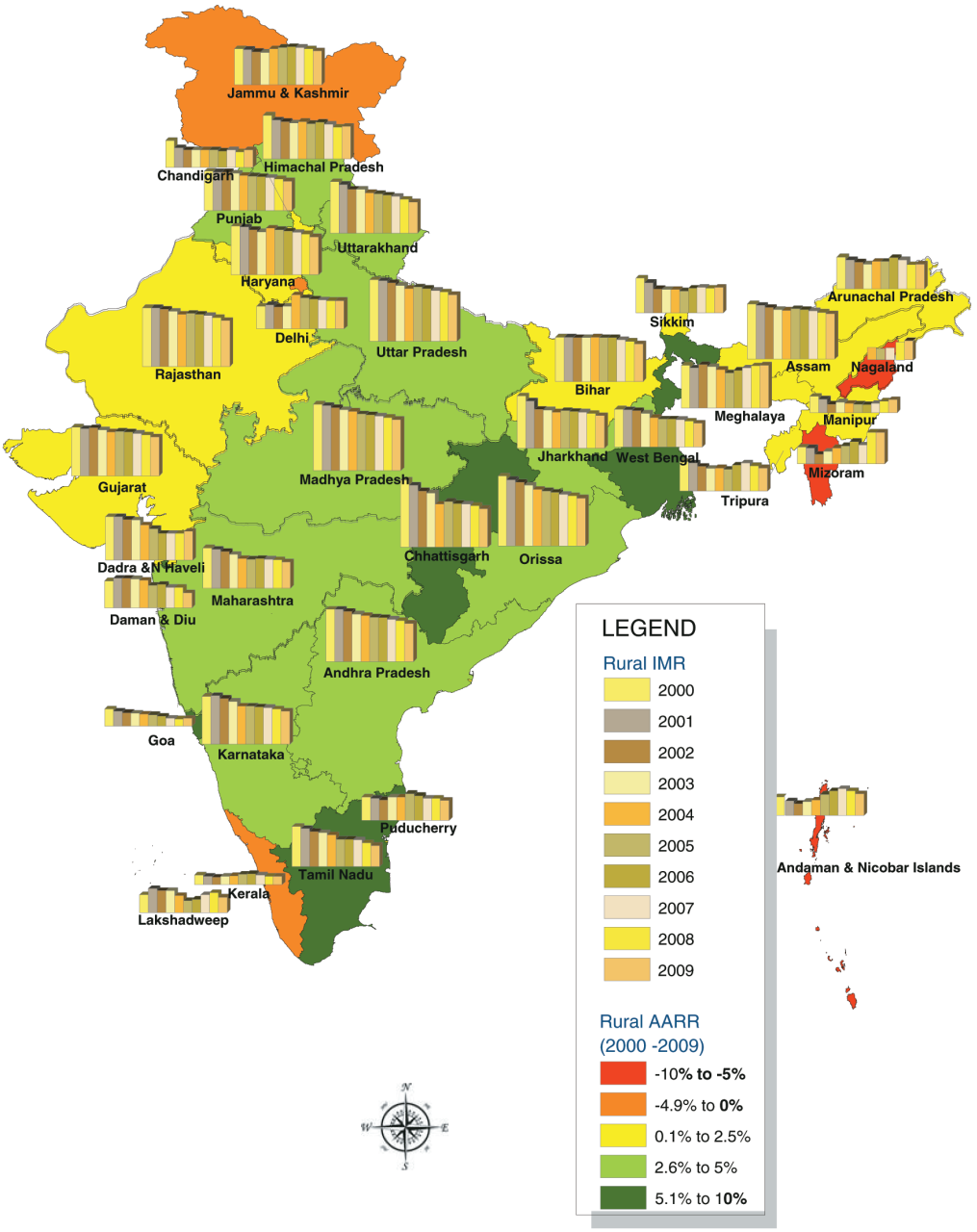

Figure 4. Map of India Showing Annual Average Reduction Rates in Infant Mortality Between 2000 and 2009. The color of state represents the AARR whereas the bars represent IMR for the period

Table 1. Overall Average Annual Reduction Rates (AARRs) in Infant Mortality Between 2000 and 2009; for India Total, Rural and Urban, as well as AARR for Rural Areas of the States

	AARR	95% CI
India total	3.10%	(2.6% to 3.5%)
India urban	2.10%	(1.3% to 2.9%)
India rural	3.00%	(2.6% to 3.4%)

High Focus States			**Non Focus States**		
	AARR	**95% CI**		**AARR**	**95% CI**
Chhattisgarh	5.70%	(4.1% to 7.2%)	Goa	9.10%	(7.4% to 10.8%)
Uttarakhand	5.00%	(4.3% to 5.6%)	Tamil Nadu	6.50%	(5.7% to 7.3%)
Jharkhand	4.10%	(2.3% to 5.9%)	Daman & Diu	6.20%	(3.5% to 8.9%)
Orissa	4.00%	(3.7% to 4.4%)	Dadra & Nagar Haveli	6.20%	(4.3% to 8.1%)
Madhya Pradesh	2.90%	(2.7% to 3.1%)	West Bengal	5.10%	(4.2% to 6.0%)
Uttar Pradesh	2.80%	(2.4% to 3.3%)	Maharashtra	4.60%	(3.4% to 5.8%)
Himachal Pradesh	2.70%	(1.6% to 3.7%)	Karnataka	4.20%	(3.4% to 5.1%)
Rajasthan	2.50%	(2.0% to 3.0%)	Chandigarh	3.40%	(0.6% to 6.1%)
Manipur	2.40%	(-3.7% to 8.2%)	Andhra Pradesh	3.40%	(3.0% to 3.8%)
Sikkim	2.30%	(-0.9% to 5.3%)	Lakshadweep	3.20%	(-2.1% to 8.2%)
Assam	1.90%	(1.3% to 2.4%)	Punjab	3.00%	(2.6% to 3.5%)
Bihar	1.50%	(0.6% to 2.4%)	Gujarat	2.30%	(1.8% to 2.8%)
Arunachal Pradesh	1.50%	(-0.8% to 3.7%)	Haryana	2.20%	(1.3% to 3.1%)
Tripura	1.10%	(-1.5% to 3.7%)	Puducherry	0.50%	(-1.9% to 2.8%)
Meghalaya	0.30%	(-1.6% to 2.0%)	Kerala	-0.50%	(-3.8% to 2.6%)
Jammu & Kashmir	-0.40%	(-1.8% to 1.0%)	Delhi	-3.20%	(-6.6% to 0.0%)
Mizoram	-9.80%	(-16.8% to -3.3%)	Andaman &	-6.80%	(-12.5% to -1.4%)
Nagaland*	-10.40%	(-18.3% to -3.1%)	Nicobar Islands		

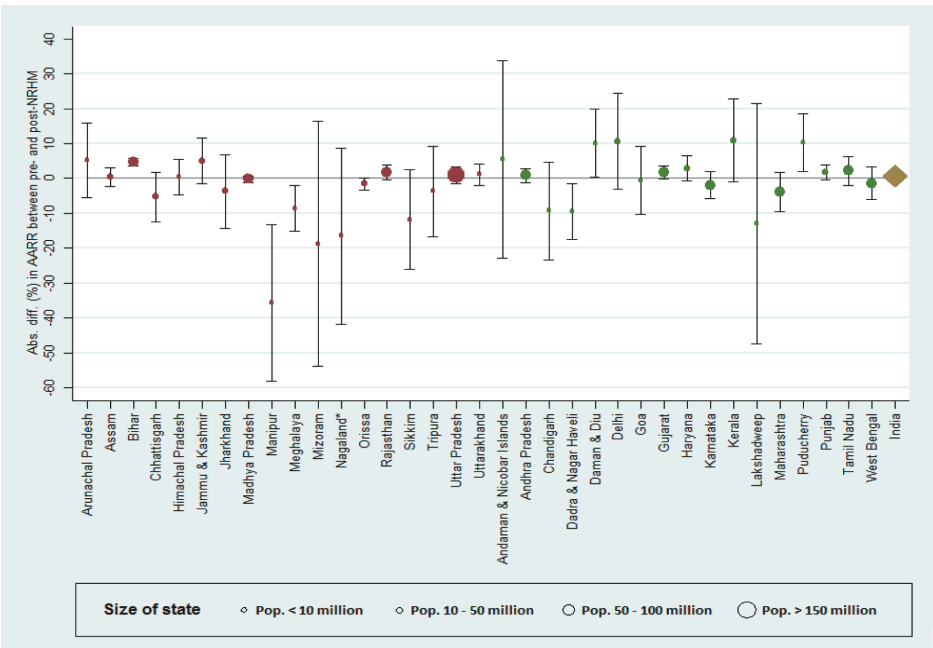

Figure 5. Absolute Differences in AARR Pre- and Post-NRHM Introduction by State.

Table 2. Average Annual Reduction Rates (AARRs) of Rural IMR Before and After the Implementation of NRHM, Along with Absolute Differences in AARR

	Pre NRHM AARR	Post NRHM AARR	Difference	P for Difference	95% CI
India rural	2.80%	3.40%	0.60%	0.49	(-1.3% to 2.4%)
India total	3.00%	3.30%	0.30%	0.71	(-1.7% to 2.4%)
High Focus States					
Arunachal Pradesh	0.20%	5.30%	5.10%	0.3	(-5.6% to 15.8%)
Jammu & Kashmir	-1.60%	3.40%	5.00%	0.12	(-1.5% to 11.5%)
Bihar	0.20%	4.80%	4.70%	<0.001	(3.6% to 5.7%)
Rajasthan	2.10%	3.70%	1.60%	0.11	(-0.5% to 3.7%)
Uttarakhand	4.60%	5.80%	1.20%	0.4	(-1.9% to 4.2%)
Uttar Pradesh	2.60%	3.50%	0.90%	0.4	(-1.5% to 3.4%)
Himachal Pradesh	2.50%	3.00%	0.50%	0.83	(-4.6% to 5.6%)
Assam	1.70%	2.20%	0.50%	0.7	(-2.3% to 3.2%)
Madhya Pradesh	2.90%	2.80%	-0.20%	0.63	(-1.1% to 0.7%)
Orissa	4.40%	2.80%	-1.60%	0.061	(-3.2% to 0.1%)
Tripura	2.10%	-1.60%	-3.70%	0.52	(-16.8% to 9.3%)
Jharkhand	4.80%	1.10%	-3.70%	0.42	(-14.3% to 6.8%)
Chhattisgarh	7.00%	1.70%	-5.30%	0.11	(-12.3% to 1.7%)
Meghalaya	2.30%	-6.30%	-8.60%	0.016	(-15.2% to -2.0%)
Sikkim	5.00%	-6.80%	-11.80%	0.085	(-26.1% to 2.5%)
Nagaland*	-0.50%	-17.00%	-16.50%	0.13	(-41.8% to 8.7%)
Mizoram	-5.40%	-24.20%	-18.80%	0.23	(-53.9% to 16.4%)
Manipur	9.30%	-26.30%	-35.60%	0.004	(-58.0% to -13.2%)
Non Focus States					
Kerala	-3.70%	7.20%	10.90%	0.071	(-1.0% to 22.7%)
Delhi	-6.00%	4.60%	10.60%	0.12	(-3.1% to 24.4%)
Puducherry	-2.10%	8.20%	10.30%	0.023	(2.1% to 18.5%)
Daman & Diu	3.50%	13.60%	10.10%	0.048	(0.4% to 19.8%)
Andaman & Nicobar Islands	-8.20%	-2.70%	5.50%	0.66	(-22.8% to 33.8%)
Haryana	1.30%	4.20%	2.90%	0.1	(-0.7% to 6.5%)
Tamil Nadu	6.10%	8.20%	2.10%	0.27	(-2.1% to 6.4%)
Gujarat	1.80%	3.60%	1.70%	0.073	(-0.2% to 3.7%)
Punjab	2.60%	4.30%	1.70%	0.085	(-0.3% to 3.7%)
Andhra Pradesh	3.20%	4.00%	0.80%	0.35	(-1.1% to 2.8%)
Goa	9.20%	8.70%	-0.60%	0.9	(-10.4% to 9.3%)
West Bengal	5.50%	4.10%	-1.40%	0.51	(-6.1% to 3.3%)
Karnataka	4.80%	2.80%	-2.00%	0.27	(-5.8% to 1.9%)
Maharashtra	5.50%	1.60%	-3.90%	0.144	(-9.5% to 1.8%)
Chandigarh	5.50%	-3.80%	-9.30%	0.151	(-23.3% to 4.7%)
Dadra & Nagar Haveli	8.10%	-1.40%	-9.50%	0.025	(-17.6% to -1.4%)
Lakshadweep	5.30%	-7.70%	-13.00%	0.38	(-47.4% to 21.5%)

Table 3. Projected and Target National and State-level IMRs for 2015. All reported state-level IMRs are total IMRs. Current and required AARRs are shown for states unlikely to achieve 2/3 reduction in IMR by 2015 as compared to the 1990 baseline. States are sorted in order of projected IMR

	IMR 1990	IMR 2009	Projectd IMR 2015	Projectd IMR 95% RR	Target IMR 2015	On Track?	Required AARR	2000-2009 Trend
India total	80	50	47	(40 to 46)	27	No	9.90%	3.10%
India rural	86	54	42	(45 to 51)	29	No	10.00%	3.00%
India urban	50	34	31	(29 to 36)	17	No	11.20%	2.10%
High Focus States								
Nagaland*	-	-	-	-	-	-	-	-
Madhya Pradesh	111	67	56	(54 to 58)	37	No	9.40%	2.90%
Assam	76	61	56	(51 to 61)	25	No	13.60%	1.90%
Meghalaya	54.3	59	55	(43 to 69)	18	No	17.90%	0.30%
Uttar Pradesh	99	63	54	(51 to 57)	33	No	10.20%	2.80%
Mizoram	15	36	51	(24 to 109)	5	No	28.00%	-9.80%
Orissa	122	65	51	(47 to 54)	41	No	7.50%	4.00%
Bihar	75	52	50	(45 to 56)	25	No	11.50%	1.50%
Jammu & Kashmir	45	45	49	(40 to 61)	15	No	16.70%	-0.40%
Rajasthan	84	59	49	(45 to 54)	28	No	11.70%	2.50%
Chhattisgarh	111	54	43	(35 to 53)	37	Maybe	6.10%	5.70%
Uttarakhand	99	41	40	(31 to 52)	33	Maybe	3.60%	5.00%
Himachal Pradesh	68	45	37	(33 to 43)	23	No	10.70%	2.70%
Jharkhand	75	44	34	(26 to 44)	25	No	9.00%	4.10%
Tripura	43	31	30	(21 to 42)	14	No	12.10%	1.10%
Arunachal Pradesh	63	32	29	(22 to 38)	21	No	6.80%	1.50%
Sikkim	37	34	25	(17 to 39)	12	No	15.50%	2.30%
Manipur	23	16	9	(5 to 18)	8	Maybe	11.50%	2.40%
Non Focus States								
Andaman & Nicobar Islands	30	27	48	(23 to 100)	10	No	15.30%	-6.80%
Haryana	69	51	44	(41 to 48)	23	No	12.40%	2.20%
Andhra Pradesh	70	49	42	(39 to 45)	23	No	11.60%	3.40%
Gujarat	72	48	41	(38 to 44)	24	No	10.90%	2.30%
Delhi	43	33	41	(31 to 53)	14	No	13.10%	-3.20%
Karnataka	70	41	35	(31 to 38)	23	No	9.00%	4.20%
Punjab	61	38	32	(29 to 35)	20	No	9.90%	3.00%
Puducherry	31	22	27	(20 to 37)	10	No	11.80%	0.50%
Chandigarh	32	25	26	(15 to 45)	11	No	13.20%	3.40%
West Bengal	63	33	24	(21 to 27)	21	No	7.30%	5.10%
Lakshadweep	27	25	24	(15 to 38)	9	No	15.70%	3.20%
Maharashtra	58	31	22	(19 to 25)	19	Maybe	7.60%	4.60%
Dadra & Nagar Haveli	78	37	21	(15 to 29)	26	Maybe	5.70%	6.20%
Tamil Nadu	59	28	20	(18 to 23)	20	Maybe	5.70%	6.50%
Daman & Diu	43	24	16	(11 to 23)	14	Maybe	8.20%	6.20%
Kerala	17	12	14	(9 to 22)	6	No	11.80%	-0.50%
Goa	21	11	7	(5 to 9)	7	Maybe	7.30%	9.10%

1990 IMRs for states with figures in brown were extrapolated using 1992-1994 figures as 1990 figures were unavailable.
Baseline IMRs for Madhya Pradesh, Bihar and Uttar Pradesh were used for Chhattisgarh, Jharkhand and Uttarakhand respectively as the latter states were carved out of the former.
* No projections done for Nagaland due to insufficient data.

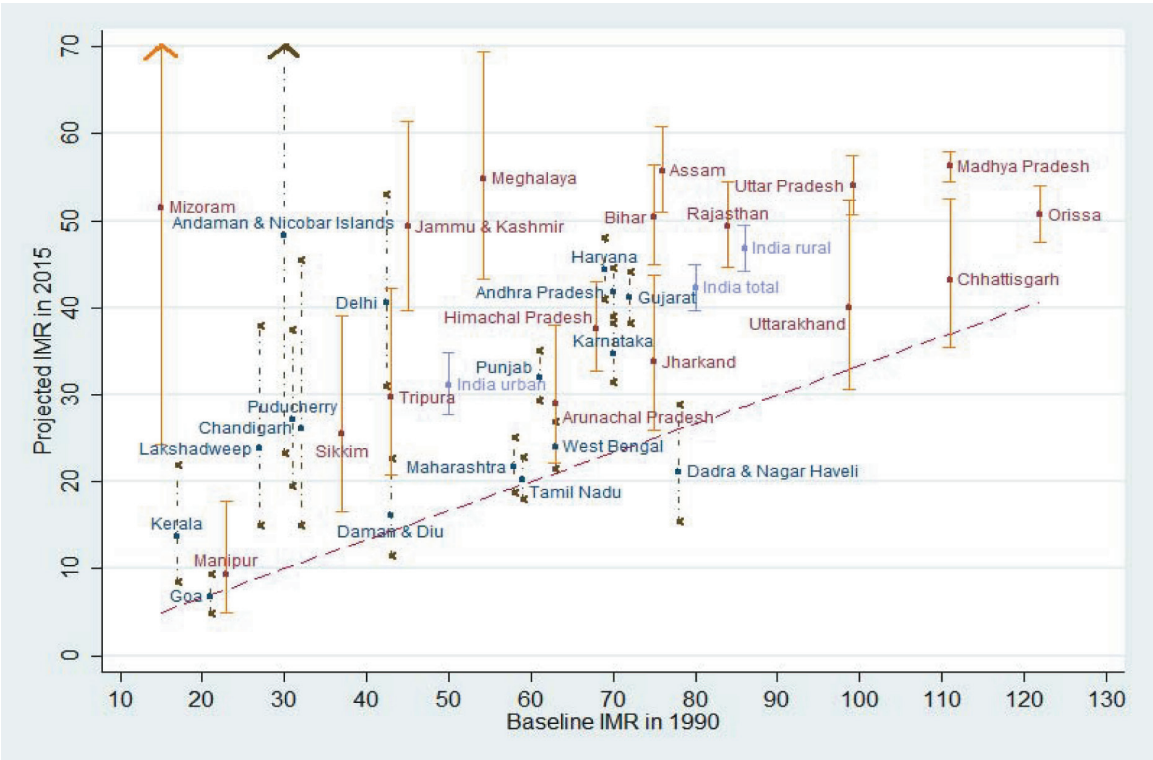

Figure 6. Statewise Projected Total IMRs and Reference Ranges (Brown lines for High Focus, Blue dotted lines for Non-Focus states) in 2015 against the Baseline IMR of 1990. The irregular diagonal line represents Two-third reduction cutoff and states with Reference ranges falling on or below this cutoff line are likely to achieve MDG4.

into the future. Given the scope of this research, no provisions were made for likely extrinsic shocks or influences of medical technology, demographic or radical behavioral or socioeconomic changes on future mortality. All statistical analyses were carried out in Stata11 and maps were created using Arc GIS 9.2

Results

India total

The total IMR in India decreased from 68 to 50 per 1000 live births between 2000 and 2009, with an AARR of 3.1% (95% CI=2.6% to 3.5%). The IMR declined with an AARR of 3.0% (95% CI =2.2% to 3.8%) during pre-NRHM era and 3.3% (95% CI=1.8% to 4.8%) in the post-NRHM era. There was no evidence that the rate of IMR reduction had increased in India after launch of NRHM (absolute difference 0.3%; p=0.71).

Rural and Urban India

Between 2000 and 2009, the IMR in urban areas declined by 21% from 43 to 34 per 1000 live births with an AARR of 2.1%, whereas in rural India it declined by 26% from 74 to 55 with an AARR of 3.0%. There is evidence that the urban-rural gap in IMR narrowed (p=0.036) with AARR in rural areas being nearly 1½ times higher than urban areas. However, there was no evidence that the rate of IMR reduction in rural India post-NRHM (3.4%, 95% CI=2.0%-4.7%) was larger than the pre-NRHM rate (2.8%, 95% CI=2.1%-3.5%, p=0.71 for a difference in rates).

Overall state trends for rural IMR 2000-2009

Table 1 shows AARR figures over the ten-year period between 2000 and 2009 for total,

rural and urban India, as well as for rural areas of all states in descending order of AARR. A declining IMR trend was observed in most Indian states (see web appendix). Relative declines in IMR were highest in Goa (AARR 9.1%; 95% CI=7.4 to 10.8%) and Tamil Nadu (AARR 6.5%; 95% CI =5.7% to 7.3%) for Non Focus States; Chhattisgarh (AARR 5.7%; 95% CI=4.1% to 7.2%) and Uttarakhand (AARR 5.0%; 95% CI=4.3% to 5.6%) for High Focus States. Nine states showed no clear evidence of change in IMR: Manipur, Sikkim, Arunachal Pradesh, Tripura, Meghalaya, Jammu & Kashmir, Lakshadweep, Puducherry and Kerala. There was evidence for negative AARRs in 4 states suggesting the underlying trend in IMR increased rather than decreased; by 10.4% per year (95% CI=3.1% to 18.3%) in Nagaland, 9.8% per year (95% CI=3.3% to 16.8%) in Mizoram, 6.8% (95% CI 1.4% to 12.5%) in Andaman and Nicobar islands and 3.2% (95% CI=0.0% to 6.6%) in Delhi.

There was no clear evidence for a change in trend in all except two states; for Bihar AARR increased by 4.7% from 0.2% pre-NRHM to 4.8% post-NRHM ($p<0.001$; 95% CI=3.6% to 5.7%) and for Manipur AARR reversed from an annual reduction of 9.3% to an annual increase in IMR of 26.3% post-NRHM ($p=0.004$; 95% CI=13.2% to 58.0%). For three states, we found weak evidence for a difference; the estimated trend in IMR in Meghalaya was an annual decrease of 2.3% during the pre-NRHM era and -6.3% post-NRHM ($p=0.016$; 95% CI for difference = -15.2% to -2.0%), for Puducherry the AARR changed from -2.1% during the pre-NRHM era to 8.2% post-NRHM ($p=0.023$; 95% CI=2.1% to 18.5%), for Daman and Diu from 3.5% to 13.6% ($p=0.048$; 95% CI=0.4% to 19.8%) and for Dadra & Nagar Haveli from 8.1% to -1.4% ($p=0.025$; 95% CI=-17.6% to -1.4%).

Projections

Table 3/Figure 6 shows projected national and state-level IMR figures for 2015. India appears unlikely to achieve either the NRHM goal of reducing IMR to 30 by 2012 or MDG4 of reducing IMR to 27/1000 live births by 2015. The predicted total IMR for 2015 is 47 (95% RR=40 to 46) - 74% higher than the target. In order to achieve MDG4, an AARR of 9.9% is needed between 2009 and 2015, which is more than triple the AARR of 3.1% between 2000 and 2009.

At the state-level, no state was clearly `on track' for 2/3 reduction in IMR compared to the 1990 baseline by 2015; Dadra & Nagar Haveli, Tamil Nadu, Maharashtra, Chhattisgarh, Uttarakhand, Jharkhand, Manipur and Daman & Diu are `potentially on track'. The remaining states were `off track'. For detailed figures, please refer to Table 3.

Discussion

Our analysis showed that India's IMR in rural areas declined with an AARR of 3.0% between 2000 and 2009, significantly higher than the AARR of 2.1% in urban India. There was evidence suggesting that the nation-wide urban-rural gap in IMR has narrowed over this period. However, we found no evidence to suggest that the AARR at both the rural or national level had increased after the launch of NRHM in comparison to the AARR of the pre-NRHM era. Our projections of IMR suggested that despite good progress in some states, India is unlikely to achieve child health related NRHM or Millennium Development Goals.

A recent multinational study[22] suggested similar findings for India's country level child mortality trends. The persistent decline in infant mortality rates over the past decade may be attributed to economic growth, better living standards, improved drinking water sources and sanitation facilities[23], increased maternal literacy rates and availability and utilization of healthcare services[24-26]. However, there were considerable variations at state level. The increasing IMR trends in Mizoram and Nagaland and stagnation in Jammu and Kashmir may be explained by ongoing political instability, which could have led to disruption of healthcare and other public services. Kerala on the other hand already had low IMR and further decline would need substantial efforts. However, there was no clear explanation for other states, for example, the increasing IMR trends in Andaman & Nicobar and Delhi.

Claeson et al. quoted a narrowing urban-rural gap in IMR for 1990-2000[27]; we found strong evidence that this trend continued in the following years. This tapering might be explained by greater proportionate increase in standards of living, literacy rates, and utilization of MCH services in rural areas[24-26]; whereas, owing to

Web Appendix-I

Infant Mortality Rates (IMR), India and its states; 2000 to 2009

Year	2000			2001			2002			2003			2004			2005			2006			2007			2008			2009		
State	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
Andaman & Nicobar Islands	23	27	10	18	21	8	15	17	10	18	20	11	19	22	11	27	30	18	31	35	21	34	38	23	31	35	23	27	31	20
Andhra Pradesh	65	74	36	66	74	39	62	71	35	59	67	33	59	65	39	57	63	39	56	62	38	54	60	37	52	58	36	49	54	35
Arunachal Pradesh	44	45	11	39	41	11	37	38	12	34	35	11	38	39	17	37	39	17	40	44	19	37	41	15	32	34	19	32	35	14
Assam	75	78	35	73	76	33	70	73	38	67	70	35	66	69	38	68	71	39	67	70	42	66	68	41	64	66	39	61	64	37
Bihar	62	63	53	62	63	52	61	62	50	60	62	59	61	63	47	61	62	47	60	62	45	58	59	44	56	57	42	52	53	40
Chandigarh	28	38	26	24	28	23	21	25	21	19	25	18	21	25	20	19	25	18	23	23	23	27	25	28	28	22	29	25	25	25
Chhattisgarh	79	95	49	76	88	56	63	80	59	70	77	55	60	61	52	63	65	52	61	62	50	59	61	49	57	59	48	54	55	47
Dadra & Nagar Haveli	58	62	14	58	62	9	56	58	21	54	57	19	48	50	21	42	45	29	35	38	24	34	38	18	34	38	20	37	41	24
Daman & Diu	48	38	57	40	42	35	42	42	43	39	41	38	37	39	35	28	32	21	28	33	18	27	29	23	31	29	36	24	21	30
Delhi	32	32	32	29	34	28	30	31	30	28	32	28	32	48	30	35	44	33	37	42	36	36	41	35	35	40	34	33	40	31
Goa	23	24	21	19	21	16	17	19	14	16	18	14	17	17	16	16	16	15	15	14	16	13	11	13	10	10	11	11	11	10
Gujarat	62	69	45	60	67	42	60	68	37	57	65	36	53	62	38	54	63	37	53	62	37	52	60	36	50	58	35	48	55	33
Haryana	67	69	57	65	68	54	62	64	51	59	61	49	61	66	47	60	64	45	57	62	45	55	60	44	54	58	43	51	54	41
Himachal Pradesh	60	62	37	54	55	32	52	53	28	49	51	26	51	53	23	49	50	20	50	52	26	47	49	25	44	45	27	45	46	28
Jammu & Kashmir	50	51	45	48	50	39	45	47	34	44	46	32	49	51	37	50	53	39	52	54	38	51	53	38	49	51	37	45	48	34
Jharkhand	70	74	48	62	67	40	51	55	33	51	54	34	49	51	34	50	53	33	49	52	32	48	51	31	46	49	32	44	46	30
Kerala	14	14	14	11	12	9	10	11	8	11	12	10	12	13	9	14	15	12	15	16	12	13	14	10	12	12	10	12	12	11
Karnataka	57	68	24	58	69	27	55	65	25	52	61	24	49	54	38	50	54	39	48	53	36	47	52	35	45	50	33	41	47	31
Lakshadweep	27	25	29	33	34	33	25	31	18	26	31	21	30	24	37	22	17	27	25	19	31	24	25	23	31	28	35	25	22	28
Maharashtra	48	57	33	45	55	27	45	52	34	42	48	32	36	42	27	36	41	27	35	42	26	34	41	24	30	40	23	31	37	22
Meghalaya	58	61	32	56	57	41	61	62	49	57	59	44	54	55	43	49	50	42	53	54	43	56	57	46	58	60	43	59	61	40
Mizoram	21	24	15	19	23	12	14	14	14	16	18	14	19	23	13	20	26	10	25	32	13	23	27	16	37	45	24	36	45	19
Manipur	22	23	25	20	119	23	14	12	21	16	15	19	14	13	19	13	12	14	11	11	11	12	13	9	14	16	8	16	18	11
Madhya Pradesh	88	94	54	86	92	53	85	89	56	82	86	55	79	84	56	76	80	54	74	79	52	72	77	50	70	75	48	67	72	45
Nagaland	.	.	23	.	.	13	.	.	20	.	.	16	17	17	16	18	17	22	20	18	27	21	18	29	26	25	28	26	27	23
Orissa	96	99	66	90	94	60	87	90	56	83	86	55	77	80	58	75	78	55	73	76	53	71	73	52	69	71	49	65	68	46
Puducherry	23	33	15	22	31	15	22	29	17	24	33	17	24	33	19	28	38	22	28	35	24	25	31	22	25	31	22	22	28	19
Punjab	52	56	38	51	55	37	51	55	35	49	53	34	45	50	36	44	49	37	44	48	38	43	47	35	41	45	33	38	42	31
Rajasthan	79	83	58	79	83	57	78	81	55	75	78	53	67	74	43	68	75	43	67	74	41	65	72	40	63	69	38	59	65	35
Sikkim	49	49	36	42	43	31	34	34	25	33	33	23	32	33	20	30	31	15	33	35	16	34	36	20	33	35	19	34	36	21
Tamil Nadu	51	57	38	49	54	35	44	50	32	43	48	31	41	45	35	37	39	34	37	39	33	35	38	31	31	34	28	28	30	26
Tripura	41	42	32	39	40	30	34	35	32	32	32	31	32	33	29	31	31	29	36	37	30	39	40	32	34	36	26	31	33	20
Uttarakhand	50	73	26	48	69	26	41	62	21	41	62	21	42	57	22	42	56	19	43	54	22	48	52	25	44	48	28	41	44	27
Uttar Pradesh	83	87	65	82	86	62	80	83	58	76	79	55	72	75	53	73	77	54	71	75	53	69	72	51	67	70	49	63	66	47
West Bengal	51	54	37	51	53	38	49	52	36	46	48	34	42	42	32	38	40	31	38	40	29	37	39	29	35	37	29	33	34	27
India	68	74	43	66	72	42	63	69	40	60	66	38	58	64	40	58	64	40	57	62	39	55	61	37	53	58	36	50	55	34

** Data Source: Sample Registration System, India*

** IMR data seggregared byurban-rural not available for Nagaland from yrs 2000-03*

** IMR data is expressed per 1000 live births*

high migration, the number of urban poor living under unhygienic and crowded conditions has grown[28, 29]. The higher IMR in these populations might be diluting the overall AARR for urban India. The AARR in IMR at state level did not show clear evidence of change except in Bihar, where it increased by 4.7 percentage points and Manipur where it decreased by 35.6 percentage points. However, it would be premature to attribute this to NRHM and will require further analysis of contributing factors. Note that Manipur had already achieved quite low IMRs and hence small absolute changes in IMR could have resulted in large relative shifts.

Despite apparent increases in service provision, delivery and utilization since launch of NRHM, we found no evidence for an increase in the rate of IMR reduction. A few possible explanations:

Firstly, healthcare alone does not exclusively determine infant mortality[30]. At the same time, access to and utilization of healthcare does not guarantee quality and equity[31]. The utilization of reproductive and child health services historically has stayed at a low level amongst the poorest wealth quintile[23, 32], which has the highest infant mortality[23, 33]. There is a possibility of continuing inadequate access and utilization by these groups, even post NRHM. Lim et al.'s evaluation of the NRHM's JSY (conditional cash transfer scheme) also suggested that the poorest and the least educated women had the lowest odds of receiving payments[35]. Secondly, problems were reported with regards to scale-up of NRHM across states, inadequacies in human resources & infrastructure, poor convergence, lack of community participation and funds flow mismanagement[14]. Gaps in the health budget[34], operational issues[35, 36] and lack of public health capacity in India[37, 38] could have had detrimental effects on roll out, implementation and management of this huge program. Finally, a longer time lag may be required to observe the effects of NRHM; however, cluster randomized control trials in high burden states of India using community based approaches analogous to NRHM strategies, have shown large reductions in infant and neonatal mortality over a period of two-three years[39-41].

Our projections for India's likelihood of achieving MDG4 were similar to WHO's report which suggests 'insufficient progress'[42]. Another study made similar projections for 2003 to 2015[43]. The projections showed a clear need to increase AARR in all except eight states. The High Focus States of UP, Bihar, Madhya Pradesh, Rajasthan and Orissa will have to increase AARRs by 2 to 7-fold. Pregress in these states will play a crucial role in India's endeavor to achieve MDG4, since they share two thirds of all infant deaths.

Limitations

We only used data from India's Sample Registration System (SRS). However, validity assessments have shown that surveys may underestimate neonatal deaths[44]. Any errors in SRS data could have led to over- or underestimation of AARRs and IMR projections. For evaluating progress towards MDG4, IMR was used as a proxy for U5MR. Hence, we advise interpreting the figures for 'required AARR' with care; U5MR may not decline at proportionate rates to IMR, between 2010 and 2015. In addition, we note a few statistical points. Large numbers of tests have inflated type I error; p-values near 0.05 should be considered weak, suggestive evidence. Bonferroni correction suggests $p<0.0014$ provides strong evidence, but this is not a strict law. Further, we assumed a piecewise linear dependency of log IMR on time correctly modeled the underlying trend of IMRs. For states with complex trend patterns (Andaman and Nicobar, Delhi, Jammu and Kashmir, Kerala, Lakshadweep and Mizoram) lower significance provided an adjustment for the lack of fit, but this adjustment was not rigorous. Finally, for some of the states, we got wide CIs/RRs. We believe this reflected genuine uncertainty due to measurement error and large state-level variability in IMR across time.

Conclusions and Public Health Implications

There were wide differences in the AARRs of various states underpinning varied levels of progress. However, there was clear evidence of increasing IMR trends in some states and UTs; the central and governments of high Focus North Eastern states need to closely monitor the program implementation while maintaining high levels of commitment and ownership. We specifically recommend assessing the equity of access and utilization of NRHM services. This needs to be followed up by strengthening of the mechanisms to ensure that quality services are available and accessible to the most needy

and vulnerable groups. In general, we note that Manipur, Goa, Dadra and Nagar Haveli, Tamil Nadu and Maharashtra are likely on target to help India achieve MDG4. While socioeconomic and political factors probably played an important role in the progress of these states, it would also be worth exploring the role of governance, specific strategies and health delivery systems in these states. Best practices and lessons learnt can be extrapolated to other states after assessing local capacity and needs. Similarly, it would be pertinent to investigate the reasons contributing to Bihar's success in accelerating child survival post-NRHM introduction. This study provides insight into state level IMR trends for recent years. Similarly, it explores the effectiveness of NRHM in terms of impact rather than output indicators which were previously unavailable. It will enable policy makers and health care providers to allocate resources efficiently and fine-tune prioritization of states. The study provides a basis for hypothesis formulation that may subsequently be tested in future evaluations thus improving operationalization of NRHM and eventually child survival.

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