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The state of the Indian States (1992-2016): Trend and variation in performance in reducing infant and child mortality.

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Abstract

Objectives

This paper analyses the patterns and trends in the mortality rates of infants and children under the age of five years in India (1992-2016) and quantifies the variation in performance between different geographic states.

Methods

The analysis of this paper uses the National Family Health Surveys (NFHS) I, III, and IV survey data. Variation in performance of states has been captured by use of Funnel plots. Subsequently, Cox regression analysis has been employed to examine the factors associated with infant deaths in under and well performing states.

Results

Through the use of maps, this paper clearly shows that the overall trend in infant and child mortality is on the decline in India. Computation of relative change shows that majority of the states have witnessed over 50% reduction in both IMR and U5 MR from NHFS-I to NHFS-4. However, the improvements are not evenly distributed and there is huge variation in performance between states over time. Funnel plots show that the most populous states like Uttar Pradesh Bihar and Madhya Pradesh have underperformed consistently across the survey period from 1992 to 2016. Regression analysis comparing high and low performing states revealed that female infants and women with shorter birth intervals had greater risk of infant deaths in poor performing states.

Conclusion

Attempts to reduce infant and child mortality rates in India are heading in the right direction. Even so, there is huge variation in performance between states. This paper recommends a mix of strategies that reduce child and infant mortality among the high impact states where the biggest improvements can be expected including the need to address neonatal mortality.

Key words: Infant and child mortality rate, performance of Indian states, funnel plots, Cox regression model, relative change, India.

Strengths and limitations of this study

- Trend in infant and U5MR from 1992-2016 using latest NHFS data released in Jan 2018.
- Innovative approach to quantify variation in performance of states with respect to child mortality rates using Funnel Plots.
- Factors associated with infant deaths like education, birth spacing, wealth index, etc. are know from previous studies. However, how these factors act differently in under and well performing states is not know which has been attempted in this study.
- The need to adopt differential policy response in under and well performing states and the challenge to address high neonatal mortality is discussed.
- Mortality rate may be affected as cross sectional data used and information related to age of child collected retrospectively.

INTRODUCTION

Child health is a basic right and the level of child mortality is an important indicator in the assessment of the development of any society .[1] It is therefore not surprising that the United Nations' Sustainable Development Goals declaration (2015) to improve the health and welfare of the world's poorest people includes reducing child mortality as one of its goals which was earlier laid out by Millennium Development Goal's (MDG) declaration (1990).[2] Annually, 5.6 million children under the age of five years die worldwide, primarily in developing countries[3] Given that most of these deaths can be easily prevented or treated [4] with cheap and effective interventions, such high mortality is unacceptable even in resource constrained settings.

India is the world's largest democratic nation with 16% of the global population. According to UNICEF, India has the highest number of under five deaths, with a total of 1.08 million deaths in 2016.[5] It is one of the six countries that contributes to 50% of the world's under five mortality rate (U5MR).[5] On its own, India contributes to 19 % of all under five deaths and 24% of all neonatal deaths.[5] However, infant mortality rate (IMR) and U5MR have declined over the years in India. For example, the U5MR reduced from 114 per 1000 live births in 1990 to 39 in 2016 at a rate of 3% annually.[5] Similarly, the IMR reduced from 81 to 34 per 1000 live births between 1990 and 2016.[5] However, the distribution of these gains is uneven across states.[6] For example, at the national level, U5MR is estimated at 39 and it varies from 43 in rural areas to 25 in urban areas. Among the bigger States/UTs, it varies from 11 in Kerala to 55 in Madhya Pradesh.[6] Similary, at the National level, IMR is reported to be 34 and varies from 38 in rural areas to 23 in urban areas. Among the four most populated states, it varies from 38 in Bihar to 47 in Madhya Pradesh.[6]

Healthcare in India is the responsibility of individual states, which vary in terms of their level of socio-economic development, size of population, experience of epidemiological transition, and health system capacities, factors which influence the health status experienced by the population of the states. On the one hand, states like Kerala experience relatively low levels of infant and child mortality comparable with the Western world, whereas states like Madhya Pradesh and Uttar Pradesh suffer IMRs and U5MRs comparable with some of poorest countries of the world.[7] It is therefore necessary to disaggregate the mortality data and quantify the variation between states. This would help policy makers to prioritise the underperforming states where intense efforts need to be expanded.

By providing the current status of child mortality through the use of maps, and undertaking a disaggregate analysis of infant mortality using the funnel plot technique, this paper identifies key states where performance needs to improve significantly, and the states that should be the target of intense efforts in the future. Funnel plots are an attractive way to present data to policy makers and a good tool to compare performance data, including population data.[8] Funnel plots have been used in the developed world in a number of settings including assessing institutional performance[9], comparing health care providers[10], and assessing the variations in cardiac[11-12] and cancer mortality[13-14]. However, to the best of our knowledge the

application of this technique to child mortality rates in the context of the developing world has not been previously conducted.

This paper is timely in that the NHFS-4 survey data (2015-16) has just been released in January, 2018. In addition, India is the highest contributor to the U5MR in the world and with new impetus in reducing child and maternal mortality, the rest of the world is closely monitoring India's performance.

METHODS

Data

The analysis of this paper is based on the three rounds of National Family Health Surveys (NFHS), NFHS-I, III, and IV data which were conducted during the periods between 1992-93, 2005-06 and 2015-16. For pragmatic reasons, NHFS-II survey data conducted in 1998-99 has been intentionally excluded from our analysis. The International Institute for Population Sciences is designated as a nodal agency for conducting the survey under the stewardship of the Ministry of Health and Family Welfare, Govt. of India. The National Family Health Surveys series provides information on population, health and nutrition for India and each State / Union territory. NFHS-4 gathered information from 601,509 households, 699,686 women, and 103,525 men .[15] It may be noted that we have merged the sample for Union territories into their nearby states like Andaman and Nicobar Island and Podicherry was merged into Tamil Nadu; Dadar & Nagar Haveli was merged to Maharashtra; Daman & Diu to Gujarat; Laksdweep to Kerela; and Chandigarh to Punjab.

Statistical analysis

Maps were drawn to study the patterns of the IMR and U5MR across the states of India and trends were studied between the three survey time points. Funnel plots were drawn to observe the variation in performance between states. The all India average IMR (indicated by a solid line parallel to the x-axis) was used as a baseline reference. The 99% confidence bands were constructed and each data point represents the state's IMR. The states which are located above the 99 percent band in the funnel plot are considered as under-performing states and those which are located below are considered as well performing states.

The dependent variable for the present study is considered as infant death which is coded as 1 "if the death occurred less than 1 year "and 0 "otherwise". The births which took place preceding five years from the date of survey has been considered for the analysis. The following independent variables has been taken: Sex of the Child (Male/Female) , Mother's age at child's birth into six categories (15-19 /20-24 /25-29/ 30-34 /35-39 /40-50),Mother's education (Illiterate/Primary/Secondary/Higher), Region of residence (Rural/Urban), combination of Birth Interval and birth order (1st Birth Order/two or more birth order and less than 24 months/ two or more birth order and more than 24 months), State of residence.

Cox regression analysis has been employed to examine the factors which are responsible for explaining the infant deaths in under and well performing states. Based on the results of funnel plots, the under-performing states considered for the

regression analysis are Bihar, Chhattisgarh, Madhya Pradesh (MP) and Uttar Pradesh (UP). Similarly, the well performing states considered are Haryana, Kerala, Maharashtra, Punjab and Tamil Nadu.

All analyses were performed in STATA software version 13.1

Patient and Public Involvement statement: No consent was required. The manuscript is based on analysis of secondary data in public domain.

RESULTS

Maps identifying the pattern and trend in IMR and U5MR across the states of India are presented in Figures 1 to 2. Figure 1 and 2 show that infant and U5MR has declined in India in absolute terms and in terms of distribution across states over the years between the NFHS-I and the NFHS-4 surveys. At a glance, it can be observed from Figure 1 that majority of states (i.e. 19) experienced U5MR of over 80 per 1000 live births in NHFS-I compared with only 1 state in NHFS-4. Same holds true for IMR. From Figure 2 it can be observed that most of India experienced IMR of over 50 per 1000 live births in NHFS-I whereas hardly any state experiences such infant mortality rates today.

Figures 1 and 2 also show number of states achieving MDG targets of 29 and 43 per 1000 live births for IMR and U5MR respectively. While IMR of less than 29 per1000 live births and U5MR of less than 43 per 1000 live births were restricted to a few small states in terms of population in NFHS-I, this is not so in NFHS-4. There are significantly more states with low IMR and U5MR and this trend is not restricted to less populated states.

Table 1 presents the IMR and U5MR for NHFS1-4 survey periods from 1992-2016 along with relative change in IMR and U5MR in Indian States. It can be observed that the trend of IMR is in decline from 86 in NHFS-I to 41 1000 live births in NHFS-4. During NHFS-I, the overall IMR for India was 86 per 1000 live births varying from 12 in Nagaland to 119 in Odisha. States like UP, Odisha, Bihar and MP reported IMR over 100 per 1000 live births. Similarly, NHFS-3 witnessed an overall IMR 65 per 1000 live births varying from 18 in Kerala to 83 in UP. States like UP, Chattisgarh and MP reported IMR over 80 per 1000 live births. Lastly, NHFS-4 reported overall IMR of 41per 1000 live births varying from 7 in Kerala to 64 in UP. States like UP, Chattisgarh and MP reported IMR over 50 per 1000 live births.

Table 1 also presents results of relative change in IMR and U5MR across survey periods. For survey periods NHFS-1 to 3, the overall reduction in IMR was 25% and this varied from less than 2% in Jarkhand to 47 % in Tamil Nadu. Similarly, during NHFS-1 to 4, the overall reduction in IMR was 53% and this varied from less than 36% in Jarkhand to 79 % in Kerala. It can be observed that majority of the states have witnessed over 50% reduction in both IMR and U5MR from NHFS-I to NHFS-4. The maximum benefits in terms of reduction in infant deaths was observed in Kerala, Odisha, Tamil Nadu, West Bengal, Karnataka, Goa and Tripura whereas Chattisgarh, Megalaya and Jammu and Kashmir observed least improvements in infant mortality. Surprisingly two states, namely, Mizoram and Nagaland, had in fact experienced increase in IMRs over the two survey period. Similar pattern was observed in the

U5MR. It may be noted that most of the reduction in both IMR and U5MR was seen between NHFS-3 and NHFS-4 survey period.

India/States	NFHS-1		NFHS-3		NFHS-4		NFHS-1 to NFHS 3		NFHS-1 to NFHS4		NFHS-3 to NFHS-4	
	IMR	U5MR	IMR	U5MR	IMR	U5MR	IMR	U5MR	IMR	U5MR	IMR	U5MR
India	**86**	**119**	**65**	**85**	**41**	**50**	**-25**	**-28**	**-53**	**-58**	**-37**	**-41**
Assam	93	144	71	95	48	58	-24	-34	-48	-59	-33	-39
Bihar	103	145	65	95	48	59	-37	-34	-54	-59	-27	-38
Chhattisgarh	90	115	81	106	58	70	-10	-8	-35	-39	-28	-33
Gujarat	74	104	63	77	36	44	-15	-26	-52	-58	-43	-43
Jharkhand	78	111	77	112	47	57	-2	2	-40	-48	-39	-49
Kerala	31	40	18	20	7	7	-43	-52	-79	-82	-63	-62
Maharashtra	56	76	45	53	24	30	-19	-30	-57	-61	-47	-44
Madhya Pradesh	99	152	82	108	53	68	-17	-29	-46	-55	-35	-37
Odisha	119	137	68	95	45	56	-43	-31	-63	-59	-34	-40
Rajasthan	76	108	73	93	43	53	-5	-13	-44	-51	-41	-43
Uttarakhand	73	110	55	70	42	49	-25	-36	-42	-55	-23	-30
Uttar Pradesh	118	163	83	112	64	81	-29	-31	-45	-50	-22	-28
West Bengal	81	107	52	65	31	37	-36	-39	-62	-66	-41	-43
Tamil Nadu	71	95	38	45	20	25	-47	-53	-72	-73	-47	-44
AndhraPradesh	73	96	68	78	41	46	-7	-18	-45	-52	-40	-41
Goa	33	41	26	32	13	13	-22	-21	-61	-68	-50	-60
Haryana	80	108	44	59	33	41	-44	-45	-59	-62	-25	-30
Himachal Pradesh	65	85	38	43	34	38	-41	-50	-48	-55	-11	-11
Jammu& Kashmir	50	68	46	54	32	38	-9	-21	-36	-44	-30	-29
Karnataka	75	102	53	66	28	32	-29	-35	-63	-69	-47	-52
Manipur	39	60	36	50	22	26	-8	-17	-44	-57	-39	-48
Meghalaya	46	65	48	74	30	40	4	14	-35	-38	-37	-46
Mizoram	17	27	33	48	40	46	100	80	141	71	20	-5
Nagaland	12	14	48	70	29	37	300	384	140	156	-40	-47
Punjab	53	69	45	55	29	33	-15	-21	-45	-52	-35	-40
Delhi	62	78	38	46	35	47	-38	-41	-44	-40	-9	1
Arunachal Pradesh	50	87	67	98	23	33	34	12	-54	-62	-65	-66
Tripura	88	115	58	73	27	33	-35	-36	-69	-71	-53	-55

Table 1: Relative change in Infant and U5 Mortality rates in Indian States, 1992-2016.

Having observed the general pattern and trends in infant and U5MR in India, it would be useful to see the variation in performance of the various states. Figures 3a, 3b and 3c present the funnel plots for NHFS I, 3 and 4 survey periods which help to identify the states with the lowest IMR and the states with the highest IMR, compared with the Indian average figures as indicated by a solid line parallel to the x-axis. The overall Indian IMR was used as a baseline comparison for each state. It can be observed that plots closer to the Y-axis are low birth states (small populated states) and those to the right are high birth states (large populated states). Data

points that lie outside the confidence interval (CI) band are interpreted as experiencing IMR differently from the Indian average. Those states outside the 99% CI can be considered as outliers in terms of their performance with respect to IMR. States which are above the Indian average are the worst performing states and those below are the best performing states in terms of IMR.

Figure 3a shows huge variation in the performance of the states with respect to IMR in NHFS-I. Of the 21 major states and territories, four states namely Uttar Pradesh, Odisha, Bihar and Madhya Pradesh performing so poorly with respect to IMR that they lie above the upper limits of the distribution of the funnel plot. The majority of the states were below the overall Indian baseline. Whereas Figure 3b presents data for NHFS-3 where it can be observed that in addition to the 4 states mentioned above, additional states like Rajasthan, Jarkhand and Chattisgarh are also outliers. Lastly, Figure 3c presents data for NHFS-4 where improvements are observed in performance of states with only 4 underperforming states namely MP, Bihar, UP and Chattisgarh.

From the above it can be observed that there is huge variation in performance among the states. These results hold true for both IMR and U5MR. Uttar Pradesh Bihar and Madhya Pradesh need a special mention as these states are not only the most populous states in India but also have underperformed consistently across the survey period from 1992 both with respect to IMR and U5MR.

Table (not shown) shows the percentage distribution of infant deaths by some selected background characteristics in India. There were total 9792 infant deaths that took place in a period five years prior to survey. Of the total infant deaths, nearly 56 percent were male and rest were females. Nearly 70 percent of the total infant deaths occurred to mothers who were in the age group 20 years to 29 years at the time of child birth. Contrary to the expectation, trend with respect to education is not clear cut. Illiterate mothers and those who had secondary education experienced high infant mortality. More than four fifth of the infant deaths took place in rural areas. Nearly 60 percent of the total infant deaths occurred to mothers who belonged to poorest and poorer wealth group and only 20 percent of the total infant deaths occurred to richer and richest mothers. The gradient with respect to wealth index is clear. Those who are least well off (poorest 20%) experienced three times infant deaths when compared to the richest 20%. Nearly one third of infant deaths were of first order and 34 percent of the infant deaths were of two and higher birth order and had birth interval more than 24 months. Of the total infant deaths, nearly 28 percent infant deaths occurred in Uttar Pradesh, 15 percent in Bihar and 9 percent in Madhya Pradesh respectively. Finally, it may be noted that five states namely UP, MP, Bihar, Rajasthan and West Bengal contribute over 65 % of total infant deaths in India.

Covariates	GOOD PERFORMING STATES			BAD PERFORMING STATES		
	Hazards Ratio	95% CI for Exp (β)		Hazards Ratio	95% CI for Exp (β)	
		L	U		L	U
States						
Kerela(Good Performing States)®						
Haryana	3.51***	1.487	8.304		NA	
Maharashtra	1.86	0.782	4.440		NA	
Punjab	2.60**	1.041	6.474		NA	
Tamil Nadu	1.85	0.767	4.464		NA	
Bihar(Bad Performing States)®	NA					
Chhattisgarh	NA			1.23	0.952	1.589
Madhya Pradesh	NA			1.47***	1.232	1.749
Uttar Pradesh	NA			1.93***	1.671	2.232
Place of Residence						
Rural®						
Urban	1.15	0.856	1.551	1.03	0.880	1.213
Sex of the child						
Male ®						
Female	1.14	0.875	1.473	1.18***	1.061	1.308
Mother's age (at child's birth)						
<=19 yrs.®						
20-24 yrs.	0.69	0.464	1.037	0.66***	0.555	0.786
25-29 yrs.	0.76	0.484	1.208	0.80**	0.660	0.977
30+ yrs.	0.82	0.471	1.430	1.03	0.834	1.277
BMI						
Low®						
High	1.09	0.772	1.552	1.00	0.892	1.130
Missing	3.27***	1.582	6.771	0.87	0.479	1.588
Caste						
SC®						
ST	1.07	0.553	2.055	0.88	0.712	1.088
Others	0.78	0.571	1.066	0.95	0.834	1.082
Religion						
Hindu®						
Muslim	1.41	0.941	2.120	0.94	0.805	1.098
Others	1.34	0.870	2.073	0.99	0.408	2.386
Birth Interval						
First Birth®						
Less than 24 months	1.38	0.959	1.982	1.56***	1.347	1.818
24 or more months	0.97	0.692	1.359	0.82**	0.705	0.957
Age of the child						
Up to 6 months®						
7-11 months	0.92	0.488	1.717	0.83	0.641	1.071
12-23 months	0.65	0.366	1.145	0.707***	0.565	0.885
24-35 months	0.71	0.406	1.250	0.71***	0.569	0.891
36 plus months	0.65	0.383	1.102	0.69***	0.562	0.852
Mother's Education						
Illiterate ®						
Primary	0.60**	0.364	0.981	0.96	0.828	1.119
Secondary	0.70	0.477	1.023	0.76***	0.662	0.879
Higher	0.49**	0.267	0.913	0.47***	0.340	0.649
Wealth Index						
Poorest®						
Poorer	1.69	0.881	3.254	0.89	0.774	1.019
Middle	1.26	0.652	2.442	0.92	0.773	1.085
Richer	1.18	0.598	2.324	0.84	0.680	1.034
Richest	0.88	0.421	1.849	0.61***	0.454	0.814

Table 2: Adjusted hazards ratio for infant mortality preceding five years from the date of survey by selected characteristics according to well & bad performing States, India, 2015-16.

Note: ***p<0.01;p<0.05;** ® Reference category

We estimate two separate multivariable regression models to examine the significant factors affecting infant mortality (Table 2). The first and second model display the adjusted effect of selected covariates on infant deaths in well and poor performing states respectively. Among well performing states, infants from Haryana and Punjab had higher risk of infant death as opposed to Kerala. However, in case of poor performing states, Madhya Pradesh and Uttar Pradesh had higher risk of infant deaths in comparison to Bihar. Place of residence, mother's body mass index, caste and religion of the women had insignificant association with infant deaths in both the models. Females had higher chance of infant deaths in the group of poor performing states but no significant association was found in the case of well performing states. Mother's age at birth had no role in case of well performing states but the risk of infant deaths was low in the 20-29 years age-group in case of poor performing states. Women who had shorter birth interval had higher chance of experiencing infant deaths in the poor performing states and it was not significant in case of well performing states. Mother's education had significant role in the both group of states. As education level increases, the chances of experiencing infant deaths decreases. Older child had lower chance to experience infant deaths in the poor performing states and had no significant association in case of well performing states. Women who belong to richest wealth quintile had 39 percent lower chance to experience infant deaths in the group of poor performing states.

DISCUSSION

The analysis of this paper is based on U5MR and IMR estimates from NHFS surveys from 1992-2016 period. IMR is defined as the number of infant deaths per 1,000 live births and is one of the indicators used to assess a country's overall level of development.[16]

Through the use of maps, this paper clearly shows that the overall trend in IMR and U5MR in India is decreasing and thus headed in the right direction. Reduction in infant and child mortality among states was observed over time from the NFHS-I to NFHS-4 survey period. Smaller populated states already show a significant reduction in IMR. However, much effort still needs to be done in the heavily populated states where mortality decline has been at a much slower pace than expected.

Maps are powerful tools in presenting the trends and the current distribution of child mortality across states. However, what is more useful to policy makers is to have a tool that can not only provide information at a glance about the size of the states in terms of population but also help identify the states that are outliers in terms of their performance with respect to child mortality. Funnel plots are one such tool that we used in identifying underperforming states. Similar to prior studies result shows that hugely populated and least developed states like Uttar Pradesh, Madhya Pradesh, Bihar still contribute significantly to India's overall high IMR and U5MR.[7,17] In spite of reduction in child deaths in these states over the years, even today, these three states alone contribute to over 50% of all infant deaths in India. Unfortunately, as

seen in Funnel plots, these three states are persistent outliers with respect to under performance since 1992.

The analysis from this paper reveals that India has made progress in terms of reducing infant and child mortality but this progress has been relatively slow from 1992-2006. During this period less than 10% reduction in infant mortality was observed in number of states namely Chhattisgarh, Jharkhand, Rajasthan, Andhra Pradesh, Jammu and Kashmir and Manipur. In contrast, much of the reduction in infant and child mortality was observed during 2006 to 2016 period. Even the worst performing states had more than 35% reduction in infant mortality. In addition, the variation in performance between the worst and best performing states too drastically reduced from over 20 times in 1992 - 2006 period to just over 2 times in 1992- 2016 period.

Hence, in spite of significant reduction in infant and child mortality rates in recent years, a lot needs to be done especially with respect to under performing states which are persistent outliers. There are a number of policy implications from our study. It is important that policy makers target the underperforming states (upper outliers) as identified by the funnel in order to ensure reduction in variation between the states. These should fall down within the 95% CI. In addition, policy makers should focus on the larger states lying above CI on the right, namely the high impact states, as these represent the biggest population states with the potential for the most significant improvements in terms of reduction of IMR and U5MR.

Current policy in India is to focus on 18 states including eight empowered action group states[18] (EAG) which are poor performing states with targeting of below poverty line families. There is a need for a more flexible approach to reducing child mortality among underperforming states. Selective targeting of lower socio-economic groups may be necessary. However, our study suggests that states like MP, UP Chhattisgarh and Bihar would benefit from rapid scaling up of interventions that reduce the average child mortality, irrespective of the socio-economic groups that may benefit from the reductions.

Another important aspect to consider is the contribution of neonatal mortality to total infant mortality. Over the years, proportion of neonatal mortality has been on the rise from 62% in 1992 to 73% in 2016. In addition, even low performing states like UP, MP, Bihar, Chhattisgarh experience high neonatal mortality especially in rural areas. This observation has important implications for policy makers. India has achieved reduction in infant mortality mainly due to reduction in post-neonatal mortality rates which are comparatively more amenable to existing set of interventions. However, existing strategies and interventions on their own may not be adequate and new set of high tech and expensive strategies would be needed if the focus is to shift to neonatal mortality.

Cox regression analysis shows that in well performing states only mother's education significantly associated with increased ratio of infant mortality. However, in poor performing states sex of the child, mother's age at child birth, birth interval, and age of the child, mother's education and wealth index emerges as a significant predictor of infant mortality.

Similar to previous studies our results also show that female child had a higher risk of death during infancy than a male child in the poor performing states in India.[19-22] Reason of excess female infant mortality could be human intervention at different stage of life cycle. Numerous studies have recognized gender gap in vaccination[23-24], breast feeding[25], allocation of food, nutrition (milk, fats, cereals, and sugars) even medical care and expenses.[26-28] These deliberate negligence were more pronounced in the poor performing states which leaves female infants at higher risk of mortality.

After adjusting other covariates in the model this study suggest that less than 24 moths birth interval are invariably more hazardous in terms of infant mortality. Various studies have documented the significant effect of birth interval and infant mortality.[29-30] Short preceding intervals is associated with enhanced risk of prematurity and low birth weight for gestational age.[31] Also cross-infection, less maternal attention and limited household resources between closely spaced siblings may be the probable pathways through which infant mortality seems to be high.[32-33] The poor performing states which had higher fertility than well performing states also had lower birth interval.

Compared with other countries in the region, it is evident that even poorer nations like Bangladesh and Nepal have performed better than India.[34-36] India's poor performance can also be noted with respect to immunization coverage, child anemia, and nutrition. Despite its economic progress and significant efforts since the 1980s, for example with the Expanded Program on Immunization and Universal Immunization Programme, India has the lowest immunization coverage rates in Asia.[37] Only 62% of children between the age of 12 and 23 months receive the recommended vaccinations.[15] The prevalence rate of anemia in Indian children below the age of five years is as high as 60%. Even in richer states like Maharashtra and Gujarat, the percentage of children who are under weight is 36% and 40%, respectively.[15] Obviously, these figures are significantly worse for the poorer performing states identified in our study. Reddy et al., (2011) in their recent call to action for universal health coverage, also mention the limited health gains achieved by India over the last decade.[38]

It is therefore not surprising to see a number of initiatives launched by the Government of India (GOI) in recent years. National Rural Health Mission (NRHM) in 2005 which is the flagship programme of the GOI, attempting to meet people's health needs particularly in rural areas.[18] It aims to reduce child and maternal mortality by strengthening the rural health system and introducing innovative public private partnerships. Recognising that the past public health expenditure is inadequate (1% of its GDP), the NRHM aimed to double this expenditure by 2012 and increase its health expenditure to 3% of its GDP.[39] Similarly, though Accredited Social Health Activist (ASHA), it aims to address the need for a community worker to achieve universal coverage especially in the priority states. A good example of role of community health care workers in reducing infant and child mortality is provided in a recently published study in Lancet Global health by Tripathy et al.[40] Subsequently the Call to Action for Child Survival and Development, and there after Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCH+A) strategic framework in 2013. The RMNCH+A strategy is based on a continuum-of-care approach and defines integrated packages of services for different stages of life. More recently,

newer initiatives like web enabled tracking of pregnant women to ensure antenatal, intra natal and postnatal care; Janani Shishu Suraksha Karyakaram (JSSK) which entitles all pregnant women delivering in public health institutions to absolutely free delivery including Caesarean section and free transport; Rashtriya Bal Swasthya Karyakram (RBSK), an introduction of child health screening for 4Ds i.e. defects at birth, deficiencies, diseases, development delays[41] are landmark policies in reducing the infant and child mortality.These packages provide a framework for delivering services at the state and district level.

Policy makers could benefit from further analysis to target the under performing states. For example, it would be necessary to analysing inequalities with respect to infant and child mortality across states and within states. For the first time district level data is available and such analysis could guide policy makers with micro level planning and cluster analysis could help with selective targeting of specific districts. Few previous studies cited the role of family level clustering of infant deaths in the low performing states.[42-43]

From our analysis, it appears that the trend in reducing IMR and U5MR is headed in the right direction. Even so, there is huge variation between states and within states. However, a blanket approach to reducing infant and child mortality in all underperforming states of India may not be the best option. Depending upon a state's performance and the socio-economic differentials, policy makers may wish to be flexible in their approach in reducing infant and child mortality as discussed in this paper. Given the greater contribution of neonatal mortality, India's challenge in reducing infant mortality would depend largely on how it addresses the issue of neonatal deaths.

CONCLUSION

The results of this study confirm that to bring the overall Indian national average of IMR and U5MR to a more respectable level, policy makers will have to target the underperforming large states and population groups where mortality rates are still high. This is particularly so when the improvements with respect to infant and child mortality have been unevenly distributed across states and population groups. As India continues to reduce its infant and child mortality, the challenge is to accelerate its reform process by adopting a differential strategy. To a large extent, India's under performing states and its approach to reducing neonatal mortality will determine its success or failure in reducing infant and child mortality in future.

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Figure 1:

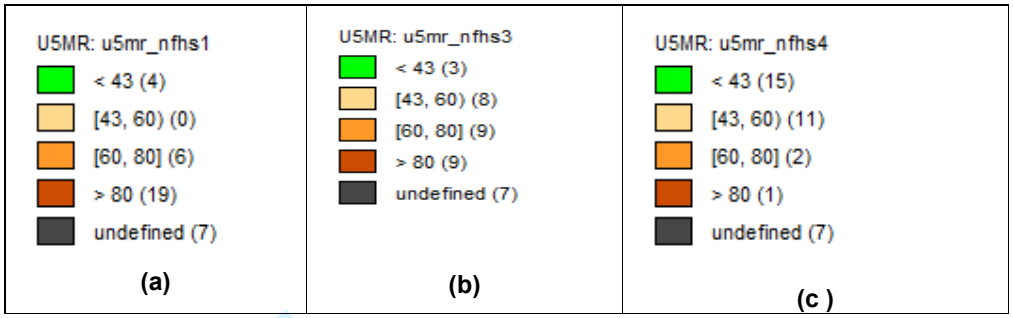


Figure 2

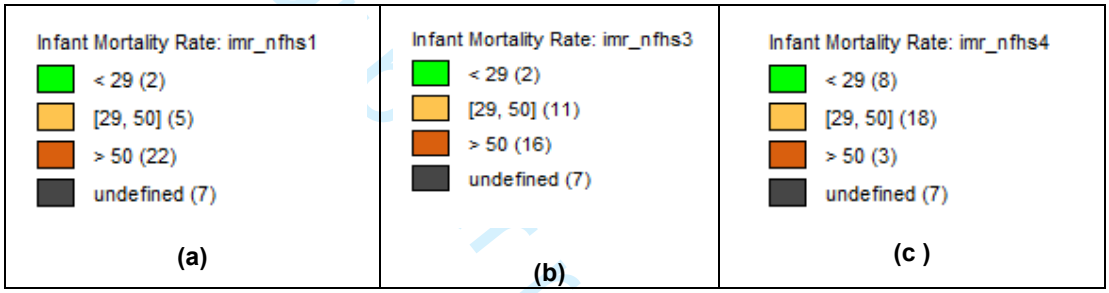
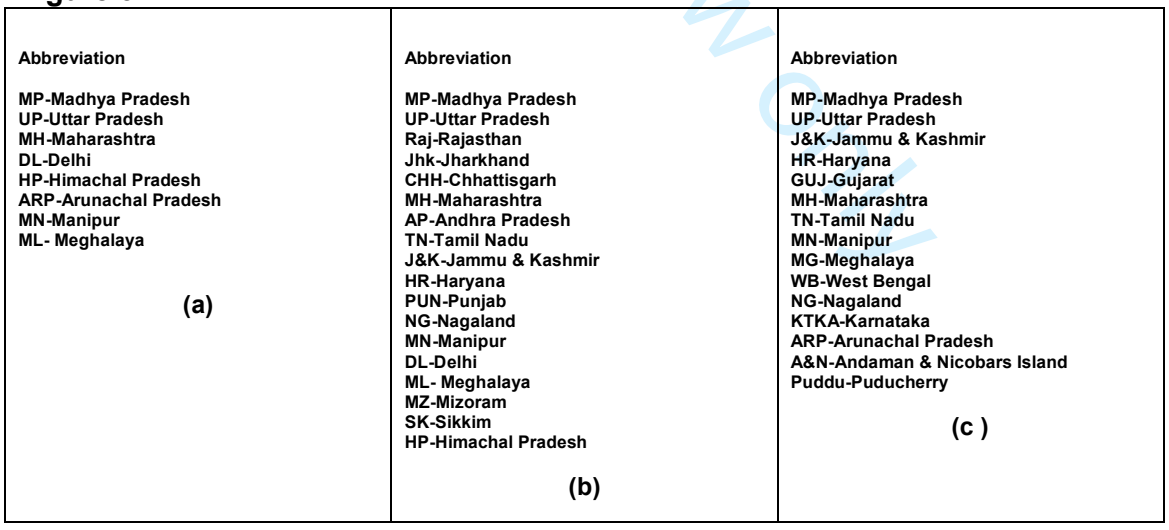


Figure 3



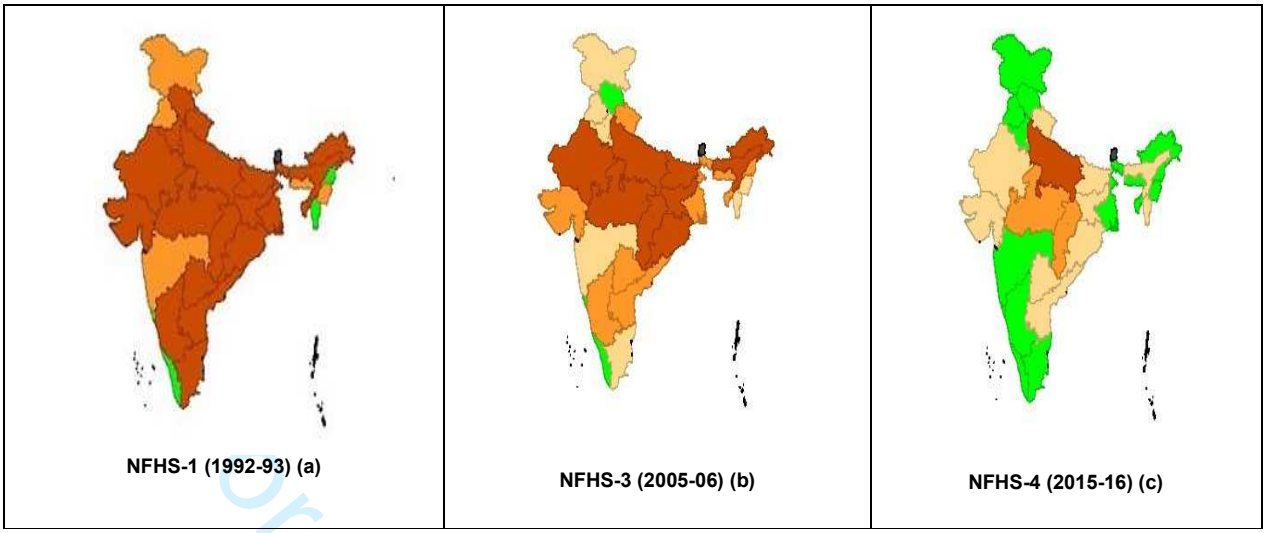


Figure 1: Trends in U5MR for India & states.

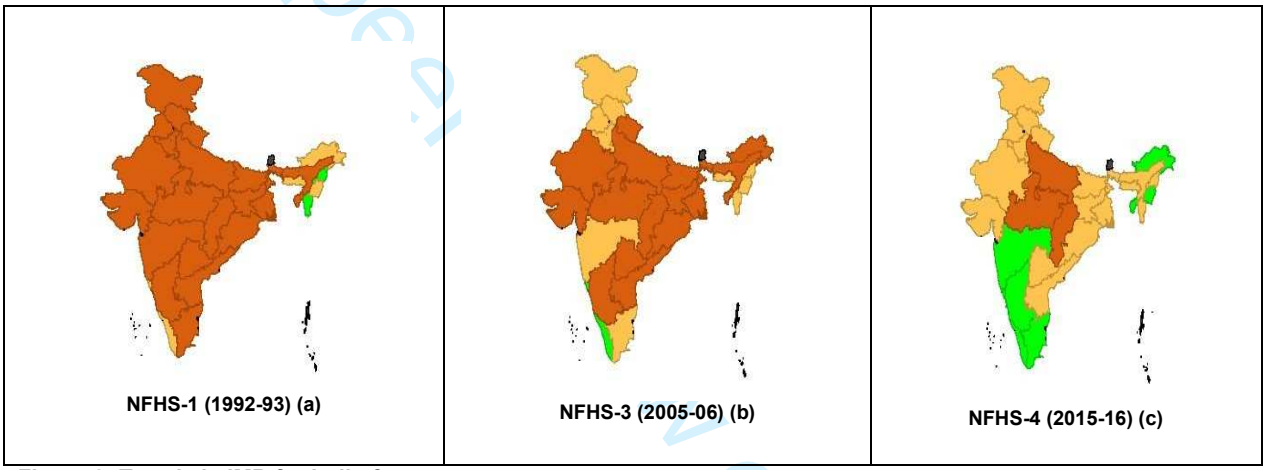
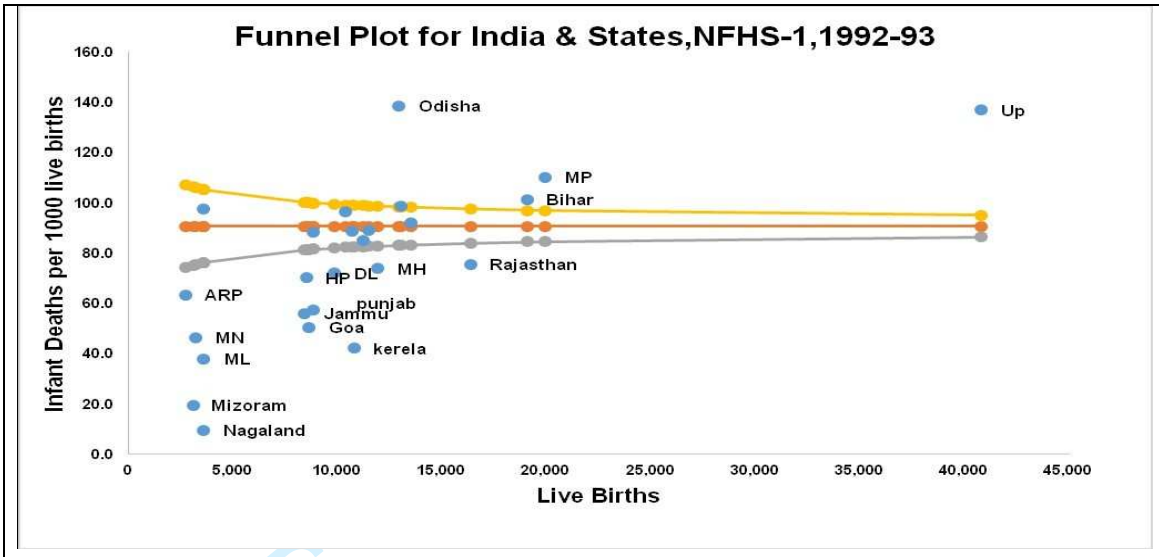
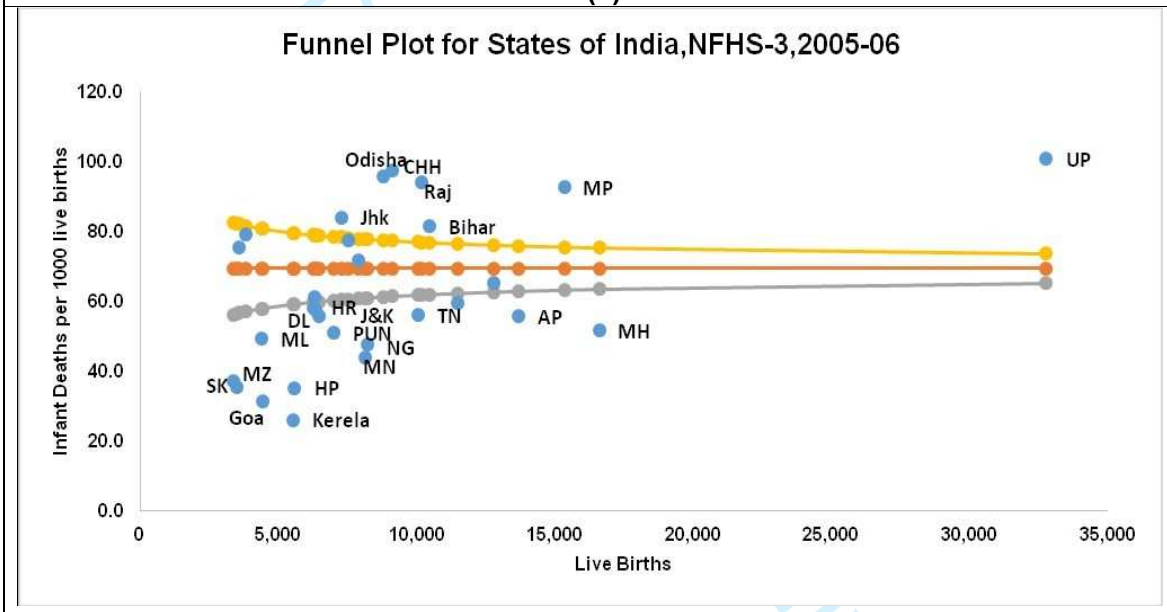


Figure 2: Trends in IMR for India & states.



(a)



(b)

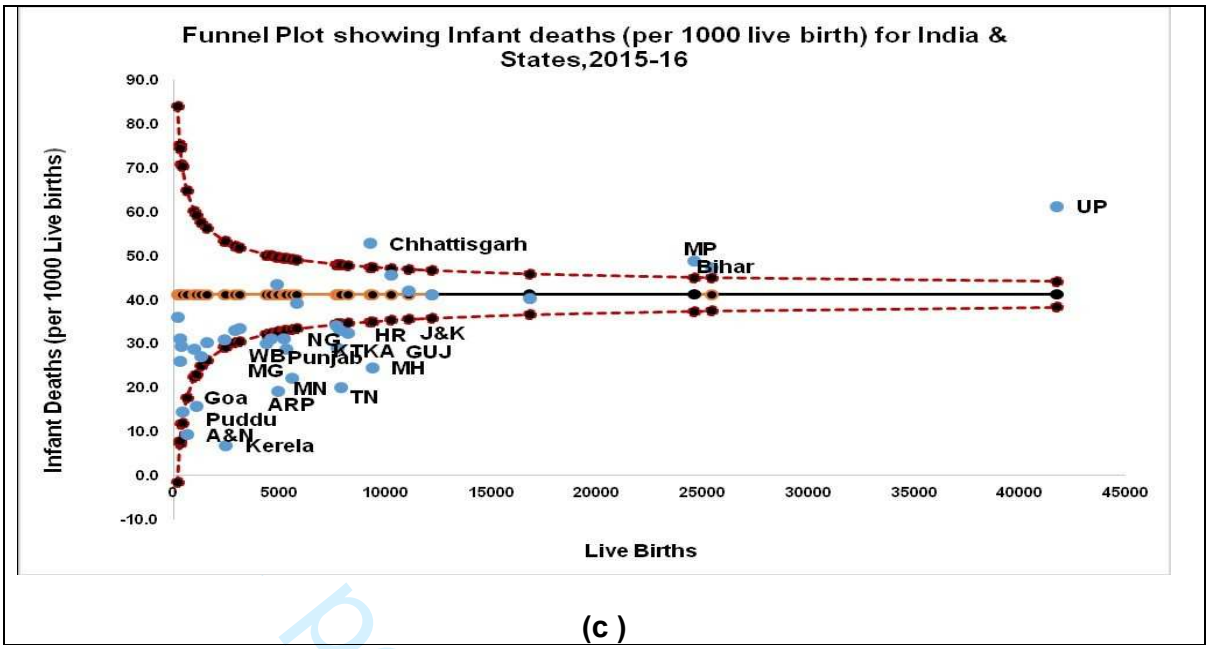


Figure 3: Funnel Plots for India & states.

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Trends, patterns and predictive factors of infant and child mortality in well and underperforming states of India: A secondary analysis using National Family Health surveys.

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Abstract

Objectives

This paper analyses the patterns and trends in the mortality rates of infants and children under the age of five years in India (1992-2016) and quantifies the variation in performance between different geographic states.

Methods

The analysis of this paper uses the National Family Health Surveys (NFHS) I, III, and IV survey data. Variation in performance of states has been captured by use of Funnel plots. Subsequently, Cox regression analysis has been employed to examine the factors associated with infant deaths in under and well performing states.

Results

Through the use of maps, this paper clearly shows that the overall trend in infant and child mortality is on the decline in India. Computation of relative change shows that majority of the states have witnessed over 50% reduction in both IMR and U5 MR from NFHS-I to NFHS-4. However, the improvements are not evenly distributed and there is huge variation in performance between states over time. Funnel plots show that the most populous states like Uttar Pradesh Bihar and Madhya Pradesh have underperformed consistently across the survey period from 1992 to 2016. Regression analysis comparing high and low performing states revealed that female infants and women with shorter birth intervals had greater risk of infant deaths in poor performing states.

Conclusion

Attempts to reduce infant and child mortality rates in India are heading in the right direction. Even so, there is huge variation in performance between states. This paper recommends a mix of strategies that reduce child and infant mortality among the high impact states where the biggest improvements can be expected including the need to address neonatal mortality.

Key words: Infant and child mortality rate, performance of Indian states, funnel plots, Cox regression model, relative change, India.

Strengths and limitations of this study

- Trends in infant and U5MR from 1992-2016 using latest NFHS data released in January, 2018.
- Innovative approach to quantify variation in performance of states with respect to child mortality rates using Funnel Plots.
- Factors associated with infant deaths like education, birth spacing, wealth index, etc. are know from previous studies. However, how these factors act differently in under and well performing states is not know which has been attempted in this study.
- The need to adopt differential policy response in under and well performing states and the challenge to address high neonatal mortality is discussed.
- Mortality rate may be affected as cross sectional data used and information related to age of child collected retrospectively.

INTRODUCTION

Child health is a basic right and the level of child mortality is an important indicator in the assessment of the development of any society .[1] It is therefore not surprising that the United Nations' Sustainable Development Goals declaration (2015) to improve the health and welfare of the world's poorest people includes reducing child mortality as one of its goals which was earlier laid out by Millennium Development Goal's (MDG) declaration (1990).[2] Annually, 5.6 million children under the age of five years die worldwide, primarily in developing countries.[3] Given that most of these deaths can be easily prevented or treated [4] with cheap and effective interventions, such high mortality is unacceptable even in resource constrained settings.

India is the world's largest democratic nation with 16% of the global population. According to UNICEF, India has the highest number of under five deaths, with a total of 1.08 million deaths in 2016.[5] It is one of the six countries that contributes to 50% of the world's under five mortality rate (U5MR).[5] On its own, India contributes to 19 % of all under five deaths and 24% of all neonatal deaths.[5] However, infant mortality rate (IMR) and U5MR have declined over the years in India. For example, the U5MR reduced from 114 per 1000 live births in 1990 to 39 in 2016 at a rate of 3% annually.[5] Similarly, the IMR reduced from 81 to 34 per 1000 live births between 1990 and 2016.[5] However, the distribution of these gains is uneven across states.[6] For example, at the national level, U5MR is estimated at 39 and it varies from 43 in rural areas to 25 in urban areas. Among the bigger States/UTs, it varies from 11 in Kerala to 55 in Madhya Pradesh.[6] Similary, at the National level, IMR is reported to be 34 and varies from 38 in rural areas to 23 in urban areas. Among the four most populated states, it varies from 38 in Bihar to 47 in Madhya Pradesh.[6]

Healthcare in India is the responsibility of individual states, which vary in terms of their level of socio-economic development, size of population, experience of epidemiological transition, and health system capacities, factors which influence the health status experienced by the population of the states. On the one hand, states like Kerala experience relatively low levels of infant and child mortality comparable with the Western world, whereas states like Madhya Pradesh and Uttar Pradesh suffer IMRs and U5MRs comparable with some of poorest countries of the world.[7] Therefore, it is necessary to disaggregate the mortality data and quantify the variation between states. This would help policy makers to prioritise the underperforming states where intense efforts need to be expanded.

By providing the current status of child mortality through the use of maps, and undertaking a disaggregate analysis of infant mortality using the funnel plot technique, this paper identifies key states where performance needs to improve significantly, and the states that should be the target of intense efforts in the future. Funnel plots are an attractive way to present data to policy makers and a good tool to compare performance data, including population data.[8] Funnel plots have been used in the developed world in a number of settings including assessing institutional performance[9], comparing health care providers[10], and assessing the variations in cardiac[11-12] and cancer mortality[13-14]. However, to the best of our knowledge the

application of this technique to child mortality rates in the context of the developing world has not been previously conducted.

This paper is timely in that the NFHS-4 survey data (2015-16) has just been released in January, 2018. In addition, India is the highest contributor to the U5MR in the world and with new impetus in reducing child and maternal mortality, the rest of the world is closely monitoring India's performance.

METHODS

Data

The analysis of this paper is based on the three rounds of National Family Health Surveys (NFHS), NFHS-I, III, and IV data which were conducted during the periods between 1992-93, 2005-06 and 2015-16. For pragmatic reasons, NFHS-II survey data conducted in 1998-99 has been intentionally excluded from our analysis. An important consideration for not including NFHS-II survey in the analysis is the short time interval between1992-93 and 1998-99 and that there were no major changes with respect to policies and programs during this period. The International Institute for Population Sciences is designated as a nodal agency for conducting the survey under the stewardship of the Ministry of Health and Family Welfare, Govt. of India. The National Family Health Surveys series provides information on population, health and nutrition for India and each State / Union territory. NFHS-4 gathered information from 601,509 households, 699,686 women, and 103,525 men.[15] In NFHS-3, Interviews were conducted with 124,385 women age 15-49 and 74,369 men age 15-54 from all 29 states.[16] NFHS-1 is a household survey which has a nationally representative sample of 88,562 households and 89777 ever married women in the age group 13 to 49 years covering the population in 24 states and the National Capital Territory of Delhi.[17] It may be noted that we have merged the sample for Union territories into their nearby states like Andaman and Nicobar Island and Puducherry was merged into Tamil Nadu; Dadar & Nagar Haveli was merged to Maharashtra; Daman & Diu to Gujarat; Laksdweep to Kerela; and Chandigarh to Punjab. The present study has utilized ten years retrospective birth history information to estimate the mortality rates. The information related to births and deaths which women had during her reproductive period is collected in NFHS surveys. Further, the information collected on deaths and age at death of child were consistent across all rounds of NFHS.[18] Literature suggests that omission of births is almost virtually nil but displacement of births in reporting of age of child is visible in DHS surveys.[19]

Statistical analysis

Maps were drawn to study the patterns of the IMR and U5MR across the states of India and trends were studied between the three survey time points. Funnel plots were drawn to observe the variation in performance between states. The all India average IMR (indicated by a solid line parallel to the x-axis) was used as a baseline reference. The 99% confidence bands were constructed and each data point represents the state's IMR. The states which are located above the 99 percent band in the funnel plot are considered as under-performing states and those which are located below are considered as well performing states. The states namely Haryana, Kerala, Maharashtra, Punjab and Tamil Nadu fall in the category of good performing states. The poor performing states are Bihar, Chhattisgarh, Madhya Pradesh, and

Uttar Pradesh. In addition, we have compared the results of 99% confidence bands with 95%.

The dependent variable for the present study is considered as infant death which is coded as 1 “if the death occurred less than 1 year “and 0 “otherwise”. The births which took place preceding five years from the date of survey has been considered for the analysis. The following independent variables has been taken: Sex of the Child (Male/Female) , Mother’s age at child’s birth into six categories (15-19 /20-24 /25-29/ 30-34 /35-39 /40-50), Mother’s education (Illiterate/Primary/Secondary/Higher), Caste of women (Scheduled Caste (SC)/Scheduled Tribe (ST)/Other than SC & ST), Religion of women (Hindu/Muslim/Others) combination of Birth Interval and birth order (1st Birth Order/two or more birth order and less than 24 months/ two or more birth order and more than 24 months), Region of residence (Rural/Urban), Wealth Index (Poorest/Poorer/Middle/Richer/Richest) and Body Mass Index (Low/High/Missing).
The first category of each covariate is considered as a reference category. Further, for poor performing states (Bihar /Chhattisgarh/Madhya Pradesh/Uttar Pradesh), Bihar is considered as a reference category. However, for good performing states (Kerala/Haryana, Maharashtra, Punjab and Tamil Nadu), Kerala is considered as a reference category in the separate regression model.

Cox regression analysis has been employed to examine the factors[20] which are responsible for explaining the infant deaths in under and well performing states using recent round of NFHS-4 data. Based on the results of funnel plots of 99% confidence, the under-performing states considered for the regression analysis are Bihar, Chhattisgarh, Madhya Pradesh (MP) and Uttar Pradesh (UP). Similarly, the well performing states considered are Haryana, Kerala, Maharashtra, Punjab and Tamil Nadu. For the regression analysis only recent round of NFHS-4 data has been considered.
The brief mathematical description of this model is given below:

Let X_1, X_2 , X_3, ….. X_p are p predictors which affect the dependent variable that is, infant deaths. Further, suppose that hazards at time t is $\lambda(t)$ then Cox proportional hazards model (Cox PH model) is generally written in the form of
$\lambda(t) = \lambda_0(t) \exp(\beta_1 X_1+\beta_2 X_2+.....+\beta pXp)$

$$= \lambda_0(t)\exp(\sum_{i=1}^{p}\beta_i X_i)$$

$$= \lambda_0(t)e^{\sum_{i=1}^{p}(\beta_i x_i)} \quad (1)$$

Where $\lambda_0(t)$ is baseline hazard at time t and β_1, β_2, ... β_p are unknown regression coefficients. The advantage of hazards model is that exponential expression permits the specification of the model without any further restrictions on the covariates. The base line hazard is a function of t, but does not involve the X’s (covariates) (Cox, 1972).

All analyses were performed in STATA software version 13.1

Patient and Public Involvement statement: No consent was required. The manuscript is based on analysis of secondary data of NHFS I-4 series which is available in public domain.

RESULTS

Maps identifying the pattern and trend in IMR and U5MR across the states of India are presented in Figures 1 to 2. Figure 1 and 2 show that infant and U5MR has declined in India in absolute terms and in terms of distribution across states over the years between the NFHS-I and the NFHS-4 surveys. At a glance, it can be observed from Figure 1 that majority of states (i.e. 19) experienced U5MR of over 80 per 1000 live births in NFHS-I compared with only 1 state in NFHS-4. Same holds true for IMR. From Figure 2 it can be observed that most of India experienced IMR of over 50 per 1000 live births in NFHS-I whereas hardly any state experiences such infant mortality rates today.

Figures1 and 2: Trends in U5MR and IMR for India and States.

Figures 1 and 2 also show number of states achieving MDG targets of 29 and 43 per 1000 live births which was set as a goal post for India for IMR and U5MR respectively. While IMR of less than 29 per1000 live births and U5MR of less than 43 per 1000 live births were restricted to a few small states in terms of population in NFHS-I, this is not so in NFHS-4. There are significantly more states with low IMR and U5MR and this trend is not restricted to less populated states. By examining the MDG targets for each states of India, it can be observed that only Kerala, Tamil Nadu and Tripura have achieved the targets of reducing its IMR by 2/3rd from 1990. Surprisingly, none of the states have achieved its goal of U5MR.

Table 1 presents the IMR and U5MR for NFHS1-4 survey periods from 1992-2016.

	NFHS-1						NFHS-3						NFHS-4						NFHS-1 to NFHS 3		NFHS-1 to NFHS4		NFHS-3 to NFHS-4	
India & States	IMR	LL_IMR	UL_IMR	U5MR	LL_U5MR	UL_U5MR	IMR	LL_IMR	UL_IMR	U5MR	LL_U5MR	UL_U5MR	IMR	LL_IMR	UL_IMR	U5MR	LL_U5MR	UL_U5MR	IMR	U5MR	IMR	U5MR	IMR	U5MR
India	86	84	88	119	117	121	65	63	67	85	83	87	42	41	43	52	51	53	-25	-28	-51	-56	-35	-39
Assam	93	83	103	144	131	156	71	62	80	95	84	106	48	44	51	58	54	62	-24	-34	-48	-59	-33	-39
Bihar	103	95	111	145	135	155	65	57	72	95	86	104	48	46	50	59	57	61	-37	-34	-54	-59	-27	-38
Chhattisgarh	90	72	107	115	95	135	81	71	90	106	95	116	58	55	62	70	66	75	-10	-8	-35	-39	-28	-33
Gujarat	74	68	79	104	96	111	63	55	70	77	70	84	36	32	39	44	40	47	-15	-26	-52	-58	-43	-43
Jharkhand	78	66	91	111	96	126	77	67	87	112	101	124	47	43	51	57	53	62	-2	2	-40	-48	-39	-49
Kerela	31	25	36	40	35	46	18	12	23	20	14	25	7	4	9	7	5	10	-43	-52	-79	-82	-63	-62
Maharashtra	56	49	62	76	69	83	45	39	52	53	47	60	24	20	27	30	26	33	-19	-30	-57	-61	-47	-44
Madhya Pradesh	99	91	107	152	143	162	82	75	89	108	99	117	53	51	56	68	66	70	-17	-29	-46	-55	-35	-37
Odisha	119	113	126	137	130	144	68	60	75	95	87	103	45	42	47	56	53	60	-43	-31	-63	-59	-34	-40
Rajasthan	76	71	82	108	101	114	73	65	80	93	85	101	43	41	45	53	51	55	-5	-13	-44	-51	-41	-43
Tamil Nadu	71	65	77	95	87	103	38	32	44	45	39	52	20	18	23	25	23	28	-47	-53	-72	-73	-47	-44
Uttar Pradesh	118	111	124	163	157	170	83	78	88	112	106	118	64	63	66	81	79	83	-29	-31	-45	-50	-22	-28
Uttarakhand	73	55	91	110	90	130	55	47	62	70	62	78	42	38	46	49	45	54	-25	-36	-42	-55	-23	-30
West Bengal	81	73	89	107	99	116	52	46	58	65	58	73	31	27	35	37	33	41	-36	-39	-62	-66	-41	-43
Haryana	80	72	87	108	101	114	44	36	53	59	49	68	31	28	34	39	36	43	-44	-45	-61	-63	-30	-33
Goa	33	26	41	41	33	49	26	19	33	32	25	40	16	8	23	17	8	26	-21	-22	-53	-58	-40	-46
Andhra Pradesh	73	67	80	96	88	104	44	61	76	59	70	87	43	38	48	49	43	54	-40	-39	-41	-49	-2	-17
Himachal Pradesh	65	56	75	85	74	96	38	30	46	43	35	50	34	29	40	39	33	44	-42	-49	-48	-54	-11	-10
Jammu& Kashmir	50	43	57	68	61	76	46	38	53	54	46	61	32	30	35	36	33	39	-8	-21	-36	-46	-30	-33
Karnataka	75	68	82	102	94	110	53	46	60	66	59	74	27	24	30	31	27	34	-29	-35	-64	-70	-49	-54
Manipur	39	30	48	60	49	71	36	29	43	50	41	59	22	19	25	28	24	32	-8	-17	-44	-53	-39	-44
Meghalaya	46	35	57	65	53	77	48	38	58	74	61	87	29	26	33	41	37	44	4	14	-36	-38	-39	-45
Mizoram	17	11	23	27	19	35	33	25	42	48	39	58	45	37	54	53	44	62	94	78	167	96	37	10
Nagaland	12	7	17	14	9	20	48	42	55	70	63	77	25	22	29	35	31	39	300	400	111	148	-47	-50
Punjab	53	45	60	69	61	78	45	39	51	55	48	61	30	26	34	35	31	39	-15	-20	-44	-49	-34	-36
Delhi	62	56	69	78	72	85	38	31	45	46	39	54	24	17	30	31	24	39	-39	-41	-62	-60	-38	-32
Arunachal Pradesh	50	38	61	87	75	100	67	55	78	98	85	110	23	20	27	34	30	38	34	13	-53	-61	-65	-65
Tripura	88	74	102	115	101	130	58	44	71	73	59	88	25	18	32	32	25	39	-34	-37	-72	-72	-57	-56

Table 1 presents the IMR and U5MR for NFHS1-4 survey periods from 1992-2016 along with relative change in IMR and U5MR in Indian States. It can be observed that the trend of IMR is in decline significantly from 86 (95% CI: 84 - 88) in NFHS-I to 42 (95% CI: 41 - 43) 1000 live births in NFHS-4. During NFHS-I, the overall IMR for India was 86 per 1000 live births varying from 12 (95% CI: 7 - 17) in Nagaland to 119 (95% CI: 113 - 126) in Odisha. States like UP, Odisha, Bihar and MP reported IMR over 100 per 1000 live births. Similarly, NFHS-3 witnessed an overall IMR 65 (95% CI: 63 - 67) per 1000 live births varying from 18 (95% CI: 12 - 23) in Kerala to 83 (95% CI: 78 - 88) in UP. States like UP, Chhattisgarh and MP reported IMR over 80 per 1000 live births. Lastly, NFHS-4 reported overall IMR of 42 per 1000 live births varying from 7 (95% CI: 4 - 9) in Kerala to 64 (95% CI: 63 - 66) in UP. States like UP, Chhattisgarh and MP reported IMR over 50 per 1000 live births.

Table 1 also presents results of relative change in IMR and U5MR across survey periods. For survey periods NFHS-1 to 3, the overall reduction in IMR was 25% and this varied from less than 2% in Jarkhand to 47 % in Tamil Nadu. Similarly, during NFHS-1 to 4, the overall reduction in IMR was 51% and this varied from less than 36% in Meghalaya and Jammu & Kashmir to 79 % in Kerala. It can be observed that majority of the states have witnessed over 50% reduction in both IMR and U5MR from NFHS-I to NFHS-4. The maximum benefits in terms of reduction in infant deaths was observed in Kerala, Odisha, Tamil Nadu, West Bengal, Karnataka, Goa Tripura and Haryana whereas Chhattisgarh, Meghalaya and Jammu and Kashmir observed least improvements in infant mortality. Surprisingly two states, namely, Mizoram and Nagaland, had in fact experienced increase in IMRs over the two survey period. Similar pattern was observed in the U5MR. It may be noted that most of the reduction in both IMR and U5MR was seen between NFHS-3 and NFHS-4 survey period.

Figure 3: Funnel Plots for India & states.

Having observed the general pattern and trends in infant and U5MR in India, it would be useful to see the variation in performance of the various states. Figures 3a, 3b and 3c present the funnel plots for NFHS I, 3 and 4 survey periods which help to identify the states with the lowest IMR and the states with the highest IMR, compared with the Indian average figures as indicated by a solid line parallel to the x-axis. The overall Indian IMR was used as a baseline comparison for each state. It can be observed that plots closer to the Y-axis are low birth states (small populated states) and those to the right are high birth states (large populated states). Data points that lie outside the confidence interval (CI) band are interpreted as experiencing IMR differently from the Indian average. Those states outside the 99% CI can be considered as outliers in terms of their performance with respect to IMR. States which are above the Indian average are the worst performing states and those below are the best performing states in terms of IMR.

Figure 3a also shows huge variation in the performance of the states with respect to IMR in NFHS-I. Of the 21 major states, four states namely Uttar Pradesh, Odisha, Bihar and Madhya Pradesh are performing so poorly with respect to IMR that they lie above the upper limits of the distribution of the funnel plot which has been created at 99% confidence bands. It may be noted that with respect to 95 % band, Assam is the only state to also be included in the category of poor performing states. The majority of the states were below the overall Indian baseline at 99% bands. Whereas Figure

3b presents data for NFHS-3 where it can be observed that in addition to the 4 states mentioned above, additional states like Rajasthan, Jarkhand and Chhattisgarh are also outliers at 99% bands. Lastly, Figure 3c presents data for NFHS-4 where improvements are observed in performance of states with only 4 underperforming states namely MP, Bihar, UP and Chhattisgarh.

From the above it can be observed that there is huge variation in performance among the states. These results hold true for both IMR and U5MR. Uttar Pradesh Bihar and Madhya Pradesh need a special mention as these states are not only the most populous states in India but also have underperformed consistently across the survey period from 1992 both with respect to IMR and U5MR.

Table (not shown) shows the percentage distribution of infant deaths by some selected background characteristics in India. There were total 9792 infant deaths that took place in a period five years prior to survey. Of the total infant deaths, nearly 56 percent were male and rest were females. Nearly 70 percent of the total infant deaths occurred to mothers who were in the age group 20 years to 29 years at the time of child birth. Contrary to the expectation, trend with respect to education is not clear cut. Illiterate mothers and those who had secondary education experienced high infant mortality. More than four fifth of the infant deaths took place in rural areas. Nearly 60 percent of the total infant deaths occurred to mothers who belonged to poorest and poorer wealth group and only 20 percent of the total infant deaths occurred to richer and richest mothers. The gradient with respect to wealth index is clear. Those who are least well off (poorest 20%) experienced three times infant deaths when compared to the richest 20%. Nearly one third of infant deaths were of first order and 34 percent of the infant deaths were of two and higher birth order and had birth interval more than 24 months. Of the total infant deaths, nearly 28 percent infant deaths occurred in Uttar Pradesh, 15 percent in Bihar and 9 percent in Madhya Pradesh respectively. Finally, it may be noted that five states namely UP, MP, Bihar, Rajasthan and West Bengal contribute over 65 % of total infant deaths in India.

We estimate two separate multivariable regression models to examine the significant factors affecting infant mortality (Table 2). The first and second model display the adjusted effect of selected covariates on infant deaths in good and poor performing states respectively. Among good performing states, infants from Haryana and Punjab had higher risk of infant death as opposed to Kerala. However, in case of poor performing states, Madhya Pradesh and Uttar Pradesh had higher risk of infant deaths in comparison to Bihar. Place of residence, mother's body mass index, caste and religion of the women had insignificant association with infant deaths in both the models. Females had higher chance of infant deaths in the group of poor performing states but no significant association was found in the case of good performing states. Mother's age at birth had no role in case of good performing states but the risk of infant deaths was low in the 20-29 years age-group in case of poor performing states. Women who had shorter birth interval had higher chance of experiencing infant deaths in the poor performing states and it was not significant in case of good performing states. Mother's education had significant role in the both group of states. As education level increases, the chances of experiencing infant deaths decreases. Women who belong to richest wealth quintile had 39 percent lower chance to experience infant deaths in the group of poor performing states.

Table 2: Adjusted hazards ratio for infant mortality preceding five years from the date of survey by selected characteristics according to well & poor performing States, India, 2015-16.

Covariates	GOOD PERFORMING STATES				POOR PERFORMING STATES	
	Hazards Ratio	95% CI for Exp (β)		Hazards Ratio	95% CI for Exp (β)	
		L	U		L	U
States						
Kerela(Good Performing States)						
Haryana	3.57***	1.51	8.43	NA	NA	NA
Maharashtra	1.88	0.79	4.49	NA	NA	NA
Punjab	2.62**	1.05	6.55	NA	NA	NA
Tamil Nadu	1.86	0.77	4.50	NA	NA	NA
Bihar(Poor Performing States)	NA	NA	NA			
Chhattisgarh	NA	NA	NA	1.23	0.96	1.59
MP	NA	NA	NA	1.46***	1.23	1.74
UP	NA	NA	NA	1.93***	1.67	2.23
Place of Residence						
Rural						
Urban	1.15	0.85	1.54	1.03	0.88	1.21
Sex of the child						
Male						
Female	1.14	0.87	1.47	1.18***	1.06	1.31
Mother's age (at child's birth)						
<=19 yrs.						
20-24 yrs.	0.70	0.47	1.05	0.67***	0.56	0.79
25-29 yrs.	0.78	0.49	1.23	0.81**	0.67	0.99
30+ yrs.	0.83	0.48	1.45	1.04	0.84	1.29
BMI						
Low						
High	1.09	0.77	1.54	1.00	0.89	1.13
Missing	3.26***	1.58	6.75	0.87	0.48	1.58
Caste						
SC						
ST	1.07	0.55	2.06	0.88	0.71	1.09
Others	0.78	0.57	1.06	0.95	0.83	1.08
Religion						
Hindu						
Muslim	1.43	0.95	2.14	0.94	0.81	1.10
Others	1.34	0.87	2.07	0.99	0.41	2.40
Birth Interval						
First Birth						
Less than 24 months	1.37	0.95	1.97	1.56***	1.34	1.81
24 or more months	0.97	0.69	1.36	0.82**	0.70	0.96
Mother's Education						
Illiterate						
Primary	0.60**	0.36	0.98	0.97	0.83	1.12
Secondary	0.71	0.48	1.03	0.77***	0.67	0.89
Higher	0.51**	0.27	0.93	0.48***	0.35	0.66
Wealth Index						
Poorest						
Poorer	1.70	0.88	3.26	0.89	0.77	1.02
Middle	1.27	0.66	2.45	0.92	0.77	1.09
Richer	1.18	0.60	2.34	0.84	0.68	1.03
Richest	0.88	0.42	1.86	0.61***	0.45	0.81

Note: ***p<0.01;p<0.05;** ® Reference category

DISCUSSION

The analysis of this paper is based on U5MR and IMR estimates from NFHS surveys from 1992-2016 period. IMR is defined as the number of infant deaths per 1,000 live births and is one of the indicators used to assess a country's overall level of development.[21]

Through the use of maps, this paper clearly shows that the overall trend in IMR and U5MR in India is decreasing and thus headed in the right direction. Reduction in infant and child mortality among states was observed over time from the NFHS-I to NFHS-4 survey period. Smaller populated states already show a significant reduction in IMR. However, much effort still needs to be done in the heavily populated states where mortality decline has been at a much slower pace than expected.

Maps are powerful tools in presenting the trends and the current distribution of child mortality across states. However, what is more useful to policy makers is to have a tool that can not only provide information at a glance about the size of the states in terms of population but also help identify the states that are outliers in terms of their performance with respect to child mortality. Funnel plots are one such tool that we used in identifying underperforming states. Similar to prior studies our results show that hugely populated and least developed states like Uttar Pradesh, Madhya Pradesh, Bihar still contribute significantly to India's overall high IMR and U5MR.[7,22] In spite of reduction in child deaths in these states over the years, even today, these three states alone contribute to over 50% of all infant deaths in India. Unfortunately, as seen in Funnel plots, these three states are persistent outliers with respect to under performance since 1992.

The analysis from this paper reveals that India has made progress in terms of reducing infant and child mortality but this progress has been relatively slow from 1992-2006. During this period less than 10% reduction in infant mortality was observed in number of states namely Chhattisgarh, Jharkhand, Rajasthan, Andhra Pradesh, Jammu and Kashmir and Manipur. In contrast, much of the reduction in infant and child mortality was observed during 2006 to 2016 period. Even the worst performing states had more than 35% reduction in infant mortality. In addition, the variation in performance between the worst and best performing states too drastically reduced from over 20 times in 1992 - 2006 period to just over 2 times in 1992- 2016 period.

Hence, in spite of significant reduction in infant and child mortality rates in recent years, a lot needs to be done especially with respect to under performing states which are persistent outliers. There are a number of policy implications from our study. It is important that policy makers target the underperforming states (upper outliers) as identified by the funnel in order to ensure reduction in variation between the states. These should fall down within the 95% CI. In addition, policy makers should focus on the larger states lying above CI on the right, namely the high impact states, as these represent the biggest population states with the potential for the most significant improvements in terms of reduction of IMR and U5MR.

Current policy in India is to focus on 18 states including eight empowered action group states[23] (EAG) which are poor performing states with targeting of below

poverty line families. There is a need for a more flexible approach to reducing child mortality among underperforming states. Selective targeting of lower socio-economic groups may be necessary. However, our study suggests that states like MP, UP Chhattisgarh and Bihar would benefit from rapid scaling up of interventions that reduce the average child mortality, irrespective of the socio-economic groups that may benefit from the reductions.

Another important aspect to consider is the contribution of neonatal mortality to total infant mortality. Over the years, proportion of neonatal mortality has been on the rise from 62% in 1992 to 73% in 2016. In addition, even low performing states like UP, MP, Bihar, Chhattisgarh experience high neonatal mortality especially in rural areas. This observation has important implications for policy makers. India has achieved reduction in infant mortality mainly due to reduction in post-neonatal mortality rates which are comparatively more amenable to existing set of interventions. However, existing strategies and interventions on their own may not be adequate and new set of high tech and expensive strategies would be needed if the focus is to shift to neonatal mortality.

Cox regression analysis shows that in well performing states only mother's education significantly associated with increased ratio of infant mortality. However, in poor performing states sex of the child, mother's age at child birth, birth interval, and age of the child, mother's education and wealth index emerges as a significant predictor of infant mortality.

Similar to previous studies our results also show that female child had a higher risk of death during infancy than a male child in the poor performing states in India.[24-27] Reason of excess female infant mortality could be human intervention at different stage of life cycle. Numerous studies have recognized gender gap in vaccination[28-29], breast feeding[30], allocation of food, nutrition (milk, fats, cereals, and sugars) even medical care and expenses.[31-33] These deliberate negligence were more pronounced in the poor performing states which leaves female infants at higher risk of mortality.

After adjusting other covariates in the model this study suggest that less than 24 moths birth interval are invariably more hazardous in terms of infant mortality. Various studies have documented the significant effect of birth interval and infant mortality.[34-35] Short preceding intervals is associated with enhanced risk of prematurity and low birth weight for gestational age.[36] Also cross-infection, less maternal attention and limited household resources between closely spaced siblings may be the probable pathways through which infant mortality seems to be high.[37-38] The poor performing states which had higher fertility than well performing states also had lower birth interval.

Compared with other countries in the region, it is evident that even poorer nations like Bangladesh and Nepal have performed better than India.[39-41] India's poor performance can also be noted with respect to immunization coverage, child anemia, and nutrition. Despite its economic progress and significant efforts since the 1980s, for example with the Expanded Program on Immunization and Universal Immunization Programme, India has the lowest immunization coverage rates in Asia.[42] Only 62% of children between the age of 12 and 23 months receive the

recommended vaccinations.[15] The prevalence rate of anemia in Indian children below the age of five years is as high as 60%. Even in richer states like Maharashtra and Gujarat, the percentage of children who are under weight is 36% and 40%, respectively.[15] Obviously, these figures are significantly worse for the poorer performing states identified in our study. Reddy et al., (2011) in their recent call to action for universal health coverage, also mention the limited health gains achieved by India over the last decade.[43]

It is therefore not surprising to see a number of initiatives launched by the Government of India (GOI) in recent years. National Rural Health Mission (NRHM) in 2005 which is the flagship programme of the GOI, attempting to meet people's health needs particularly in rural areas.[23] It aims to reduce child and maternal mortality by strengthening the rural health system and introducing innovative public private partnerships. Recognising that the past public health expenditure is inadequate (1% of its GDP), the NRHM aimed to double this expenditure by 2012 and increase its health expenditure to 3% of its GDP.[44] Similarly, though Accredited Social Health Activist (ASHA), it aims to address the need for a community worker to achieve universal coverage especially in the priority states. A good example of role of community health care workers in reducing infant and child mortality is provided in a recently published study in Lancet Global health by Tripathy et al.[45] Subsequently the Call to Action for Child Survival and Development, and there after Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCH+A) strategic framework in 2013. The RMNCH+A strategy is based on a continuum-of-care approach and defines integrated packages of services for different stages of life. More recently, newer initiatives like web enabled tracking of pregnant women to ensure antenatal, intra natal and postnatal care; Janani Shishu Suraksha Karyakaram (JSSK) which entitles all pregnant women delivering in public health institutions to absolutely free delivery including Caesarean section and free transport; Rashtriya Bal Swasthya Karyakram (RBSK), an introduction of child health screening for 4Ds i.e. defects at birth, deficiencies, diseases, development delays[46] are landmark policies in reducing the infant and child mortality.These packages provide a framework for delivering services at the state and district level.

Policy makers could benefit from further analysis to target the under performing states. For example, it would be necessary to analysing inequalities with respect to infant and child mortality across states and within states[47]. For the first time district level data is available and such analysis could guide policy makers with micro level planning and cluster analysis could help with selective targeting of specific districts. Few previous studies cited the role of family level clustering of infant deaths in the low performing states.[48]

From our analysis, it appears that the trend in reducing IMR and U5MR is headed in the right direction. Even so, there is huge variation between states and within states. However, a blanket approach to reducing infant and child mortality in all underperforming states of India may not be the best option. Depending upon a state's performance and the socio-economic differentials, policy makers may wish to be flexible in their approach in reducing infant and child mortality as discussed in this paper. Given the greater contribution of neonatal mortality, India's challenge in reducing infant mortality would depend largely on how it addresses the issue of neonatal deaths.

CONCLUSIONS

The results of this study confirm that to bring the overall Indian national average of IMR and U5MR to a more respectable level, policy makers will have to target the underperforming large states and population groups where mortality rates are still high. This is particularly so when the improvements with respect to infant and child mortality have been unevenly distributed across states and population groups. As India continues to reduce its infant and child mortality, the challenge is to accelerate its reform process by adopting a differential strategy. To a large extent, India's under performing states and its approach to reducing neonatal mortality will determine its success or failure in reducing infant and child mortality in future.

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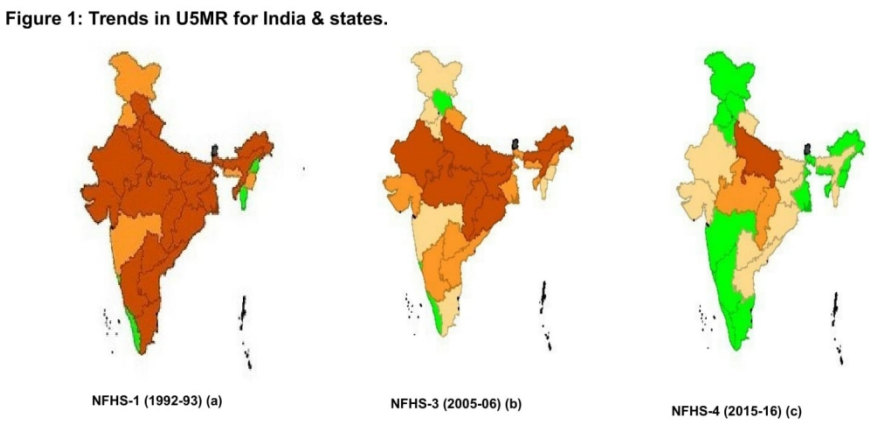

Figure1: Trends in U5MR for India and States

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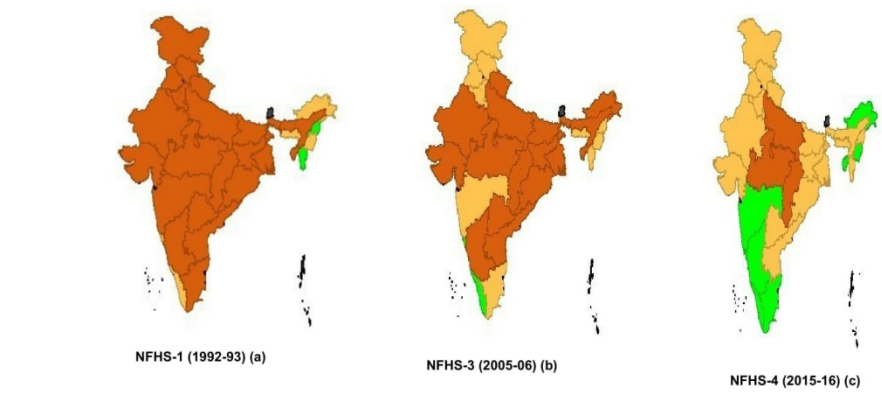

Figure2: Trends in IMR for India and States

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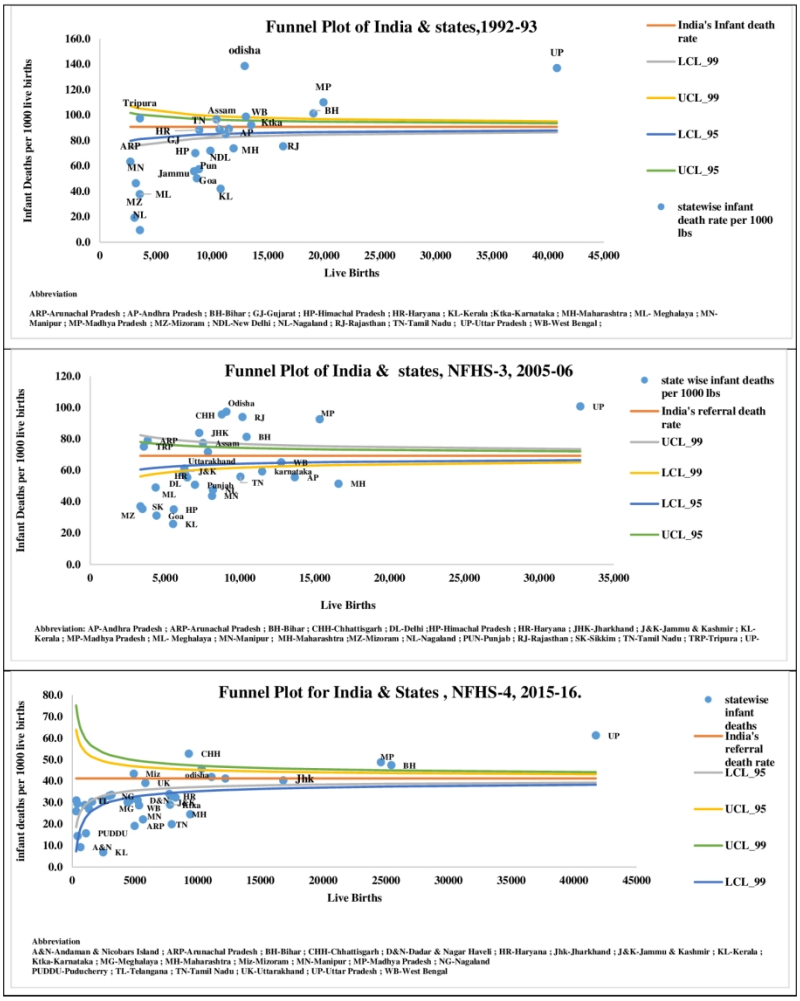

Figure 3: Funnel Plots for India & states.

1400x1980mm (30 x 30 DPI)

The STROBE checklist

	Item No	Recommendation
Title and abstract	1	*(a)* Indicate the study's design with a commonly used term in the title or the abstract [**Within the title page 1 and method section of the abstract page 2]** *(b)* Provide in the abstract an informative and balanced summary of what was done and what was found **[See abstract page 2]**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported [**page 4]**
Objectives	3	State specific objectives, including any prespecified hypotheses **[pages 4 and 5, paragraphs 3,4 and 5]**
Methods		
Study design	4	Present key elements of study design early in the paper **[Methods page 5]**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **[pages 5, section methods, subsection data]**
Participants	6	*(a) Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **[N/A]** *Case-control study*— Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls **[N/A]** *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants **[pages 5, section methods, subsection data and table 1]** *(b) Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed **[N/A]** *Case-control study*—For matched studies, give matching criteria and the number of controls per case [**N/A]**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **[table 1 and table 2]**
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 **[pages 5, section methods, subsection data and table 1]**
Bias	9	Describe any efforts to address potential sources of bias **[N/A]**
Study size	10	Explain how the study size was arrived at **[N/A – not required since it is secondary data]**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **[N/A]**
Results		
Statistical methods	12	Describe all statistical methods, including those used to control for confounding **[page 5-6]** Describe any methods used to examine subgroups and interactions **[N/A]** Explain how missing data were addressed **[N/A]** *Cohort study*—If applicable, explain how loss to follow-up was addressed **[N/A]** *Case-control study*—If applicable, explain how matching of cases and controls was addressed **[N/A]**

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy **[N/A]**
		Describe any sensitivity analyses **[N/A]**
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 6 and table 1**]
		(b) Give reasons for non-participation at each stage [**N/A]**
		(c) (c) Consider use of a flow diagram [**N/A information in table 1**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **[page 6-8 and table 1]**
		(b) Indicate number of participants with missing data for each variable of interest **[N/A]**
		(a) (c) Cohort study—Summarise follow-up time (eg, average and total amount **[N/A]**
Outcome data	15*	(b) *Cohort study*—Report numbers of outcome events or summary measures over time **[N/A]**
		(c) *Case-control study*—Report numbers in each exposure category, or summary measures of exposure **[N/A]**
		(d) *Cross-sectional study*—Report numbers of outcome events or summary measures [**N/A]**
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included **[Table 2]**
		(b) Report category boundaries when continuous variables were categorized [**Table 2]**
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period [**Table 2]**
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses [**N/A]**

Discussion		
Key results	18	Summarise key results with reference to study objectives [**pages 12 and 13, page 15, section conclusions]**
Limitations	19	Discuss limitations of the study, considering sources of potential bias or imprecision**. [page 3, section Strengths and limitations of this study]**
		Discuss both direction and magnitude of any potential bias [**N/A]**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [**pages 12-14, page 15, section conclusions]**
Generalisability	21	Discuss the generalisability (external validity) of the study results [**pages 12-14, page 15, section conclusions]**

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 16]**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.[i]

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 www.strobe-statement.org.

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"Trends, patterns and predictive factors of infant and child mortality in well and underperforming states of India: A secondary analysis using National Family Health surveys"

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Trends, patterns and predictive factors of infant and child mortality in well and underperforming states of India: A secondary analysis using National Family Health surveys.

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Abstract

Objectives
This paper analyses the patterns and trends in the mortality rates of infants and children under the age of five years in India (1992-2016) and quantifies the variation in performance between different geographic states through three rounds of nationally representative household surveys.

Design
Three rounds of cross-sectional survey data.

Setting

National level. India and its selected good performing states namely Haryana, Kerala, Maharashtra, Punjab and Tamil Nadu and selected under poor performing states namely Bihar, Chhattisgarh, Madhya Pradesh and Uttar Pradesh.

Participants
Adopting a multistage stratified random sampling, 601,509 households with 699,686 women age 15-49 years in 2015-16,109,041 households with 124,385 women age 15-49 years in 2005-06 and 88,562 households with 89777 ever married women in the age group 13 to 49 years in 1992-93 were selected.

Results
Through the use of maps, this paper clearly shows that the overall trend in infant and child mortality is on the decline in India. Computation of relative change shows that majority of the states have witnessed over 50% reduction in both IMR and U5 MR from NFHS-I to NFHS-4. However, the improvements are not evenly distributed and there is huge variation in performance between states over time. Funnel plots show that the most populous states like Uttar Pradesh Bihar and Madhya Pradesh have underperformed consistently across the survey period from 1992 to 2016. Regression analysis comparing high and low performing states revealed that female infants and women with shorter birth intervals had greater risk of infant deaths in poor performing states.

Conclusion
Attempts to reduce infant and child mortality rates in India are heading in the right direction. Even so, there is huge variation in performance between states. This paper recommends a mix of strategies that reduce child and infant mortality among the high impact states where the biggest improvements can be expected including the need to address neonatal mortality.

Key words: Infant and child mortality rate, performance of Indian states, funnel plots, Cox regression model, relative change, India.

Strengths and limitations of this study

- Trends in infant and U5MR from 1992-2016 using three rounds of data covering most of India.
- A more effective approach to quantify variation in performance of states with respect to child mortality rates using Funnel Plots.
- This study attempts to understand how factors associated with infant deaths act differently in under and well performing states.
- Limitations of analysis based on secondary data also apply to this study.
- As a result of grouping of states, some state specific factors affecting infant mortality may get diluted.

INTRODUCTION

Child health is a basic right and the level of child mortality is an important indicator in the assessment of the development of any society .[1] It is therefore not surprising that the United Nations' Sustainable Development Goals declaration (2015) to improve the health and welfare of the world's poorest people includes reducing child mortality as one of its goals which was earlier laid out by Millennium Development Goal's (MDG) declaration (1990).[2] Annually, 5.6 million children under the age of five years die worldwide, primarily in developing countries.[3] Given that most of these deaths can be easily prevented or treated [4] with cheap and effective interventions, such high mortality is unacceptable even in resource constrained settings.

India is the world's largest democratic nation with 16% of the global population. According to UNICEF, India has the highest number of under five deaths, with a total of 1.08 million deaths in 2016.[5] It is one of the six countries that contributes to 50% of the world's under five mortality rate (U5MR).[5] On its own, India contributes to 19 % of all under five deaths and 24% of all neonatal deaths.[5] However, infant mortality rate (IMR) and U5MR have declined over the years in India. For example, the U5MR reduced from 114 per 1000 live births in 1990 to 39 in 2016 at a rate of 3% annually.[5] Similarly, the IMR reduced from 81 to 34 per 1000 live births between 1990 and 2016.[5] However, the distribution of these gains is uneven across states.[6] For example, at the national level, U5MR is estimated at 39 and it varies from 43 in rural areas to 25 in urban areas. Among the bigger States/UTs, it varies from 11 in Kerala to 55 in Madhya Pradesh.[6] Similary, at the National level, IMR is reported to be 34 and varies from 38 in rural areas to 23 in urban areas. Among the four most populated states, it varies from 38 in Bihar to 47 in Madhya Pradesh.[6]

Healthcare in India is the responsibility of individual states, which vary in terms of their level of socio-economic development, size of population, experience of epidemiological transition, and health system capacities, factors which influence the health status experienced by the population of the states. On the one hand, states like Kerala experience relatively low levels of infant and child mortality comparable with the Western world, whereas states like Madhya Pradesh and Uttar Pradesh suffer IMRs and U5MRs comparable with some of poorest countries of the world.[7] Therefore, it is necessary to disaggregate the mortality data and quantify the variation between states. This would help policy makers to prioritise the underperforming states where intense efforts need to be expanded.

By providing the current status of child mortality through the use of maps, and undertaking a disaggregate analysis of infant mortality using the funnel plot technique, this paper identifies key states where performance needs to improve significantly, and the states that should be the target of intense efforts in the future. Funnel plots are an attractive way to present data to policy makers and a good tool to compare performance data, including population data.[8] Funnel plots have been used in the developed world in a number of settings including assessing institutional performance[9], comparing health care providers[10], and assessing the variations in cardiac[11-12] and cancer mortality[13-14]. However, to the best of our knowledge the application of this technique to child mortality rates in the context of the developing world has not been previously conducted.

This paper is timely in that the NFHS-4 survey data (2015-16) has just been released in January, 2018. In addition, India is the highest contributor to the U5MR in the

world and with new impetus in reducing child and maternal mortality, the rest of the world is closely monitoring India's performance.

METHODS

Data

The analysis of this paper is based on the three rounds of National Family Health Surveys (NFHS), NFHS-I, III, and IV data which were conducted during the periods between 1992-93, 2005-06 and 2015-16. For pragmatic reasons, NFHS-II survey data conducted in 1998-99 has been intentionally excluded from our analysis. An important consideration for not including NFHS-II survey in the analysis is the short time interval between1992-93 and 1998-99 and that there were no major changes with respect to policies and programs during this period. The International Institute for Population Sciences is designated as a nodal agency for conducting the survey under the stewardship of the Ministry of Health and Family Welfare, Govt. of India. The National Family Health Surveys series provides information on population, health and nutrition for India and each State / Union territory. NFHS-4 gathered information from 601,509 households, 699,686 women, and 103,525 men.[15] In NFHS-3, Interviews were conducted with 124,385 women age 15-49 and 74,369 men age 15-54 from all 29 states.[16] NFHS-1 is a household survey which has a nationally representative sample of 88,562 households and 89777 ever married women in the age group 13 to 49 years covering the population in 24 states and the National Capital Territory of Delhi.[17] It may be noted that we have merged the sample for Union territories into their nearby states like Andaman and Nicobar Island and Puducherry was merged into Tamil Nadu; Dadar & Nagar Haveli was merged to Maharashtra; Daman & Diu to Gujarat; Laksdweep to Kerela; and Chandigarh to Punjab. The states of Chhattisgarh and Jharkhand were modelled based on district information available in NFHS-1 to make it comparable with NFHS-3 and NFHS-4. However, it was not possible to separate out the Telangana state from NFHS-3.The present study has utilized ten years retrospective birth history information to estimate the mortality rates. The information related to births and deaths which women had during her reproductive period is collected in NFHS surveys. Further, the information collected on deaths and age at death of child were consistent across all rounds of NFHS.[18] Literature suggests that omission of births is almost virtually nil but displacement of births in reporting of age of child is visible in DHS surveys.[19]

Statistical analysis

Maps were drawn to study the patterns of the IMR and U5MR across the states of India and trends were studied between the three survey time points. Funnel plots were drawn to observe the variation in performance between states. The all India average IMR (indicated by a solid line parallel to the x-axis) was used as a baseline reference. The 99% confidence bands were constructed and each data point represents the state's IMR. The states which are located above the 99 percent band in the funnel plot are considered as under-performing states and those which are located below are considered as well performing states. The states namely Haryana, Kerala, Maharashtra, Punjab and Tamil Nadu fall in the category of good performing states. The poor performing states are Bihar, Chhattisgarh, Madhya Pradesh, and Uttar Pradesh. In addition, we have compared the results of 99% confidence bands with 95%.

The dependent variable for the present study is considered as infant death which is coded as 1 “if the death occurred less than 1 year “and 0 “otherwise”. The births which took place preceding five years from the date of survey has been considered for the analysis. The following independent variables has been taken: Sex of the Child (Male/Female) , Mother’s age at child’s birth into six categories (15-19 /20-24 /25-29/ 30-34 /35-39 /40-50), Mother’s education (Illiterate/Primary/Secondary/Higher), Caste of women (Scheduled Caste (SC)/Scheduled Tribe (ST)/Other than SC & ST), Religion of women (Hindu/Muslim/Others) combination of Birth Interval and birth order (1st Birth Order/two or more birth order and less than 24 months/ two or more birth order and more than 24 months), Region of residence (Rural/Urban), Wealth Index (Poorest/Poorer/Middle/Richer/Richest) and Body Mass Index (Low/High/Missing).
The first category of each covariate is considered as a reference category. Further, for poor performing states (Bihar /Chhattisgarh/Madhya Pradesh/Uttar Pradesh), Bihar is considered as a reference category. However, for good performing states (Kerala/Haryana, Maharashtra, Punjab and Tamil Nadu), Kerala is considered as a reference category in the separate regression model.

Cox regression analysis has been employed to examine the factors[20] which are responsible for explaining the infant deaths in under and well performing states using recent round of NFHS-4 data. Based on the results of funnel plots of 99% confidence, the under-performing states considered for the regression analysis are Bihar, Chhattisgarh, Madhya Pradesh (MP) and Uttar Pradesh (UP). Similarly, the well performing states considered are Haryana, Kerala, Maharashtra, Punjab and Tamil Nadu. For the regression analysis only recent round of NFHS-4 data has been considered.
The brief mathematical description of this model is given below:

Let X_1, X_2 , X_3, ….. X_p are p predictors which affect the dependent variable that is, infant deaths. Further, suppose that hazards at time t is $\lambda(t)$ then Cox proportional hazards model (Cox PH model) is generally written in the form of
$\lambda(t) = \lambda_0(t) \exp(\beta_1X_1+\beta_2X_2+.....+\beta pXp)$

$$= \lambda_0(t)\exp(\sum_{i=1}^{p}\beta_i X_i)$$

$$= \lambda_0(t)e^{\sum_{i=1}^{p}(\beta_i x_i)} \quad (1)$$

Where $\lambda_0(t)$ is baseline hazard at time t and β_1, β_2, ... β_p are unknown regression coefficients. The advantage of hazards model is that exponential expression permits the specification of the model without any further restrictions on the covariates. The base line hazard is a function of t, but does not involve the X’s (covariates) (Cox, 1972).

All analyses were performed in STATA software version 13.1

Patient and Public Involvement statement: Participants were not involved in the design of this study. The manuscript is based on analysis of secondary data of NHFS I-4 series which

is available in public domain.

RESULTS

Maps identifying the pattern and trend in IMR and U5MR across the states of India are presented in Figures 1 to 2. Figure 1 and 2 show that infant and U5MR has declined in India in absolute terms and in terms of distribution across states over the years between the NFHS-I and the NFHS-4 surveys. At a glance, it can be observed from Figure 1 that majority of states (i.e. 19) experienced U5MR of over 80 per 1000 live births in NFHS-I compared with only 1 state in NFHS-4. Same holds true for IMR. From Figure 2 it can be observed that most of India experienced IMR of over 50 per 1000 live births in NFHS-I whereas hardly any state experiences such infant mortality rates today.

Figures1 and 2: Trends in U5MR and IMR for India and States.

Figures 1 and 2 also show number of states achieving MDG targets of 29 and 43 per 1000 live births which was set as a goal post for India for IMR and U5MR respectively. While IMR of less than 29 per1000 live births and U5MR of less than 43 per 1000 live births were restricted to a few small states in terms of population in NFHS-I, this is not so in NFHS-4. There are significantly more states with low IMR and U5MR and this trend is not restricted to less populated states. By examining the MDG targets for each states of India, it can be observed that only Kerala, Tamil Nadu and Tripura have achieved the targets of reducing its IMR by 2/3rd from 1990. Surprisingly, none of the states have achieved its goal of U5MR.

Table 1 presents the IMR and U5MR for NFHS1-4 survey periods from 1992-2016.

	NFHS-1						NFHS-3						NFHS-4						NFHS-1 to NFHS 3		NFHS-1 to NFHS4		NFHS-3 to NFHS-4	
India & States	IMR	LL_IMR	UL_IMR	U5MR	LL_U5MR	UL_U5MR	IMR	LL_IMR	UL_IMR	U5MR	LL_U5MR	UL_U5MR	IMR	LL_IMR	UL_IMR	U5MR	LL_U5MR	UL_U5MR	IMR	U5MR	IMR	U5MR	IMR	U5MR
India	86	84	88	119	117	121	65	63	67	85	83	87	42	41	43	52		53	-25	-28	-51	-56	-35	-39
Assam	93	83	103	144	131	156	71	62	80	95	84	106	48	44	51	58		62	-24	-34	-48	-59	-33	-39
Bihar	103	95	111	145	135	155	65	57	72	95	86	104	48	46	50	59		61	-37	-34	-54	-59	-27	-38
Chhattisgarh	90	72	107	115	95	135	81	71	90	106	95	116	58	55	62	70		75	-10	-8	-35	-39	-28	-33
Gujarat	74	68	79	104	96	111	63	55	70	77	70	84	36	32	39	44		47	-15	-26	-52	-58	-43	-43
Jharkhand	78	66	91	111	96	126	77	67	87	112	101	124	47	43	51	57		62	-2	2	-40	-48	-39	-49
Kerela	31	25	36	40	35	46	18	12	23	20	14	25	7	4	9	7		10	-43	-52	-79	-82	-63	-62
Maharashtra	56	49	62	76	69	83	45	39	52	53	47	60	24	20	27	30		33	-19	-30	-57	-61	-47	-44
Madhya Pradesh	99	91	107	152	143	162	82	75	89	108	99	117	53	51	56	68		70	-17	-29	-46	-55	-35	-37
Odisha	119	113	126	137	130	144	68	60	75	95	87	103	45	42	47	56		60	-43	-31	-63	-59	-34	-40
Rajasthan	76	71	82	108	101	114	73	65	80	93	85	101	43	41	45	53		55	-5	-13	-44	-51	-41	-43
Tamil Nadu	71	65	77	95	87	103	38	32	44	45	39	52	20	18	23	25		28	-47	-53	-72	-73	-47	-44
Uttar Pradesh	118	111	124	163	157	170	83	78	88	112	106	118	64	63	66	81		83	-29	-31	-45	-50	-22	-28
Uttarakhand	73	55	91	110	90	130	55	47	62	70	62	78	42	38	46	49		54	-25	-36	-42	-55	-23	-30
West Bengal	81	73	89	107	99	116	52	46	58	65	58	73	31	27	35	37		41	-36	-39	-62	-66	-41	-43
Haryana	80	72	87	108	101	114	44	36	53	59	49	68	31	28	34	39		43	-44	-45	-61	-63	-30	-33
Goa	33	26	41	41	33	49	26	19	33	32	25	40	16	8	23	17		26	-21	-22	-53	-58	-40	-46
Andhra Pradesh	73	67	80	96	88	104	44	61	76	59	70	87	43	38	48	49		54	-40	-39	-41	-49	-2	-17
Himachal Pradesh	65	56	75	85	74	96	38	30	46	43	35	50	34	29	40	39		44	-42	-49	-48	-54	-11	-10
Jammu& Kashmir	50	43	57	68	61	76	46	38	53	54	46	61	32	30	35	36		39	-8	-21	-36	-46	-30	-33
Karnataka	75	68	82	102	94	110	53	46	60	66	59	74	27	24	30	31		34	-29	-35	-64	-70	-49	-54
Manipur	39	30	48	60	49	71	36	29	43	50	41	59	22	19	25	28		32	-8	-17	-44	-53	-39	-44
Meghalaya	46	35	57	65	53	77	48	38	58	74	61	87	29	26	33	41		44	4	14	-36	-38	-39	-45
Mizoram	17	11	23	27	19	35	33	25	42	48	39	58	45	37	54	53		62	94	78	167	96	37	10
Nagaland	12	7	17	14	9	20	48	42	55	70	63	77	25	22	29	35		39	300	400	111	148	-47	-50
Punjab	53	45	60	69	61	78	45	39	51	55	48	61	30	26	34	35		39	-15	-20	-44	-49	-34	-36
Delhi	62	56	69	78	72	85	38	31	45	46	39	54	24	17	30	31		39	-39	-41	-62	-60	-38	-32
Arunachal Pradesh	50	38	61	87	75	100	67	55	78	98	85	110	23	20	27	34		38	34	13	-53	-61	-65	-65
Tripura	88	74	102	115	101	130	58	44	71	73	59	88	25	18	32	32		39	-34	-37	-72	-72	-57	-56

Table 1 presents the IMR and U5MR for NFHS1-4 survey periods from 1992-2016 along with relative change in IMR and U5MR in Indian States. It can be observed that the trend of IMR is in decline significantly from 86 (95% CI: 84 - 88) in NFHS-I to 42 (95% CI: 41 - 43) 1000 live births in NFHS-4. During NFHS-I, the overall IMR for India was 86 per 1000 live births varying from 12 (95% CI: 7 - 17) in Nagaland to 119 (95% CI: 113 - 126) in Odisha. States like UP, Odisha, Bihar and MP reported IMR over 100 per 1000 live births. Similarly, NFHS-3 witnessed an overall IMR 65 (95% CI: 63 - 67) per 1000 live births varying from 18 (95% CI: 12 - 23) in Kerala to 83 (95% CI: 78 - 88) in UP. States like UP, Chhattisgarh and MP reported IMR over 80 per 1000 live births. Lastly, NFHS-4 reported overall IMR of 42 per 1000 live births varying from 7 (95% CI: 4 - 9) in Kerala to 64 (95% CI: 63 - 66) in UP. States like UP, Chhattisgarh and MP reported IMR over 50 per 1000 live births.

Table 1 also presents results of relative change in IMR and U5MR across survey periods. For survey periods NFHS-1 to 3, the overall reduction in IMR was 25% and this varied from less than 2% in Jarkhand to 47 % in Tamil Nadu. Similarly, during NFHS-1 to 4, the overall reduction in IMR was 51% and this varied from less than 36% in Meghalaya and Jammu & Kashmir to 79 % in Kerala. It can be observed that majority of the states have witnessed over 50% reduction in both IMR and U5MR from NFHS-I to NFHS-4. The maximum benefits in terms of reduction in infant deaths was observed in Kerala, Odisha, Tamil Nadu, West Bengal, Karnataka, Goa Tripura and Haryana whereas Chhattisgarh, Meghalaya and Jammu and Kashmir observed least improvements in infant mortality. Surprisingly two states, namely, Mizoram and Nagaland, had in fact experienced increase in IMRs over the two survey period. Similar pattern was observed in the U5MR. It may be noted that most of the reduction in both IMR and U5MR was seen between NFHS-3 and NFHS-4 survey period.

Figure 3: Funnel Plots for India & states.

Having observed the general pattern and trends in infant and U5MR in India, it would be useful to see the variation in performance of the various states. Figures 3a, 3b and 3c present the funnel plots for NFHS I, 3 and 4 survey periods which help to identify the states with the lowest IMR and the states with the highest IMR, compared with the Indian average figures as indicated by a solid line parallel to the x-axis. The overall Indian IMR was used as a baseline comparison for each state. It can be observed that plots closer to the Y-axis are low birth states (small populated states) and those to the right are high birth states (large populated states). Data points that lie outside the confidence interval (CI) band are interpreted as experiencing IMR differently from the Indian average. Those states outside the 99% CI can be considered as outliers in terms of their performance with respect to IMR. States which are above the Indian average are the worst performing states and those below are the best performing states in terms of IMR.

Figure 3a also shows huge variation in the performance of the states with respect to IMR in NFHS-I. Of the 21 major states, four states namely Uttar Pradesh, Odisha, Bihar and Madhya Pradesh are performing so poorly with respect to IMR that they lie above the upper limits of the distribution of the funnel plot which has been created at 99% confidence bands. It may be noted that with respect to 95 % band, Assam is the only state to also be included in the category of poor performing states. The majority of the states were below the overall Indian baseline at 99% bands. Whereas Figure

3b presents data for NFHS-3 where it can be observed that in addition to the 4 states mentioned above, additional states like Rajasthan, Jarkhand and Chhattisgarh are also outliers at 99% bands. Lastly, Figure 3c presents data for NFHS-4 where improvements are observed in performance of states with only 4 underperforming states namely MP, Bihar, UP and Chhattisgarh.

From the above it can be observed that there is huge variation in performance among the states. These results hold true for both IMR and U5MR. Uttar Pradesh Bihar and Madhya Pradesh need a special mention as these states are not only the most populous states in India but also have underperformed consistently across the survey period from 1992 both with respect to IMR and U5MR.

Table (not shown) shows the percentage distribution of infant deaths by some selected background characteristics in India. There were total 9792 infant deaths that took place in a period five years prior to survey. Of the total infant deaths, nearly 56 percent were male and rest were females. Nearly 70 percent of the total infant deaths occurred to mothers who were in the age group 20 years to 29 years at the time of child birth. Contrary to the expectation, trend with respect to education is not clear cut. Illiterate mothers and those who had secondary education experienced high infant mortality. More than four fifth of the infant deaths took place in rural areas. Nearly 60 percent of the total infant deaths occurred to mothers who belonged to poorest and poorer wealth group and only 20 percent of the total infant deaths occurred to richer and richest mothers. The gradient with respect to wealth index is clear. Those who are least well off (poorest 20%) experienced three times infant deaths when compared to the richest 20%. Nearly one third of infant deaths were of first order and 34 percent of the infant deaths were of two and higher birth order and had birth interval more than 24 months. Of the total infant deaths, nearly 28 percent infant deaths occurred in Uttar Pradesh, 15 percent in Bihar and 9 percent in Madhya Pradesh respectively. Finally, it may be noted that five states namely UP, MP, Bihar, Rajasthan and West Bengal contribute over 65 % of total infant deaths in India.

We estimate two separate multivariable regression models to examine the significant factors affecting infant mortality (Table 2). The first and second model display the adjusted effect of selected covariates on infant deaths in good and poor performing states respectively. Among good performing states, infants from Haryana and Punjab had higher risk of infant death as opposed to Kerala. However, in case of poor performing states, Madhya Pradesh and Uttar Pradesh had higher risk of infant deaths in comparison to Bihar. Place of residence, mother's body mass index, caste and religion of the women had insignificant association with infant deaths in both the models. Females had higher chance of infant deaths in the group of poor performing states but no significant association was found in the case of good performing states. Mother's age at birth had no role in case of good performing states but the risk of infant deaths was low in the 20-29 years age-group in case of poor performing states. Women who had shorter birth interval had higher chance of experiencing infant deaths in the poor performing states and it was not significant in case of good performing states. Mother's education had significant role in the both group of states. As education level increases, the chances of experiencing infant deaths decreases. Women who belong to richest wealth quintile had 39 percent lower chance to experience infant deaths in the group of poor performing states.

Table 2: Adjusted hazards ratio for infant mortality preceding five years from the date of survey by selected characteristics according to well & poor performing States, India, 2015-16.

Covariates	GOOD PERFORMING STATES				POOR PERFORMING STATES	
	Hazards Ratio	95% CI for Exp (β)		Hazards Ratio	95% CI for Exp (β)	
		L	U		L	U
States						
Kerela(Good Performing States)						
Haryana	3.57***	1.51	8.43	NA	NA	NA
Maharashtra	1.88	0.79	4.49	NA	NA	NA
Punjab	2.62**	1.05	6.55	NA	NA	NA
Tamil Nadu	1.86	0.77	4.50	NA	NA	NA
Bihar(Poor Performing States)	NA	NA	NA			
Chhattisgarh	NA	NA	NA	1.23	0.96	1.59
MP	NA	NA	NA	1.46***	1.23	1.74
UP	NA	NA	NA	1.93***	1.67	2.23
Place of Residence						
Rural						
Urban	1.15	0.85	1.54	1.03	0.88	1.21
Sex of the child						
Male						
Female	1.14	0.87	1.47	1.18***	1.06	1.31
Mother's age (at child's birth)						
<=19 yrs.						
20-24 yrs.	0.70	0.47	1.05	0.67***	0.56	0.79
25-29 yrs.	0.78	0.49	1.23	0.81**	0.67	0.99
30+ yrs.	0.83	0.48	1.45	1.04	0.84	1.29
BMI						
Low						
High	1.09	0.77	1.54	1.00	0.89	1.13
Missing	3.26***	1.58	6.75	0.87	0.48	1.58
Caste						
SC						
ST	1.07	0.55	2.06	0.88	0.71	1.09
Others	0.78	0.57	1.06	0.95	0.83	1.08
Religion						
Hindu						
Muslim	1.43	0.95	2.14	0.94	0.81	1.10
Others	1.34	0.87	2.07	0.99	0.41	2.40
Birth Interval						
First Birth						
Less than 24 months	1.37	0.95	1.97	1.56***	1.34	1.81
24 or more months	0.97	0.69	1.36	0.82**	0.70	0.96
Mother's Education						
Illiterate						
Primary	0.60**	0.36	0.98	0.97	0.83	1.12
Secondary	0.71	0.48	1.03	0.77***	0.67	0.89
Higher	0.51**	0.27	0.93	0.48***	0.35	0.66
Wealth Index						
Poorest						
Poorer	1.70	0.88	3.26	0.89	0.77	1.02
Middle	1.27	0.66	2.45	0.92	0.77	1.09
Richer	1.18	0.60	2.34	0.84	0.68	1.03
Richest	0.88	0.42	1.86	0.61***	0.45	0.81

Note: ***p<0.01;p<0.05;** ® Reference category

DISCUSSION

The analysis of this paper is based on U5MR and IMR estimates from NFHS surveys from 1992-2016 period. IMR is defined as the number of infant deaths per 1,000 live births and is one of the indicators used to assess a country's overall level of development.[21]

Through the use of maps, this paper clearly shows that the overall trend in IMR and U5MR in India is decreasing and thus headed in the right direction. Reduction in infant and child mortality among states was observed over time from the NFHS-I to NFHS-4 survey period. Smaller populated states already show a significant reduction in IMR. However, much effort still needs to be done in the heavily populated states where mortality decline has been at a much slower pace than expected as these states continue to remain outliers in spite of number of policy initiatives.

Maps are powerful tools in presenting the trends and the current distribution of child mortality across states. However, what is more useful to policy makers is to have a tool that can not only provide information at a glance about the size of the states in terms of population but also help identify the states that are outliers in terms of their performance with respect to child mortality. Funnel plots are one such tool that we used in identifying underperforming states. Similar to prior studies our results show that hugely populated and least developed states like Uttar Pradesh, Madhya Pradesh, Bihar still contribute significantly to India's overall high IMR and U5MR.[7,22] In spite of reduction in child deaths in these states over the years, even today, these three states alone contribute to over 50% of all infant deaths in India. Unfortunately, as seen in Funnel plots, these three states are persistent outliers with respect to under performance since 1992.

The analysis from this paper reveals that India has made progress in terms of reducing infant and child mortality but this progress has been relatively slow from 1992-2006. During this period less than 10% reduction in infant mortality was observed in number of states namely Chhattisgarh, Jharkhand, Rajasthan, Andhra Pradesh, Jammu and Kashmir and Manipur. In contrast, much of the reduction in infant and child mortality was observed during 2006 to 2016 period. Even the worst performing states had more than 35% reduction in infant mortality. In addition, the variation in performance between the worst and best performing states too drastically reduced from over 20 times in 1992 - 2006 period to just over 2 times in 1992- 2016 period.

Hence, in spite of significant reduction in infant and child mortality rates in recent years, a lot needs to be done especially with respect to under performing states which are persistent outliers. There are a number of policy implications from our study. It is important that policy makers target the underperforming states (upper outliers) as identified by the funnel in order to ensure reduction in variation between the states. These should fall down within the 95% CI. In addition, policy makers should focus on the larger states lying above CI on the right, namely the high impact states, as these represent the biggest population states with the potential for the most significant improvements in terms of reduction of IMR and U5MR.

Current policy in India is to focus on 18 states including eight empowered action group states[23] (EAG) which are poor performing states with targeting of below poverty line families. There is a need for a more flexible approach to reducing child mortality among underperforming states. Selective targeting of lower socio-economic groups may be necessary. However, our study suggests that states like MP, UP Chhattisgarh and Bihar would benefit from rapid scaling up of interventions that reduce the average child mortality, irrespective of the socio-economic groups that may benefit from the reductions.

Another important aspect to consider is the contribution of neonatal mortality to total infant mortality. Over the years, proportion of neonatal mortality has been on the rise from 62% in 1992 to 73% in 2016. In addition, even low performing states like UP, MP, Bihar, Chhattisgarh experience high neonatal mortality especially in rural areas. This observation has important implications for policy makers. India has achieved reduction in infant mortality mainly due to reduction in post-neonatal mortality rates which are comparatively more amenable to existing set of interventions. However, existing strategies and interventions on their own may not be adequate and new set of high tech and expensive strategies would be needed if the focus is to shift to neonatal mortality.

Cox regression analysis shows that in well performing states only mother's education significantly associated with increased ratio of infant mortality. However, in poor performing states sex of the child, mother's age at child birth, birth interval, and age of the child, mother's education and wealth index emerges as a significant predictor of infant mortality.

Similar to previous studies our results also show that female child had a higher risk of death during infancy than a male child in the poor performing states in India.[24-27] Reason of excess female infant mortality could be human intervention at different stage of life cycle. Numerous studies have recognized gender gap in vaccination[28-29], breast feeding[30], allocation of food, nutrition (milk, fats, cereals, and sugars) even medical care and expenses.[31-33] These deliberate negligence were more pronounced in the poor performing states which leaves female infants at higher risk of mortality.

After adjusting other covariates in the model this study suggest that less than 24 moths birth interval are invariably more hazardous in terms of infant mortality. Various studies have documented the significant effect of birth interval and infant mortality.[34-35] Short preceding intervals is associated with enhanced risk of prematurity and low birth weight for gestational age.[36] Also cross-infection, less maternal attention and limited household resources between closely spaced siblings may be the probable pathways through which infant mortality seems to be high.[37-38] The poor performing states which had higher fertility than well performing states also had lower birth interval.

Compared with other countries in the region, it is evident that even poorer nations like Bangladesh and Nepal have performed better than India.[39-41] India's poor performance can also be noted with respect to immunization coverage, child anemia, and nutrition. Despite its economic progress and significant efforts since the 1980s, for example with the Expanded Program on Immunization and Universal

Immunization Programme, India has the lowest immunization coverage rates in Asia.[42] Only 62% of children between the age of 12 and 23 months receive the recommended vaccinations.[15] The prevalence rate of anemia in Indian children below the age of five years is as high as 60%. Even in richer states like Maharashtra and Gujarat, the percentage of children who are under weight is 36% and 40%, respectively.[15] Obviously, these figures are significantly worse for the poorer performing states identified in our study. Reddy et al., (2011) in their recent call to action for universal health coverage, also mention the limited health gains achieved by India over the last decade.[43]

It is therefore not surprising to see a number of initiatives launched by the Government of India (GOI) in recent years. National Rural Health Mission (NRHM) in 2005 which is the flagship programme of the GOI, attempting to meet people's health needs particularly in rural areas.[23] It aims to reduce child and maternal mortality by strengthening the rural health system and introducing innovative public private partnerships. Recognising that the past public health expenditure is inadequate (1% of its GDP), the NRHM aimed to double this expenditure by 2012 and increase its health expenditure to 3% of its GDP.[44] Similarly, though Accredited Social Health Activist (ASHA), it aims to address the need for a community worker to achieve universal coverage especially in the priority states. A good example of role of community health care workers in reducing infant and child mortality is provided in a recently published study in Lancet Global health by Tripathy et al.[45] Subsequently the Call to Action for Child Survival and Development, and there after Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCH+A) strategic framework in 2013. The RMNCH+A strategy is based on a continuum-of-care approach and defines integrated packages of services for different stages of life. More recently, newer initiatives like web enabled tracking of pregnant women to ensure antenatal, intra natal and postnatal care; Janani Shishu Suraksha Karyakaram (JSSK) which entitles all pregnant women delivering in public health institutions to absolutely free delivery including Caesarean section and free transport; Rashtriya Bal Swasthya Karyakram (RBSK), an introduction of child health screening for 4Ds i.e. defects at birth, deficiencies, diseases, development delays[46] are landmark policies in reducing the infant and child mortality.These packages provide a framework for delivering services at the state and district level.

Policy makers could benefit from further analysis to target the under performing states. For example, it would be necessary to analysing inequalities with respect to infant and child mortality across states and within states[47]. For the first time district level data is available and such analysis could guide policy makers with micro level planning and cluster analysis could help with selective targeting of specific districts. Few previous studies cited the role of family level clustering of infant deaths in the low performing states.[48]

From our analysis, it appears that the trend in reducing IMR and U5MR is headed in the right direction. Even so, there is huge variation between states and within states. However, a blanket approach to reducing infant and child mortality in all underperforming states of India may not be the best option. Depending upon a state's performance and the socio-economic differentials, policy makers may wish to be flexible in their approach in reducing infant and child mortality as discussed in this paper. Given the greater contribution of neonatal mortality, India's challenge in

reducing infant mortality would depend largely on how it addresses the issue of neonatal deaths.

CONCLUSIONS

The results of this study confirm that to bring the overall Indian national average of IMR and U5MR to a more respectable level, policy makers will have to target the underperforming large states and population groups where mortality rates are still high. This is particularly so when the improvements with respect to infant and child mortality have been unevenly distributed across states and population groups. As India continues to reduce its infant and child mortality, the challenge is to accelerate its reform process by adopting a differential strategy. To a large extent, India's under performing states and its approach to reducing neonatal mortality will determine its success or failure in reducing infant and child mortality in future.

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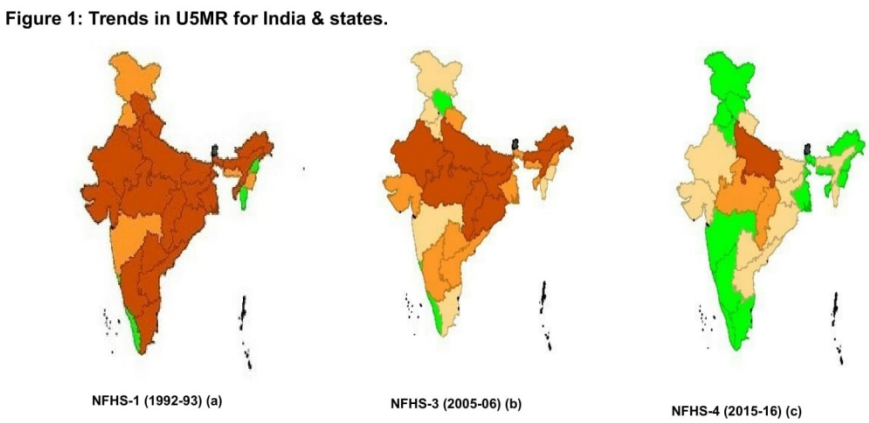

Figure1: Trends in U5MR for India and States

437x259mm (96 x 96 DPI)

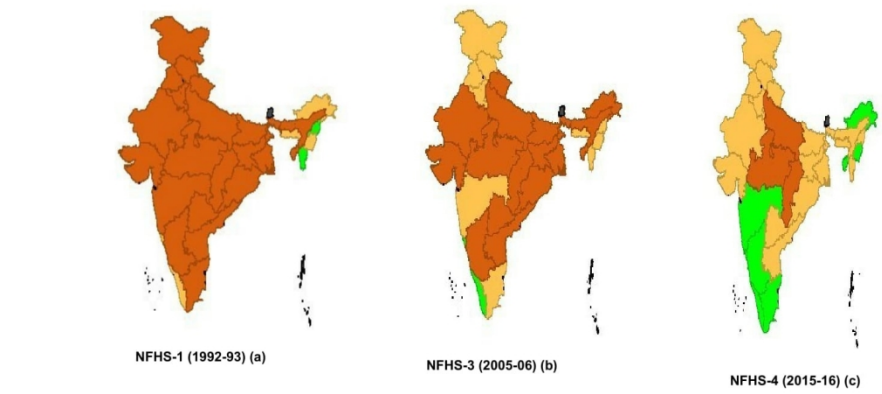

Figure2: Trends in IMR for India and States

437x278mm (96 x 96 DPI)

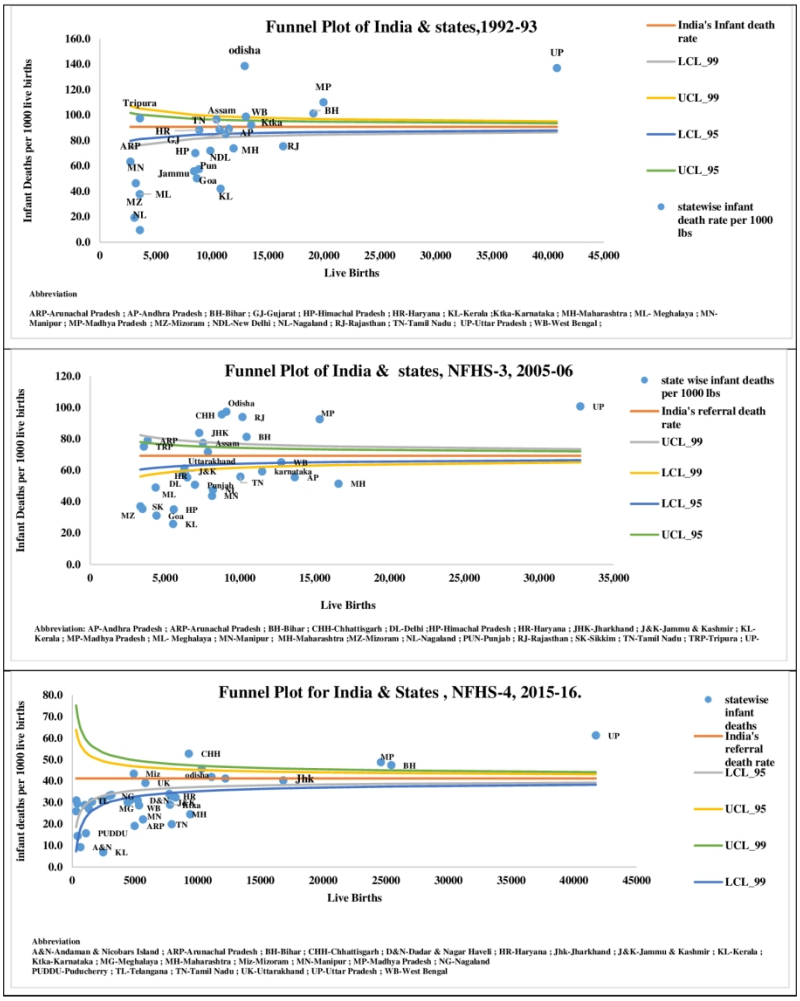

Figure 3: Funnel Plots for India & states.

1400x1980mm (30 x 30 DPI)

The STROBE checklist

	Item No	Recommendation
Title and abstract	1	*(a)* Indicate the study's design with a commonly used term in the title or the abstract [**Within the title page 1 and method section of the abstract page 2]** *(b)* Provide in the abstract an informative and balanced summary of what was done and what was found **[See abstract page 2]**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported [**page 4]**
Objectives	3	State specific objectives, including any prespecified hypotheses **[pages 4 and 5, paragraphs 3,4 and 5]**
Methods		
Study design	4	Present key elements of study design early in the paper **[Methods page 5]**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **[pages 5, section methods, subsection data]**
Participants	6	*(a) Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **[N/A]** *Case-control study*— Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls **[N/A]** *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants **[pages 5, section methods, subsection data and table 1]** *(b) Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed **[N/A]** *Case-control study*—For matched studies, give matching criteria and the number of controls per case [**N/A]**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **[table 1 and table 2]**
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 **[pages 5, section methods, subsection data and table 1]**
Bias	9	Describe any efforts to address potential sources of bias **[N/A]**
Study size	10	Explain how the study size was arrived at **[N/A – not required since it is secondary data]**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **[N/A]**
Results		
Statistical methods	12	Describe all statistical methods, including those used to control for confounding **[page 5-6]** Describe any methods used to examine subgroups and interactions **[N/A]** Explain how missing data were addressed **[N/A]** *Cohort study*—If applicable, explain how loss to follow-up was addressed **[N/A]** *Case-control study*—If applicable, explain how matching of cases and controls was addressed **[N/A]**

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy **[N/A]**
		Describe any sensitivity analyses **[N/A]**
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 6 and table 1**]
		(b) Give reasons for non-participation at each stage [**N/A]**
		(c) (c) Consider use of a flow diagram [**N/A information in table 1**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **[page 6-8 and table 1]**
		(b) Indicate number of participants with missing data for each variable of interest **[N/A]**
		(a) (c) Cohort study—Summarise follow-up time (eg, average and total amount **[N/A]**
Outcome data	15*	(b) *Cohort study*—Report numbers of outcome events or summary measures over time **[N/A]**
		(c) *Case-control study*—Report numbers in each exposure category, or summary measures of exposure **[N/A]**
		(d) *Cross-sectional study*—Report numbers of outcome events or summary measures [**N/A]**
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included **[Table 2]**
		(b) Report category boundaries when continuous variables were categorized [**Table 2]**
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period [**Table 2]**
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses [**N/A]**

Discussion		
Key results	18	Summarise key results with reference to study objectives [**pages 12 and 13, page 15, section conclusions]**
Limitations	19	Discuss limitations of the study, considering sources of potential bias or imprecision**. [page 3, section Strengths and limitations of this study]**
		Discuss both direction and magnitude of any potential bias [**N/A]**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [**pages 12-14, page 15, section conclusions]**
Generalisability	21	Discuss the generalisability (external validity) of the study results [**pages 12-14, page 15, section conclusions]**

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 16]**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.[i]

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 www.strobe-statement.org.