Can administrative health data be used to estimate population level birth and child mortality estimates? A comparison of India's Health Information Management System data with nationally representative survey data

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1. Introduction

In the absence of complete civil registration systems, birth and death rates in Low- and- Middle-Income-Countries (LMICs) including India, are estimated from nationally representative surveys like the Sample Registration System (SRS) and the National Family Health Surveys (NFHS) (Alkema & You, 2012). The right to birth registration is pledged in the United Nations Convention on the Rights of the Child. Establishment of robust civil registration systems is also enlisted under the Sustainable Development Goals (SDGs). As the COVID-19 pandemic has illustrated only too well, reliable and timely statistics on birth and mortality rates can inform both population health policies and public discussion on social priorities, often in real time (AbouZahr et al., 2021; Banaji & Gupta, 2021; Jha et al., 2022). However, registration of births and deaths in India like many other LMICs, is incomplete, often delayed, and marked by widespread social inequities (Bhatia et al., 2019).

Can administrative datasets maintained by health systems overcome some limitations of incomplete and delayed data on vital registration in LMICs? India's Health Management Information System (HMIS) was established in 2008 under India's Ministry of Health and Family Welfare (Bodavala, n.d.). In the HMIS, sub-centers, primary health centers, and hospitals provide three types of data- 1) monthly counts of a spectrum of health service delivery indicators including reproductive, maternal, and child health indicators including facility reported births and deaths, immunization, family planning, among others, 2) quarterly trainings for health professionals, 3) annual infrastructure including staff strength, equipment and services like diagnostics and surgeries among others (Krishnan et al., 2010). These data are made available on a centralized online portal. Importantly, since the HMIS includes data from all reporting health facilities; these indicators are counts, unlike estimates from sample-based surveys (Rajesh Kumar, n.d.). With the potential to generate monthly updates, HMIS also provides the most updated

available numbers on the health indicators it covers (Bodavala, n.d.). Furthermore, HMIS includes data from all states and union territories, including the north-eastern states, which are omitted from India's Sample Registration System (SRS) (Bodavala, n.d.)' (Rajesh Kumar, n. d.)' (Baviskar et al., 2020). It is also more granular, with data collated and available at the sub-district level (Bodavala, n.d.)' (Rajesh Kumar, n. d.) (Baviskar et al., 2020; Goli et al., 2021),. HMIS data are also easily accessible via the public portal maintained by India's health ministry (S, 2021).

Like other countries, India has multiple systems to measure and track health related indicators and outcomes, with varying strengths and limitations (Saikia & Kulkarni, 2016). Vital registration, although incomplete, is improving, and is embedded in a statutory identity framework (Gupta, 2020). In the absence of reliable mortality and fertility indicators from the Civil Registration System, the Sample Registration system provides annual estimates of vital rates at the state and national level (Mahapatra, 2010). This is supplemented by other periodic but intermittent surveys, such as the National Family Health Surveys, which collect richer contextual information, allowing scientific examination of the determinants of health (Gupta & Sudharsanan, 2020). Compared to these existing individual level data sources, the HMIS is a facility based administrative database, compiled in the course of service and healthcare delivery. The HMIS is finer in both geographic and periodic scales: data are compiled at the monthly frequency, and since they cover all facilities, can be aggregated to any geographic level. This key strength, helpful for internal planning as well as overall use for monitoring population health (Rajpal et al., 2021), is offset by the concern that vital events may be missed in this facility-based survey.

Our paper examines the extent to which this concern is true, by comparing the levels of births and child deaths in the HMIS to those of nationally representative surveys such as the Sample Registration System and the National Family Health System. We do this following a large

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literature in the population and social science which seeks to understand the reliability of data sources by comparing them against multiple well-regarded sources (Brown et al., 2019; Hendi, 2017; Somanchi, 2021; Warren et al., 2017). Our goal is to examine the extent to which the HMIS misses births and child deaths. Because the HMIS is a facility-based survey, we expect the HMIS to miss births and deaths that were not in facilities. However, given that access to public health facilities has increased, we expect that the coverage of the HMIS, particularly of births and deaths close to births would have increased (Bhatia et al., 2019). We also expect the HMIS to have greater coverage in states with better functioning public health systems.

A small body of recent studies from India, restricted to some states and for service delivery indicators, has considered the quality of HMIS data for a range of health-service related indicators. Immunization data from HMIS in Haryana state in north India, had an average completeness record of 88.5%, ranging from 73% for 'DPT1 vaccination date' to 94.6% for 'date of delivery', compared to a cross-sectional survey in the state (Rajesh Kumar, n.d.). A temporal analysis of HMIS data from 2008 to 2018 in West Bengal's South 24 Parganas district in eastern India identified discrepancies between HMIS, District Leddy Household and Facility Survey (DLHS) in immunization data (*Temporal Analysis of Infant and Child Health Indicators from Health Management and Information System of a Vulnerable District of India_ Tracking the Road toward the Sustainable Development Goal-3.Html*, n.d.). A cross-sectional study comparing immunization trends across districts in Maharashtra in HMIS and NFHS (2015–16) found that immunization coverage reported by HMIS was 94.13%, against NFHS's total estimated state level coverage of 56.3% during the same time, with high between district discrepancies in HMIS data within the same state (Baviskar et al., 2020). A study from a single district in Odisha state interviewed local health workers managing HMIS, while also comparing records in HMIS and the state's Mother and Child Tracking System (MCTS), and identified under-reporting as well as discrepant reporting in the HMIS (Suhita Chopra Chatterjee, n.d.). Inadequate infrastructure, weak surveillance, poor reporting of risk factors during pregnancy were identified as short-comings in HMIS (Suhita Chopra Chatterjee, n.d.).

HMIS data has also been referenced by Indian policy makers to monitor trends in key health service indicators. The National Institution for Transforming India (NITI) Aayog, the policy think-tank of the Government of India since 2014, used HMIS data for its 2019 report on overall and incremental health performances of states and UTs. Using five upweighted indicators from HMIS for its analysis, the NITI Aayog identified over-reporting of antenatal care registrations in the first trimester by 53.5% in Jharkhand, 42.4% in West Bengal, 25.9% in Chhattisgarh, 18.4% in Rajasthan, Chhattisgarh, Madhya Pradesh, Andhra Pradesh, and Uttar Pradesh over-reported institutional deliveries by 22%–36% (Kole, 2019). Importantly, the NITI Aayog acknowledged "huge disparities in the data integrity measures across states and UTs" (Kole, 2019). More recently, HMIS has emerged as an important source of monitoring gaps in routine maternal, newborn and child health services like immunization, during the national lockdown for COVID-19 in India (Dreze & Paikra, 2020; Rukmini, 2020). It has also been used for assessing the overall mortality impact of the pandemic (Jha et al., 2022) and levels of maternal mortality at the district level (Goli et al., 2021).

Briefly, international assessments of HMIS data quality have also considered health-service indicators. For Rwandan districts, an evaluation of HMIS data for a three-month period found variable data quality, with some indicators showing better quality and consistency across districts (Nshimyiryo et al., 2020). Importantly, the study noted that over-reporting was observed for indicators with more complex calculations, including gestational age, scheduling to determine antenatal care visits (Nshimyiryo et al., 2020). In Nigeria, studies have identified paucity of professional training, and, lack of policies and inadequate technological infrastructure as concerns with HMIS data (Ojo, 2018). However, comparisons of HMIS data with population level outcomes are lacking.

Importantly, several concerns have also been raised about the fidelity of HMIS data in India. Some of these include delays in reporting, over-reporting, inter-state variability on reporting, inadequate data management infrastructure, and lack of trained personnel for data entry (Rajesh Kumar, n.d.) (Baviskar et al., 2020) (Suhita Chopra Chatterjee, n.d.). HMIS data from its public platform (https://nrhm-mis.nic.in/hmisreports/frmstandard_reports.aspx) also requires considerable cleaning and wrangling for analysis (Rajesh Kumar, n.d.)ʼ(Suhita Chopra Chatterjee, n.d.)ʼ(*Temporal Analysis of Infant and Child Health Indicators from Health Management and Information System of a Vulnerable District of India_ Tracking the Road toward the Sustainable Development Goal-3.Html*, n.d.). Furthermore, indicators and their definitions are not consistent over time, making time series analysis difficult (Baviskar et al., 2020)ʼ[7]ʼ(Rajesh Kumar, n.d.). Since HMIS provides count data, it does not allow for data to be disaggregated by social group characteristics, which inhibits its direct application for monitoring of disadvantaged social groups (Suhita Chopra Chatterjee, n.d.). Identifying a denominator or an estimate of the total population in a given area to calculate prevalence estimates is another "inherent difficulty" in HMIS (*Temporal Analysis of Infant and Child Health Indicators from Health Management and Information System of a Vulnerable District of India_ Tracking the Road toward the Sustainable Development Goal-3.Html*, n.d.).

While there has been considerable discourse on HMIS data quality in recent years, it has largely focused on health-service delivery indicators. Besides recent work by Jha et al., 2022 and Goli et al., 2021, very little attention has been given to the institutional births and deaths data being collated on this platform. According to HMIS training manuals, for births in addition to monthly facility reporting, HMIS also includes lists of births and births attended by skilled birth attendants, entered by Auxiliary Nursing Midwives from the community (Government of India, 2021).

Therefore, we analyze the completeness and reliability of India's HMIS specifically for birth and child mortality rates as important population health indicators, relative to two nationally representative datasets in India-the NFHS and the SRS. Given the differing objectives, geographies of representation, and sampling techniques, we compare selected vital statistics for annual periods at the national and sub-national level, over a five-year period when data across at least two of these sources are available. First, we estimate annual birth and mortality rates from counts provided in HMIS. We then compare annual rates and counts of births, neonatal, post-neonatal, infant and child deaths across HMIS, SRS and NFHS, nationally and across states. Given that HMIS is based on data reported from health facilities, we hypothesized that HMIS would be better at capturing institutional births. So, we also compare institutional births separately, across HMIS, SRS and NFHS.

2. Methods

Data: This analysis is based on four data sources. The HMIS provides monthly reporting of key reproductive, maternal, neonatal and child health outcomes from 2008 to 2020. Data from 2014 to 20 have been used in this analysis. The NFHS is a nationally representative cross-sectional survey of population health and nutrition in India. The NFHS was fielded in 1992–93, 1998–98, 2005–06, and 2015–16(International Institute for Population Sciences, 2007). We use data from NFHS-4, which follows a multi-stage sampling procedure and has emerged as a reliable nationally representative dataset for monitoring population health trends (International Institute for Population Sciences, 2007). The NFHS follows a multi-stage sampling procedure and has emerged as a reliable nationally representative dataset for monitoring population health trends. NFHS-4 (2015–16) provides retrospective birth history for 699,686 women (aged 15–49 years) and is representative at the district level(International Institute for Population Sciences, 2007). The SRS, conducted by the Office of the Registrar General and Census Commissioner of India, provides estimates of key demographic indicators from a

nationally representative panel of unban blocks and villages(Mahapatra, 2010). SRS estimates collated from SRS summary reports from 2014 to 2018, have been used in this analysis. Finally, the USAID and DHS's spatial data repository (https://spatialdata.dhsprogram.com/home/) which provides district level annual estimates of total population and population between 0 and 5 years estimated by Leddy Jr (Leddy, n.d.) has been used to calculate the birth and mortality estimates. We use these data instead of India's official population projections because the official projections do not provide state- and age-specific estimates of population for all the years we consider in our analysis. Previous work has shown that using the official estimates or those by the DHS makes little difference to demographic estimates (Gupta & Mani, 2022).

Outcomes: We estimated the following indicators from HMIS, SRS and NFHS in 2014 and 2018:

- Crude Birth Rate, defined as the number of live births during the year per 1,000 population
- Neonatal mortality rate (NMR), defined as the number of deaths of at age less than 29 days during the year per 1,000 live births
- Post neonatal mortality Rate, or the number of deaths between ages 29 days to one year during the year per 1,000 live births
- Infant mortality rate or the number of infant deaths during the year (0–1 years) per 1,000 live births
- Child mortality Rate (0–4 years) or the age-specific mortality rate between ages 0 and 4, defined as the number of deaths among children aged 0–4 years per 1,000 population aged 0-4
- Child mortality Rate (1–4 years): the life table age-specific mortality rate between ages 1 to 4, defined as the number of deaths among children aged 1–4 per 1,000 population aged 1–4.

Given the objectives of the study to compare average trends in administrative and survey data on their capturing of births and deaths, we did not include any covariates in this analysis.

Statistical Analysis: For HMIS, we used state level counts of total live births, neonatal, infant and child deaths to estimate outcomes at 0–4 and 1–4 years for all years from 2014 to 2020. For ease of comparison with NFHS and SRS, HMIS data before 2014 was not included in the analysis. To estimate birth rates from HMIS, the total live births reported under HMIS were divided by the annual district level total population estimates from the Spatial Data Repository Program of the DHS and USAID (Leddy, n.d.).

For neonatal, post-neonatal, and infant mortality, total deaths in each population group from HMIS were divided by the total number of births from HMIS. These rates are case-fatality rates. For child mortality (0–4 years), the total number of deaths in this age group from HMIS were divided by population estimates of total children in this age group from DHS/USAID for each year of comparison. To estimate child mortality (1–4 years), we divided the difference between the child mortality (0–4 years) count and the infant mortality count with difference between DHS estimates of total child deaths (0–4 years) count and total live births as estimated under SRS. We used birth estimates from SRS instead of HMIS since HMIS underestimates total births based on comparisons of birth rates across HMIS, NFHS and SRS.

We use birth rates from Table 3 of the SRS annual reports (Mahapatra, 2010). Infant, neonatal, and post-neonatal mortality rates are from Table 9 of the SRS annual reports, and age-specific mortality rates between 0-4 and 1–4 years are from Table 8 of the SRS annual reports (Mahapatra, 2010). The proportion of births in institutional facilities is from Table 17 of the same report (Mahapatra, 2010).

For NFHS, we use standard procedures to estimate age-specific mortality rates and child mortality rates. It was not possible to estimate the birth rate from the NFHS birth history module. All other rates were calculated using the birth history module (International Institute for Population Sciences, 2007). For infant, neonatal, and post-neonatal mortality rates, we used live births as the denominator. For age-specific mortality rates between ages 0–4 and 1–4, we calculated

mortality rates by calculating person-years lived in these ages. These approaches follow standard demographic procedures for birth history data (Moultrie et al., 2013;. We also calculated accurate 95% Confidence Intervals for NFHS indicators, accounting for the clustering of observations within primary sampling units.

In 2014, rates from HMIS, the SRS, and the NFHS were available (Table 1). For 2018, rates from the SRS and the HMIS were available.

3. Results

National level: HMIS estimated birth rates of 16.8 and 15.9 per 1,000 in 2014 and 2018, compared to the SRS's estimates of 21.0 and 20.0 births per 1,000 in 2014 and 2018- a difference of 4.2 and 4.1 percentage points respectively (Table 1). For mortality rates, in 2014, the HMIS recorded 6.1 infant deaths per 1,000 births as compared to 39.2 and 39 infant deaths per 1,000 births in the NFHS and SRS, respectively (Table 1). By 2018, the HMIS recorded 11.9 as compared to 32.0 infant deaths per 1,000 births in the SRS (Table 1). The levels of under-reporting in infant deaths in HMIS compared to the other data sources were slightly lower than that in the 1–4 age-group. Similar trends are observed for neonatal deaths (Table 1). In 2014, the HMIS recorded 4.4 neonatal deaths per 1,000 births as compared to 29.0 in the NFHS and 26.0 in the SRS (Table 1). In 2018, the HMIS recorded 8.6 neonatal deaths per 1,000 births, in contrast to 23.0 in the SRS (Table 1). Among the mortality indicators, neonatal mortality showed the highest discordance between HMIS, NFHS and SRS. Among the mortality indicators, neonatal mortality showed the highest discordance between HMIS, NFHS and SRS. Barring child mortality (1–4 years), all other infant and child mortality indicators increased between 2014 and 2018 in HMIS (Table 1).

State level: State specific analysis presents five important insights. First, similar to national trends, in most states, HMIS under-reported birth and death rates, with under-reporting higher for deaths than births (Table 2). Second, as with the national estimates, we see improvement in the performance of the HMIS over time. Third, we observe a small number of states, such as Kerala in the south and Himachal Pradesh in the north, where the HMIS performs relatively well (Table 2). In Himachal Pradesh, the HMIS estimated the IMR to be 17 deaths per 1,000 births in 2018, while the SRS estimated an infant mortality rate of 19 deaths per 1,000 births (Table 2d). Fourth, in some

Table 1
Comparison of birth and mortality indicators in 2014 and 2018 at the national level, based on the Health Management Information System (HMIS), the National Family Health Survey (NFHS) and the Sample Registration Survey (SRS).

Indicator	2014			2018		
	HMIS	NFHS	SRS	HMIS	NFHS	SRS
Birth Rate	16.8	NA	21.0	15.9	NA	20.0
Neo-Natal Mortality Rate	4.4	31.5	26.0	8.6	NA	23.0
Post Neo-Natal Mortality Rate	1.8	8.6	13.0	3.3	NA	9.0
Infant Mortality Rate	6.1	40.1	39.0	11.9	NA	32.0
Child Mortality Rate ages 0-4	1.2	9.6	11.0	2.4	NA	9.0
Child Mortality Rate ages 1-4	0.2	2.0	1.7	0.4	NA	1.1
Proportion of Institutional Births (%)	68*	81	79	94	NA	83

Note: All rates are per 1,000. The proportion of institutional births in the HMIS is calculated using the total number of births estimated from the SRS. For NFHS, which is a multi-stage sample surveys, 95% CIs were calculated using a cluster-bootstrap procedure. For the NFHS, the 95% CI for the proportion of births that are institutional is [0.8069 - 0.8189], for the neonatal mortality rate is [27.062–30.864], for the post-neonatal mortality rate is [9.156–11.321], for the infant mortality rate is [37.001–41.394], for the age-specific mortality rate between ages 0 and 4 was [9.103–10.136], and for the age specific mortality rate between ages 1 and 4 was [1.708–2.310]. Like the NFHS, the SRS is also a sample survey, but 95% CIs cannot be calculated because microdata from the SRS are not available to researchers.

Table 2

State wise comparison of India's birth and mortality indicators in 2014 and 2018 in Health Management Information System (HMIS), National Family Health Survey (NFHS) and Sample Registration Survey (SRS).

(a): Birth Rates

State	2014		2018	
	HMIS	SRS	HMIS	SRS
India	16.8	21.0	15.9	20.0
A & N Islands	14.1	–	10.6	–
Andhra Pradesh	10.4	17.0	15.2	16.0
Arunachal Pradesh	11.1	–	11.9	–
Assam	19.2	22.4	17.4	21.1
Bihar	18.6	25.9	17.5	26.2
Chandigarh	24.1	–	25.8	–
Chhattisgarh	19.1	23.4	17.2	22.5
Dadra & Nagar Haveli	19.2	–	20.1	–
Daman & Diu	13.9	–	12.2	–
Delhi	14.8	16.8	15.1	14.7
Goa	11.9	–	12.4	–
Gujarat	18.8	20.6	17.5	19.7
Haryana	19.6	21.2	18.2	20.3
Himachal Pradesh	13.5	16.4	12.2	15.7
Jammu & Kashmir	14.8	16.8	14.2	15.4
Jharkhand	18.9	23.8	20.2	22.6
Karnataka	14.3	–	14.1	17.2
Kerala	15.2	14.8	14.6	13.9
Lakshadweep	10.2	–	13.1	–
Madhya Pradesh	18.2	25.7	17.0	24.6
Maharashtra	15.3	16.5	14.5	15.6
Manipur	13.7	–	11.4	–
Meghalaya	27.0	–	24.5	–
Mizoram	19.1	–	15.8	–
Nagaland	11.7	–	10.4	–
Odisha	16.6	19.4	14.5	18.2
Puducherry	31.4	–	30.5	–
Punjab	14.6	15.4	12.8	14.8
Rajasthan	20.2	25.0	18.1	24.0
Sikkim	12.7	–	11.3	–
Tamil Nadu	13.4	15.4	12.1	14.7
Telangana	12.2	18.0	17.2	16.9
Tripura	13.9	–	13.0	–
Uttar Pradesh	17.5	27.0	17.0	25.6
Uttarakhand	15.2	18.2	13.7	16.7
West Bengal	15.6	15.6	13.8	15.0

(b) Neonatal Mortality Rates

State	2014			2018	
	HMIS	NFHS	SRS	HMIS	SRS
India	4.4	29.0	26.0	8.6	23.0
A & N Islands	2.5	19.5	–	12.7	–
Andhra Pradesh	1.8	15.5	26.0	9.2	21.0
Arunachal Pradesh	1.1	12.2	–	6.1	–
Assam	4.7	28.6	26.0	13.7	21.0
Bihar	0.0	39.9	27.0	4.3	25.0
Chandigarh	43.6	27.1	–	25.9	–
Chhattisgarh	5.9	38.2	28.0	9.6	29.0
Dadra & Nagar Haveli	15.6	0.0	–	18.8	–
Daman & Diu	8.7	0.0	–	10.6	–
Delhi	8.5	6.0	13.0	13.3	10.0
Goa	1.0	0.0	–	5.7	–
Gujarat	5.2	25.7	24.0	13.4	19.0
Haryana	5.8	19.9	23.0	13.5	22.0
Himachal Pradesh	6.5	22.5	25.0	12.6	13.0
Jammu & Kashmir	0.8	24.8	26.0	8.6	17.0
Jharkhand	1.3	30.4	25.0	4.3	21.0
Karnataka	4.9	16.1	20.0	9.0	16.0
Kerala	0.8	3.0	6.0	3.0	5.0
Lakshadweep	1.5	55.6	–	4.8	–
Madhya Pradesh	6.3	37.3	35.0	17.0	35.0
Maharashtra	4.9	12.0	16.0	7.5	13.0
Manipur	0.5	12.2	–	1.3	–
Meghalaya	9.8	24.4	–	14.2	–
Mizoram	6.5	18.7	–	9.3	–
Nagaland	1.9	19.9	–	6.3	–
Odisha	14.9	22.4	36.0	15.0	31.0
Puducherry	0.3	7.3	–	8.5	–
Punjab	1.6	14.3	14.0	4.8	13.0

Table 2 (*continued*)

(a): Birth Rates

	2014		2018	
Rajasthan	7.7	25.9	32.0	13.9	26.0
Sikkim	5.9	8.5	–	9.5	–
Tamil Nadu	7.2	14.4	14.0	5.6	10.0
Telangana	0.8	29.5	25.0	5.4	19.0
Tripura	4.0	14.3	–	10.7	–
Uttar Pradesh	0.1	49.9	32.0	2.5	32.0
Uttarakhand	2.2	34.6	26.0	5.2	22.0
West Bengal	11.0	17.5	19.0	14.4	16.0

(c) Post- Neonatal Mortality Rates

State	2014			2018	
	HMIS	NFHS	SRS	HMIS	SRS
India	1.8	10.2	13.0	3.3	9.0
A & N Islands	3.0	0.0	–	2.2	–
Andhra Pradesh	1.1	10.0	13.0	2.5	8.0
Arunachal Pradesh	0.8	12.5	–	1.6	–
Assam	2.7	13.4	23.0	6.6	20.0
Bihar	0.0	12.7	15.0	1.4	7.0
Chandigarh	7.9	0.0	–	25.9	–
Chhattisgarh	3.0	10.5	15.0	4.2	12.0
Dadra & Nagar Haveli	5.5	38.2	–	9.1	–
Daman & Diu	1.9	0.0	–	2.3	–
Delhi	3.7	4.6	7.0	5.7	3.0
Goa	2.1	0.0	–	2.4	–
Gujarat	1.5	4.2	11.0	5.2	9.0
Haryana	2.8	8.0	13.0	6.2	8.0
Himachal Pradesh	3.5	10.6	7.0	4.5	6.0
Jammu & Kashmir	0.5	11.2	8.0	1.5	5.0
Jharkhand	1.0	8.9	9.0	1.7	9.0
Karnataka	1.6	10.0	9.0	3.0	7.0
Kerala	0.2	0.0	6.0	1.0	2.0
Lakshadweep	3.1	19.4	–	8.4	–
Madhya Pradesh	2.7	14.0	17.0	6.3	13.0
Maharashtra	1.5	6.3	6.0	2.6	6.0
Manipur	0.7	5.1	–	0.8	–
Meghalaya	14.9	13.7	–	12.3	–
Mizoram	29.6	38.1	–	10.2	–
Nagaland	2.2	12.8	–	4.1	–
Odisha	6.5	14.3	13.0	6.6	9.0
Puducherry	0.1	0.0	–	2.1	–
Punjab	1.7	9.4	10.0	2.7	7.0
Rajasthan	2.9	9.8	14.0	7.1	11.0
Sikkim	8.6	12.9	–	8.1	–
Tamil Nadu	2.7	7.6	6.0	2.4	5.0
Telangana	0.8	8.6	10.0	1.2	8.0
Tripura	4.6	28.7	–	7.2	–
Uttar Pradesh	0.1	14.2	16.0	1.0	11.0
Uttarakhand	0.8	10.4	7.0	2.0	9.0
West Bengal	2.8	4.4	9.0	4.1	6.0

(d) Infant Mortality Rate

State	2014			2018	
	HMIS	NFHS	SRS	HMIS	SRS
India	6.1	39.2	39.0	11.9	32.0
A & N Islands	5.5	19.5	–	14.9	–
Andhra Pradesh	3.0	25.5	39.0	11.7	29.0
Arunachal Pradesh	1.9	24.7	–	7.6	–
Assam	7.4	42.0	49.0	20.3	41.0
Bihar	0.0	52.6	42.0	5.7	32.0
Chandigarh	51.5	27.1	–	51.8	–
Chhattisgarh	8.9	48.7	43.0	13.8	41.0
Dadra & Nagar Haveli	21.2	38.2	–	27.9	–
Daman & Diu	10.6	0.0	–	12.9	–
Delhi	12.2	10.5	20.0	18.9	13.0
Goa	3.2	0.0	–	8.1	–
Gujarat	6.7	29.9	35.0	18.6	28.0
Haryana	8.6	27.9	36.0	19.7	30.0
Himachal Pradesh	9.9	33.1	32.0	17.0	19.0
Jammu & Kashmir	1.3	35.9	34.0	10.1	22.0
Jharkhand	2.3	39.2	34.0	6.0	30.0
Karnataka	6.5	26.1	29.0	12.0	23.0
Kerala	1.0	3.0	12.0	4.0	7.0
Lakshadweep	4.6	75.0	–	13.2	–
Madhya Pradesh	9.0	51.3	52.0	23.3	48.0

Table 2 (*continued*)

(a): Birth Rates

	2014			2018	
Maharashtra	6.4	18.3	22.0	10.1	19.0
Manipur	1.2	17.3	–	2.1	–
Meghalaya	24.7	38.2	–	26.5	–
Mizoram	36.1	56.8	–	19.5	–
Nagaland	4.1	32.7	–	10.4	–
Odisha	21.4	36.7	49.0	21.6	40.0
Puducherry	0.4	7.3	–	10.5	–
Punjab	3.3	23.7	24.0	7.5	20.0
Rajasthan	10.6	35.7	46.0	21.0	37.0
Sikkim	14.4	21.3	–	17.6	–
Tamil Nadu	9.9	22.1	20.0	8.0	15.0
Telangana	1.5	38.1	35.0	6.7	27.0
Tripura	8.7	43.0	–	17.9	–
Uttar Pradesh	0.2	64.0	48.0	3.6	43.0
Uttarakhand	3.1	45.0	33.0	7.1	31.0
West Bengal	13.8	21.9	28.0	18.5	22.0

(e) Child Mortality Rate (0–4 years)

	2014			2018	
State	HMIS	NFHS	SRS	HMIS	SRS
India	1.2	9.6	11.0	2.4	9.0
A & N Islands	1.2	4.3	–	2.9	–
Andhra Pradesh	0.5	6.0	10.0	2.9	9.0
Arunachal Pradesh	0.2	7.4	–	1.1	–
Assam	1.5	10.1	15.0	3.9	11.0
Bihar	0.0	13.1	12.0	0.9	8.0
Chandigarh	16.9	4.7	–	21.4	–
Chhattisgarh	1.9	12.9	12.0	3.0	11.0
Dadra & Nagar Haveli	4.5	13.7	–	6.3	–
Daman & Diu	2.2	0.0	–	2.4	–
Delhi	2.6	8.4	5.0	4.2	4.0
Goa	0.6	0.0	–	1.6	–
Gujarat	1.5	7.7	10.0	4.2	8.0
Haryana	2.1	6.8	9.0	4.5	9.0
Himachal Pradesh	1.7	6.1	11.0	3.2	6.0
Jammu & Kashmir	0.2	8.6	8.0	1.4	5.0
Jharkhand	0.5	10.7	10.0	1.3	8.0
Karnataka	1.2	6.6	7.0	2.4	7.0
Kerala	0.2	1.0	3.0	1.0	2.0
Lakshadweep	0.8	15.7	–	2.3	–
Madhya Pradesh	1.8	12.6	16.0	4.7	14.0
Maharashtra	1.4	4.3	5.0	2.1	4.0
Manipur	0.3	4.3	–	0.4	–
Meghalaya	5.8	9.5	–	6.1	–
Mizoram	6.6	13.4	–	3.5	–
Nagaland	0.5	8.6	–	1.4	–
Odisha	4.5	9.3	13.0	4.3	11.0
Puducherry	0.3	1.7	–	5.3	–
Punjab	0.8	5.1	6.0	1.5	5.0
Rajasthan	2.2	9.9	12.0	4.2	10.0
Sikkim	2.8	4.1	–	3.1	–
Tamil Nadu	1.9	5.0	4.0	1.7	4.0
Telangana	0.3	6.1	1.0	1.7	8.0
Tripura	1.5	8.6	–	3.1	–
Uttar Pradesh	0.0	15.8	16.0	0.7	14.0
Uttarakhand	0.5	11.2	6.0	1.3	5.0
West Bengal	2.8	5.2	6.0	3.7	6.0

(f) Child Mortality Rate (1–4 years)

	2014			2018	
State	HMIS	NFHS	SRS	HMIS	SRS
India	0.2	2.0	1.7	0.4	1.1
A & N Islands	–	0.0	–	–	–
Andhra Pradesh	0.1	0.7	0.3	0.4	1.1
Arunachal Pradesh	–	2.7	–	–	–
Assam	0.1	1.8	4.6	0.4	1.5
Bihar	0.0	2.4	2.9	0.1	1.2
Chandigarh	–	0.0	–	–	–
Chhattisgarh	0.3	2.8	1.7	0.6	1.1
Dadra & Nagar Haveli	–	7.8	–	–	–
Daman & Diu	–	0.0	–	–	–
Delhi	0.6	4.9	0.3	0.7	1.5
Goa	–	0.0	–	–	–
Gujarat	0.1	1.6	1.6	0.5	0.8
Haryana	0.4	1.8	1.0	0.7	1.5
Himachal Pradesh	0.1	0.7	0.4	0.5	1.8
Jammu & Kashmir	0.0	2.0	0.1	0.1	0.2
Jharkhand	0.1	3.3	2.7	0.3	1.1
Karnataka	–	1.9	0.7	0.3	1.3
Kerala	0.0	0.4	0.4	0.2	0.7
Lakshadweep	–	0.0	–	–	–
Madhya Pradesh	0.4	2.5	3.4	1.0	2.0
Maharashtra	0.3	0.7	0.4	0.4	0.6
Manipur	–	1.4	–	–	–
Meghalaya	–	1.1	–	–	–
Mizoram	–	1.4	–	–	–
Nagaland	–	2.5	–	–	–
Odisha	0.5	1.3	2.8	0.7	1.1
Puducherry	–	0.0	–	–	–
Punjab	0.2	0.5	0.8	0.2	0.5
Rajasthan	0.3	3.3	1.3	0.7	0.8
Sikkim	–	0.0	–	–	–
Tamil Nadu	0.1	2.4	0.4	0.3	0.6
Telangana	0.1	0.3	0.5	0.2	0.8
Tripura	–	0.0	–	–	–
Uttar Pradesh	0.0	2.9	2.4	0.1	0.9
Uttarakhand	0.1	1.5	0.7	0.2	–
West Bengal	0.2	0.6	0.4	0.5	1.1

Note: 95% CIs for NFHS rates are available in the appendix.

states, most notably in Bihar and Uttar Pradesh, the HMIS recorded very few deaths compared to the number of estimated deaths NFHS and SRS (Table 2). However, in many states, by 2018, the HMIS recorded about half of the estimated infant deaths (Table 2d). This was true even in some poorer states with a high mortality burden, such as Madhya Pradesh, Orissa, and Rajasthan. Finally, we found some inconsistencies between NFHS and SRS. For example, in Bihar, neonatal mortality rates in 2014 were 39.9 deaths per 1000 children in NFHS, compared to 27.0 deaths per 1000 children in SRS (Table 2b). In Uttar Pradesh, neonatal mortality rates in 2014 were 49.9 deaths per 1000 children in NFHS, compared to 32.0 deaths per 1000 children in SRS (Table 2b). In states like Gujarat, Haryana, Rajasthan and Punjab, among others, the discrepancies between NFHS and SRS were relatively smaller (Table 2). Confidence Intervals for state-wise NFHS rates are provided in the appendix.

Comparison over time: Trends from 2014 to 2018 show that the difference in birth rates between HMIS and SRS remained consistent over time (Fig. 2). For neonatal, post neonatal and child mortality rates, HMIS and SRS rates seem to converge with time, for most states including Tamil Nadu, Uttarakhand, West Bengal, Himachal Pradesh, Bihar, Rajasthan, and Punjab (Fig. 2). This shows that while there continues to be discordance in mortality data in 2018, the parity in reporting between HMIS and SRS has improved over time. Uttar Pradesh is an exception here. The figures also show increases in child mortality in some states according to the SRS(Drèze et al., 2020). Correlation between SRS and HMIS on birth rates was high in both 2014 and 2018 (Fig. 1 (a) and (b)). Poor correlation was observed between all the three data sources for the mortality indicators in 2014. However, this correlation improved by 2018. Between SRS and HMIS comparison, correlation for neonatal mortality improved from −0.13 in 2014 to 0.27 in 2018, -0.33 to 0.44 for post-neonatal mortality, and −0.22 to 0.36 for age specific mortality rates between 2014 and 2018, respectively (Fig. 1 (a) and (b)). Importantly, HMIS provides birth and mortality estimates for states such as those in the north-east, for which estimates from the SRS are not available. HMIS also provides information on mortality for recent years. Estimates for mortality rates up to 2020 can already be calculated from the HMIS (Fig. 2b and c).

Institutional births: Differences between the number of institutional births in SRS and HMIS seemed to be closing over time, moving
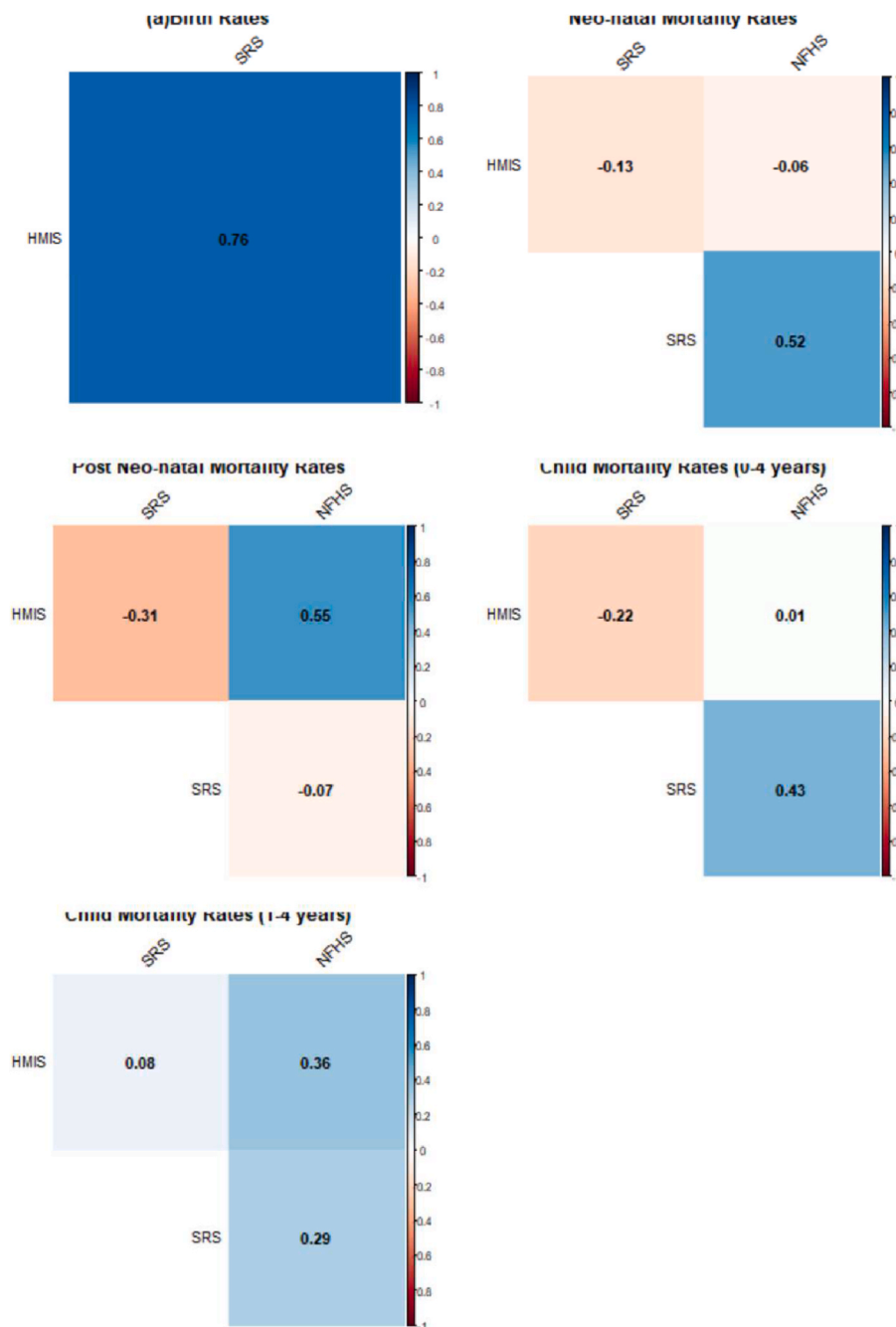
Fig. 1a. Correlation plot of all indicators across states in 2014 and 2018 between HMIS, NFHS and SRS

*Birth Rates not available for NFHS

Birth Rates, Neonatal Mortality Rate, Post-Neonatal Mortality Rate, Child Mortality Rate (0–4), Child Mortality Rate (1–4).

from 6,193,934 to 2,009,351 births from 2014 to 2018 (Table 3a). Similar trends were observed for comparisons with NFHS. Thus, in 2018, the total number of institutional births recorded in the HMIS is very close to the estimated number of institutional births in the SRS (Table 3b).

4. Discussion

Our study has several important findings. We provide what is to the best of our knowledge, the first systematic estimates of vital statistics indicators from HMIS data in an LMIC at national and state levels, over a four-year period. Second, we compare these estimates with those from two publicly available, nationally representative surveys in India, at national and state levels – the NFHS and SRS, to systematically consider the possibility of using such administrative datasets for population health analysis in India and other LMICs, where civil registration remains incomplete and delayed. We find that while the Indian HMIS is performing relatively well on birth indicators for most states, and has been improving across states in infant and child mortality estimates over time, there is still considerable room to further improve reporting in the HMIS.

State level analysis reveals that nationally and at state levels, while the HMIS under-estimates birth and death rates in India, the degree of under-estimation is much less for births compared to deaths. Additionally, for a small number of states, HMIS captures similar mortality levels as the SRS and the NFHS. Nationally and at state level, HMIS provides

Birth Rates

Neo-natal Mortality Rates

Post Neo-natal Mortality Rates

Child Mortality Rates (0-4 years)

Child Mortality Rates (1-4 years)

Fig. 1b. Correlation plot of all indicators across states in 2018 between HMIS and SRS.

better concordance with institutional births from SRS and NFHS (Table 2). We also find variation between states, with some states such as Kerala and Himachal Pradesh having higher coverage in the HMIS than others (Table 2). These states are also among the better performing states on other national health indicators (Government of India, 2021).

Based on time trends from 2014 to 2018 birth estimates from HMIS and SRS (the two datasets for which data are available for this period), have shown high concordance which has remained consistent over time, with the exception of Uttar Pradesh in north India. This is especially true of institutional births. Trends on institutional births are especially important to underscore, since HMIS as an administrative dataset, primarily captures facility level births and deaths (Government of India,
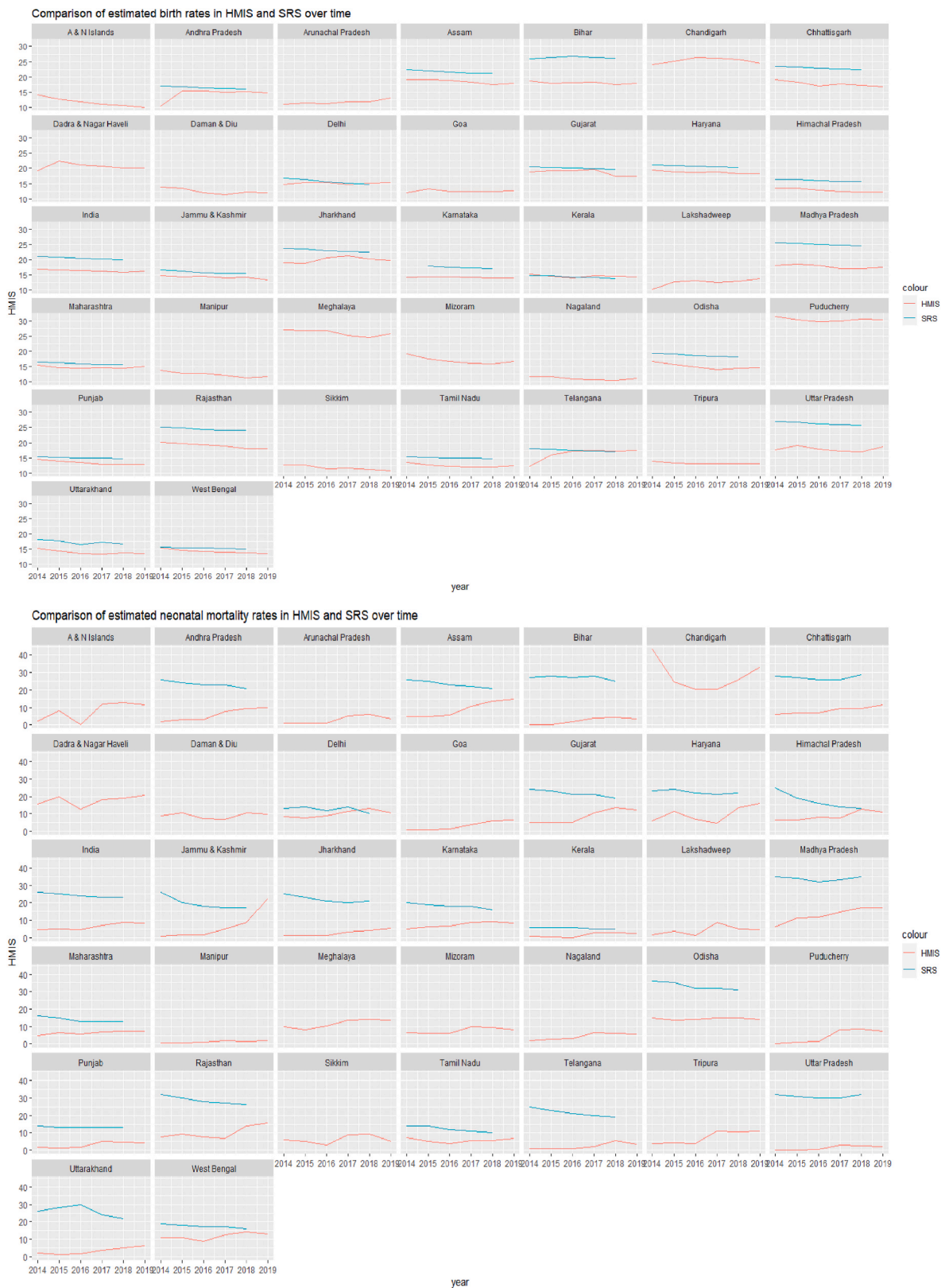
Fig. 2. Trends over time: Comparing SRS and HMIS for all indicators between 2014 and 20.

2021). For births, HMIS also includes data reported by community health workers (Government of India, 2021). While all infant and child mortality estimates from HMIS and SRS continued to be discordant in the same period, the gap in estimates seems to have reduced over time

(Fig. 2).

It is important to underscore that the three datasets we compare have very differing objectives, scope of representation and sampling techniques. While the HMIS is a collation of facility level counts of outcomes
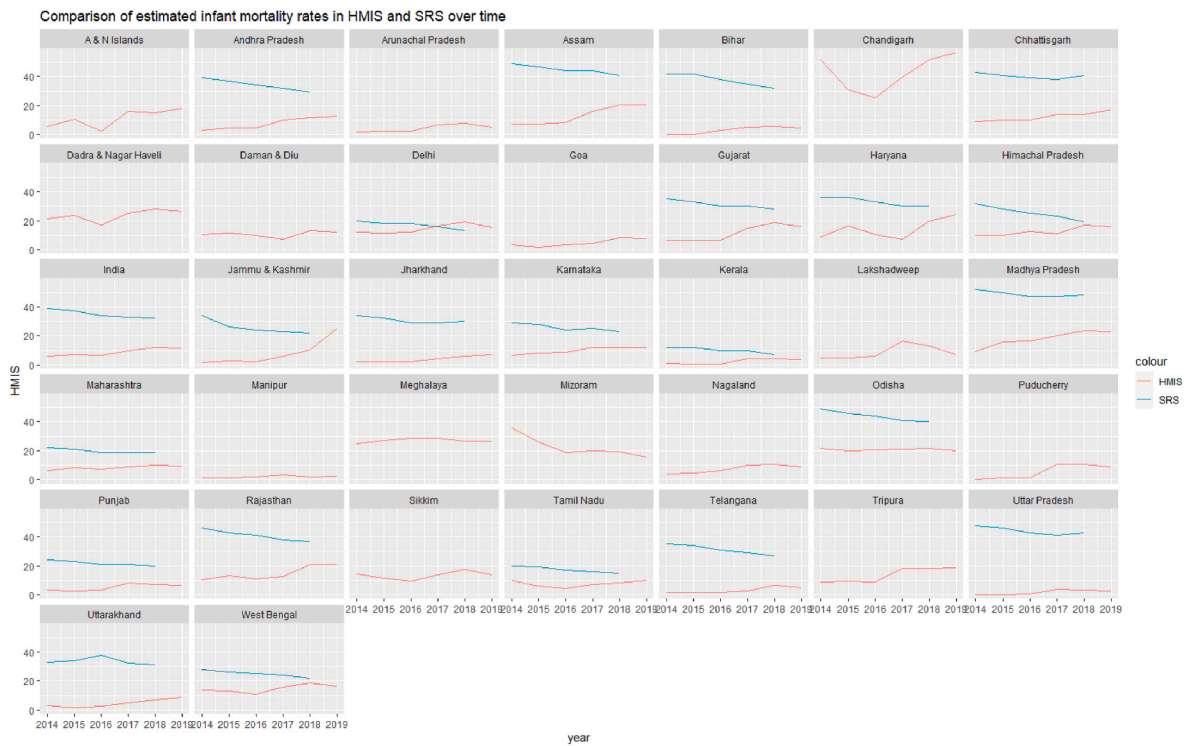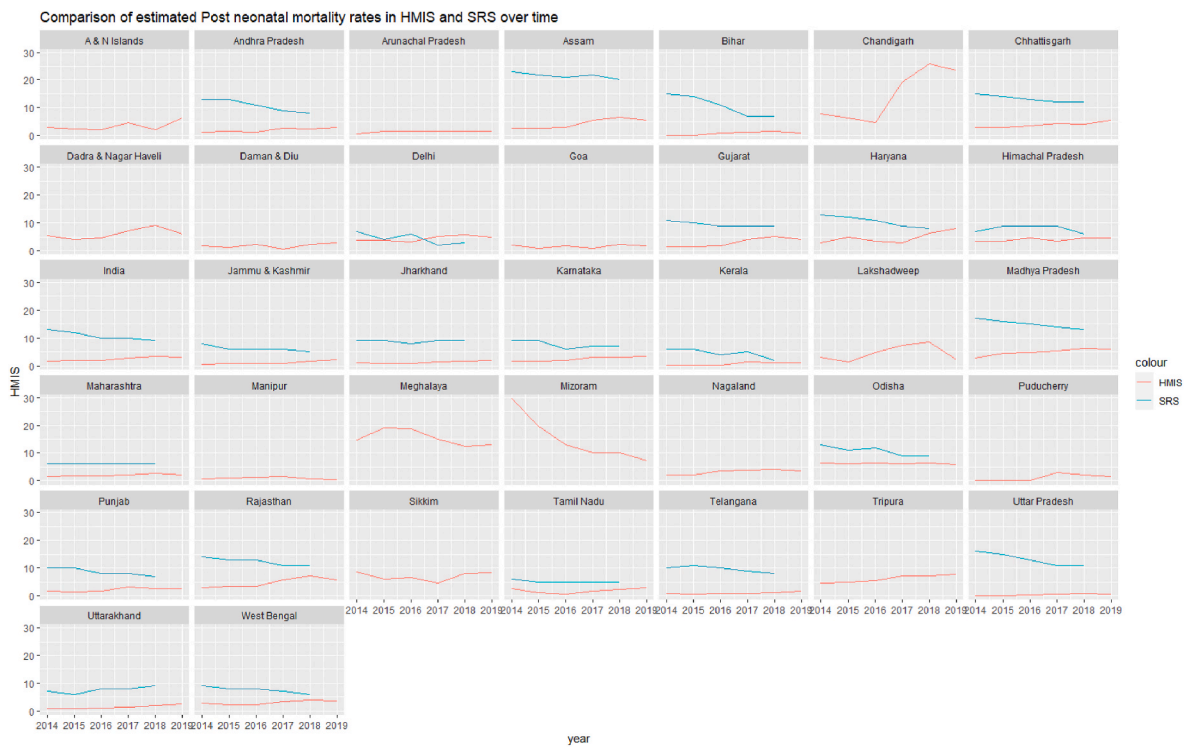
Comparison of estimated Post neonatal mortality rates in HMIS and SRS over time

Comparison of estimated infant mortality rates in HMIS and SRS over time

Fig. 2. (*continued*).

and service variables and therefore does not involve any sampling, the other two sources are nationally representative surveys. The NFHS is conducted every 5 years, is part of the Demographic Health Surveys, which are nationally representative household surveys on common health and societal indicators across births, deaths, nutrition, maternal and child health, among others, across many countries. It is based on multi-stage sampling design, in which villages or urban blocks are sampled based on decennial censuses. Households are then randomly selected within villages. The SRS, on the other hand, is a survey focused

on annual, nationally representative estimates of vital statistics. It follows a sampling strategy similar to NFHS, except that it covers all households within a village.

Our analysis reveals some potential strengths of HMIS. HMIS unit-level data are available publicly, unlike the SRS, and even the CRS. As a high frequency dataset that is updated monthly on most indicators, the HMIS is timelier, compared to SRS, an annual survey, the last publicly released estimates for which are for 2018; and the 2015–16 iteration of NFHS, a five yearly survey. Furthermore, HMIS provides facility level
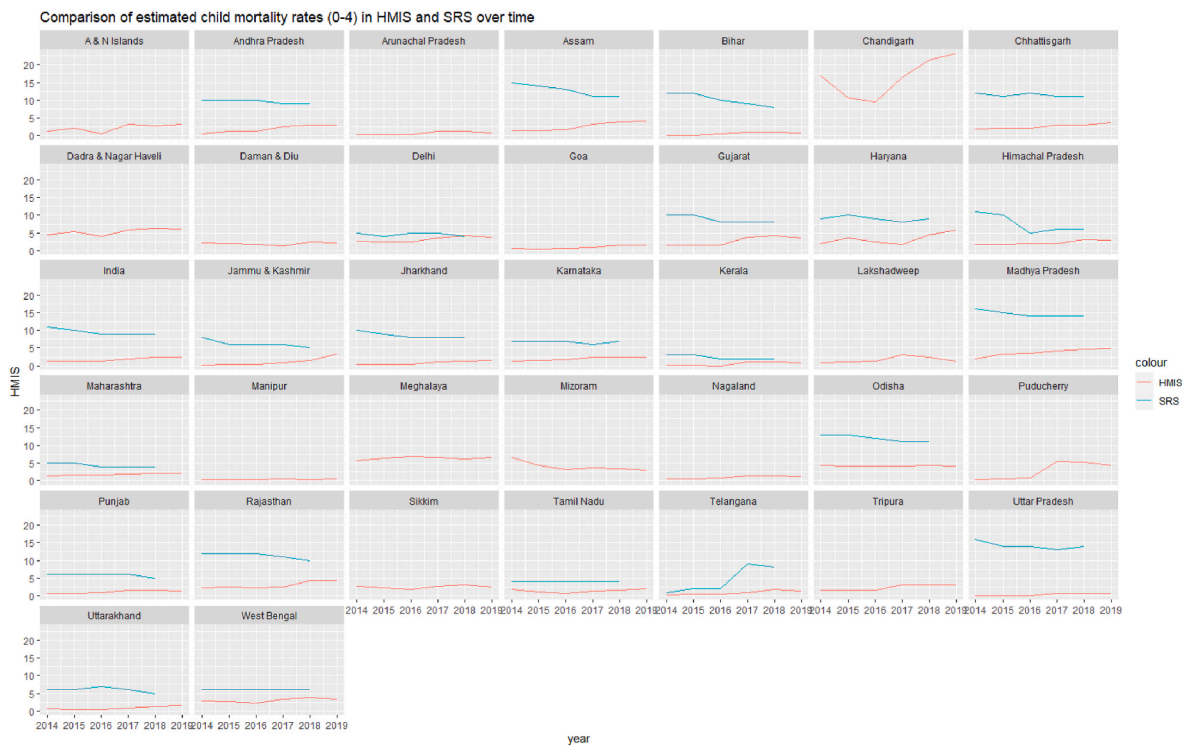
Fig. 2. (*continued*).

counts for all states and Union Territories of India. While iterations of the NFHS before 2015–16 were representative at the state and national levels, in 2015–16, for the first time, the NFHS was also representative at the district level. The SRS, also a survey, omits smaller states, including states in the north-east, but is representative at the state level for the larger Indian states.

However, HMIS has many limitations which are important to underscore. First, as this analysis elucidates, in addition to the inconsistencies in definitions of indicators in HMIS over time, levels of births and deaths are underestimated in HMIS. Furthermore, given that HMIS relies largely on facility level reporting, reporting discrepancies could be conflated with actual change in indicator values. While we focus on states, analysis at more granular levels, particularly assessments of time trends should be wary of administrative changes in district boundaries and the making of new districts. For example, in Uttar Pradesh state, Shamli spilt from Muzaffarnagar in 2012 and was included in HMIS as an independent district only from 2014. Third, given the discordance in counts between HMIS, SRS and NFHS, for the mortality indicators even in 2018, for now, HMIS might be useful to study trends in select states.

Importantly, in a comparison of datasets of this nature, it is important to acknowledge that transparency in sampling methods is desirable. Of the available sources, NFHS provides the most detail about its sampling strategy and design, as well as ease of use and accessibility of the data (International Institute for Population Sciences & ICF, 2017). It is also desired in SRS which despite being considered a standard source of demographic data in India, does not make its raw data available for analysis and interpretation (Mahapatra, 2017). More transparency in its sampling methods as well as estimation strategy for confidence interval estimates would be helpful.

Our analysis lends itself to some key policy implications. Since we find the degree of underreporting in HMIS is lower for births compared to deaths, HMIS is probably able to better capture births and incidents around births, compared to deaths. This could be due to poor reporting of deaths in health facilities, and/or inadequate capturing of death related data under HMIS. Thus, first, there is a need for facilities to better

monitor and document deaths and events around deaths. Second, HMIS infrastructure needs to be augmented to better capture death related data more robustly. Importantly, we find that trends in reporting of births and deaths under HMIS have improved with time for some states but lagged for others. This demonstrates that while there may be important limitations in HMIS, it is possible to invest in infrastructure, training, and monitoring to improve data collection around deaths in HMIS. Exemplar states that have improved their reporting of deaths under HMIS over the years, should be studied as case studies, to see if their practices can be replicated in other states. Furthermore, if the mandate of HMIS could be expanded to include individual level data on key socioeconomic variables from facility level data, population health metrics could be monitored from an equity perspective and similarly targeted in policy. Thus, HMIS has the potential to develop into a data source to improve our understanding of patterns of inequities in births and deaths reporting in India, in a relatively timely manner. Finally, despite its limitations, our analysis shows that given the wide geographic coverage and relative timeliness of HMIS reporting compared to periodical national surveys, HMIS could be utilized for pragmatic, real time policy monitoring and decisions, provided it is used after accounting for important limitations highlighted in this paper. We saw a fleeting exemplification of this to some extent, around the COVID-19 outbreak in India in 2021, when HMIS data were increasingly used by journalists and practitioners to report on trends in deaths (Rukmini S, 2020).

Our analysis has important limitations. First, we use estimated population numbers, as reported by the USAID/DHS. To our knowledge, these are the only estimates of age-specific annual population counts for each of India's states. Second, since HMIS data are aggregated from facility level counts of births and deaths, with no information on individual socioeconomic or demographic characteristics of patients, we are unable to do more granular analyses of trends in births and deaths across important social strata, or explore trends in how HMIS captures different social groups compared to national surveys. Third, as noted previously, since HMIS comprises of facility level births and deaths, births and deaths that occurred outside of facilities are not captured in the dataset,

Table 3a
State-wise comparison of estimates of live and institutional births, 2014

State	2014			
	HMIS Live Births	HMIS Institutional Births	NFHS Institutional Births	SRS Institutional Births
India	20,801,010	14,187,207	21,030,222	20,381,141
A & N Islands	5,295	–	–	–
Andhra Pradesh	513,180	271,962	776,821	792,692
Arunachal Pradesh	16,030	5,614	–	–
Assam	610,021	499,193	526,963	553,311
Bihar	2,024,498	461,829	1,940,282	1,799,682
Chandigarh	25,933	–	–	–
Chhattisgarh	504,307	315,652	439,238	444,187
Dadra & Nagar Haveli	7,415	7,321	–	–
Daman & Diu	3,782	3,729	–	–
Delhi	255,926	241,646	238,413	268,360
Goa	17,268	17,454	–	–
Gujarat	1,162,261	1,117,240	1,161,624	1,162,901
Haryana	509,116	435,437	474,718	443,806
Himachal Pradesh	93,225	76,805	88,371	84,066
Jammu & Kashmir	192,726	123,869	–	186,310
Jharkhand	646,624	455,116	527,879	460,473
Karnataka	886,369	877,928	–	–
Kerala	498,114	495,522	485,208	483,752
Lakshadweep	648	–	–	–
Madhya Pradesh	1,357,117	832,373	1,593,170	1,522,149
Maharashtra	1,748,294	1,714,503	1,713,546	1,792,633
Manipur	41,624	28,390	–	–
Meghalaya	84,258	37,480	–	–
Mizoram	21,689	14,515	–	–
Nagaland	22,236	12,660	–	–
Odisha	704,932	418,083	698,874	634,742
Puducherry	41,097	42,831	–	–
Punjab	408,614	371,250	405,326	371,693
Rajasthan	1,428,450	1,347,416	1,519,738	1,516,204
Sikkim	7,825	4,442	–	–
Tamil Nadu	982,891	986,125	1,115,798	1,070,715
Telangana	433,321	144,792	606,804	578,699
Tripura	51,649	17,929	–	–
Uttar Pradesh	3,602,856	1,386,495	3,937,760	3,449,700
Uttarakhand	157,295	108,200	139,087	127,810
West Bengal	1,434,165	1,183,874	1,120,753	1,175,353

Note: 95% CIs for NFHS rates are available in the appendix.

Table 3b
State-wise comparison of estimates of live and institutional births, 2018

State	2018		
	HMIS Live Births	HMIS Institutional Births	SRS Institutional Births
India	20,666,307	19,388,411	21,397,762
A & N Islands	4,016	3,727	–
Andhra Pradesh	757,911	752,248	778,759
Arunachal Pradesh	18,474	16,826	–
Assam	579,503	525,160	580,895
Bihar	2,048,782	1,681,219	2,150,292
Chandigarh	29,008	29,186	–
Chhattisgarh	483,992	473,943	488,054
Dadra & Nagar Haveli	9,106	9,090	–
Daman & Diu	3,867	3,865	–
Delhi	277,984	267,726	258,490
Goa	18,185	18,143	–
Gujarat	1,141,531	1,122,856	1,216,926
Haryana	500,854	476,915	477,775
Himachal Pradesh	86,778	78,657	88,220
Jammu & Kashmir	198,117	190,705	190,729
Jharkhand	734,933	703,595	506,681
Karnataka	907,016	907,668	1,082,584
Kerala	479,334	474,983	455,130
Lakshadweep	836	839	–
Madhya Pradesh	1,346,602	1,284,517	1,614,710
Maharashtra	1,720,760	1,712,778	1,799,448
Manipur	37,758	31,134	–
Meghalaya	82,825	48,261	–
Mizoram	19,219	17,269	–
Nagaland	19,455	15,994	–
Odisha	634,660	616,888	646,615
Puducherry	43,369	43,643	–
Punjab	370,467	362,717	384,493
Rajasthan	1,356,232	1,339,131	1,592,883
Sikkim	7,146	7,147	–
Tamil Nadu	920,658	920,024	1,074,755
Telangana	630,063	607,434	583,685
Tripura	50,343	47,329	–
Uttar Pradesh	3,686,464	3,180,565	3,757,899
Uttarakhand	149,298	129,600	132,642
West Bengal	1,310,761	1,286,629	1,230,231

Note: 95% CIs for NFHS rates are available in the appendix.

leading us to hypothesize that HMIS underestimates national births and deaths. Fourth, we note that our HMIS estimates are case-fatality rates, where the denominators are HMIS births, rather than total births. If total births are used as the denominator, the HMIS under-reporting would be even more severe. However, given that the HMIS does not under-estimate births considerably, this should not affect our conclusions. We also note other limitations of HMIS data. For instance, HMIS counts can change, especially if data-entry is delayed. Similarly, we have not used civil registration estimates, because for our purposes, it does not serve as a useful comparison. This is because civil registration data in India themselves may under-report mortality, and the extant literature already provides estimates of coverage in the CRS (Rao & Gupta, 2020). Finally, we are also unable to provide confidence intervals (CIs) for the SRS since CIs that account for clustering of observations within primary sampling units are not currently available from the SRS.

Our study also has several strengths. We provide the first analytic assessment of HMIS as a source to estimate timely population health data, by using it to estimate national and state level birth and mortality indicators over time. In comparing these to two commonly used national level population health surveys in India, we elucidate that while HMIS

underestimates births and deaths data compared to surveys, as may be expected from a database which collates largely facility reported data to the exclusion of home births and deaths, this underestimation is much less in the case of vital birth statistics data.

Future research should also study whether state reporting trends for births and mortality indicators in HMIS seen in this study, are reflected in other outcomes, particularly health service-related variables. Extending this analysis to include additional years, particularly years after the COVID-19 pandemic, would also be valuable. In strengthening the HMIS, learning from better performing states and capturing non-institutional demographic events may also be a priority. The HMIS could also be augmented by making available more information on the characteristics of births and deaths at the individual level, to better understand service access and disparities thereof. Ultimately, given that the HMIS records data from health facilities, improving access to health, especially after birth, and encouraging record keeping of deaths in health facilities may be the most important tools to help the HMIS become a continuous mortality surveillance tool.

5. Conclusion

While Indian HMIS is performing relatively well on birth indicators for most states, and has been improving across states in infant and child mortality estimates over time, there is still room to further improve reporting in the HMIS. Without due intervention, the HMIS cannot serve

as a robust monitoring tool for routine public health statistics. However, with some diligence in accounting for its limitations, HMIS can still provide signals for real time policy analysis, especially in case of shocks or outbreak events, when regularly updated administrative data can provide important insights about deviations from routine trends. With efforts to address the limitations of HMIS underlined in previous sections, the administrative dataset can emerge as a treasure trove of publicly available, real-time data to understand population level vital statistics in a timely manner in India. As initial steps towards this overhaul, future research should examine why the HMIS performs relatively better in some states over others, and pilot interventions to improve the coverage of the HMIS in underperforming states. Finally, expanding HMIS data to include key socioeconomic variables at individual or aggregated levels from facility data could allow for more policy relevant comparisons of birth and mortality trends across social groups in India.

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Author statement

Conceptualization and Design: PC, AG, SVS.
Data Acquisition and Analysis: PC, AG.
Data Interpretation: PC, AG, SVS.
Drafting of the Manuscript: PC, AG.
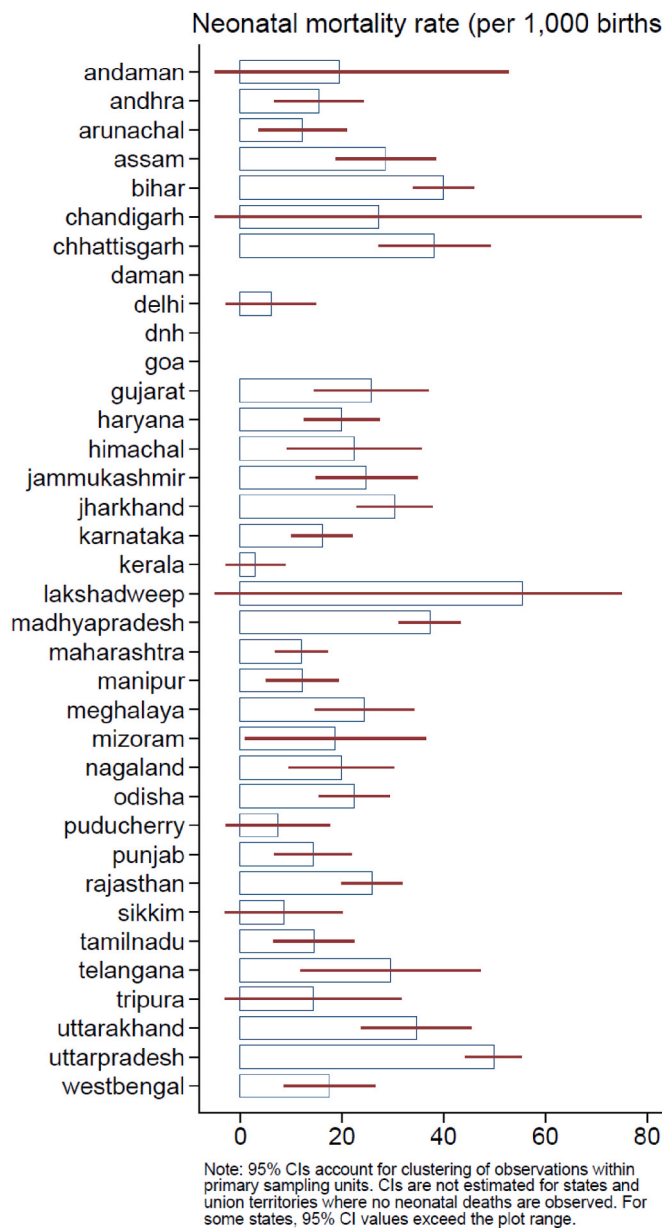Critical revisions to Manuscript: PC, AG, SVS.
Overall Supervision: SVS.

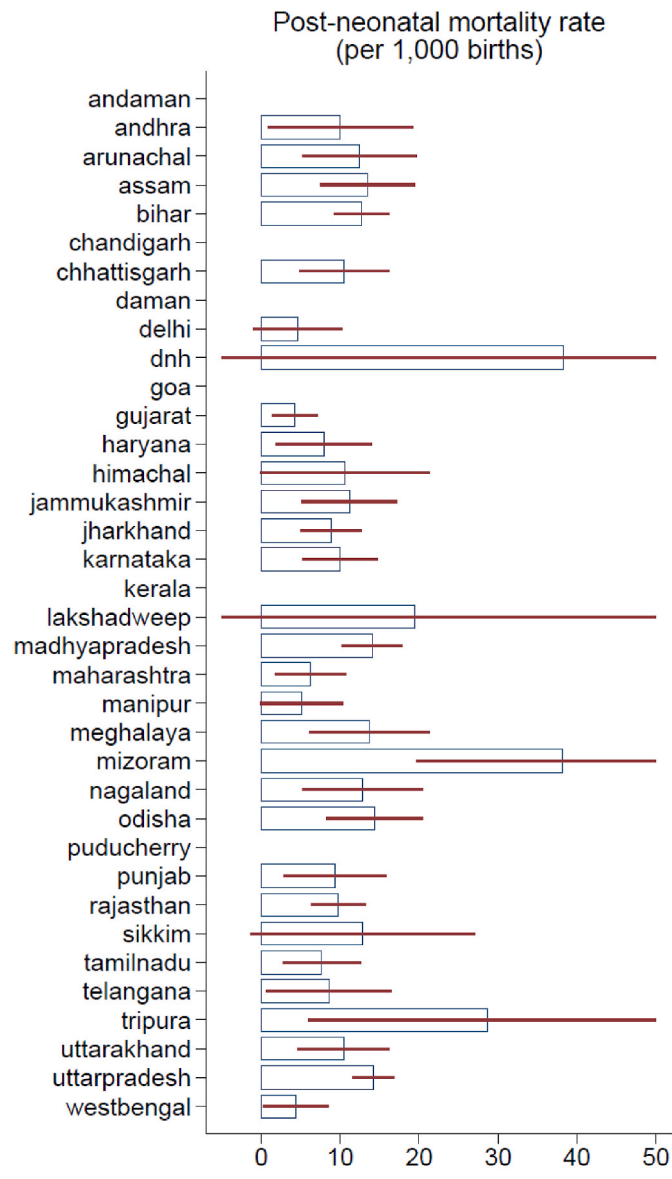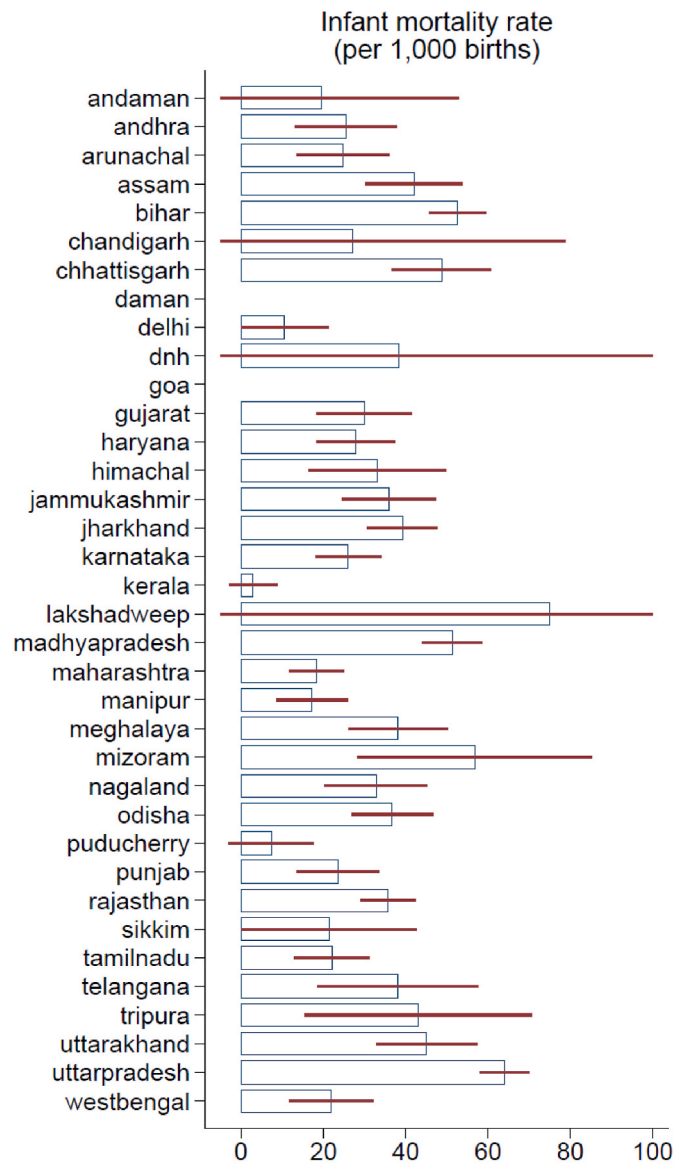## Declaration of competing interest

None.

Appendix 1. Counts of birth and mortality indicators in 2014 and 2018 at the national level, based on the Health Management Information System (HMIS), the National Family Health Survey (NFHS) and the Sample Registration Survey (SRS)

Indicator	2014			2018	
	HMIS	NFHS	SRS	HMIS	SRS
Live births	20,801,010	–	25,963,237	20,666,307	25,936,681
Institutional Births	14,187,207	21,030,222	20,381,141	19,388,411	21,397,762
Neonatal deaths	90,539	751,974	675,044	177,082	596,544
Post neonatal deaths	36,511	265,823	337,522	69,176	233,430
Infant deaths	127,050	1,017,796	1,012,566	246,258	829,974
Child deaths (0–4)	142,354	1,132,688	1,295,253	281,554	1,050,149
Child deaths (1–4)	15,304	114,892	282,687	35,296	220,175

Appendix 2. State specific estimates and 95% Confidence Intervals in 2014 for a) Neonatal Mortality Rates, b) Post Neonatal Mortality Rates, c) Infant Mortality Rates, d) age-specific mortality rate between ages 0 and 4, and d) age specific mortality rate between ages 1 and 4

Note: 95% CIs account for clustering of observations within primary sampling units. CIs are not estimated for states and union territories where no neonatal deaths are observed. For some states, 95% CI values exceed the plot range.

Post-neonatal mortality rate
(per 1,000 births)

Note: 95% CIs account for clustering of observations within
primary sampling units. CIs are not estimated for states and
union territories where no post-neonatal deaths are observed.
For some states, 95% CI values exceed the plot range.

Infant mortality rate
(per 1,000 births)

Note: 95% CIs account for clustering of observations within primary sampling units. CIs are not estimated for states and union territories where no infant deaths are observed. For some states, 95% CI values exceed the plot range.

Age-specific mortality rate, 0-4 (per 1,000 people alive)

Note: 95% CIs account for clustering of observations within primary sampling units. CIs are not estimated for states and union territories where no deaths are observed. For some states, 95% CI values exceed the plot range. CIs are calculated using a cluster bootstrap approach. 100 bootstrap samples were drawn.

Age-specific mortality rate, 1-4 (per 1,000 people alive)

Note: 95% CIs account for clustering of observations within primary sampling units. CIs are not estimated for states and union territories where no deaths are observed. For some states, 95% CI values exceed the plot range. CIs are calculated using a cluster bootstrap approach. 100 bootstrap samples were drawn.

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