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REVIEW ARTICLE

Seasonal and District Level Geo-Spatial Variations in Stillbirth Rates in India: An Analysis of Secondary Data

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Abstract
Stillbirth is a major public health problem across the world as well as in India. The programmatic interventions to tackle stillbirth require granular data upto local levels. The Health Management Information System (HMIS) in India is one of the best sources of granular data on stillbirth. This analysis was conducted using HMIS stillbirth data of three pre-pandemic years 2017-2020 to study the geo-spatial patterns of stillbirth at district level in nine states of India, forming a high burden cluster of four central Indian states and a low burden cluster of five southern states. Geo-spatial variation at sub-district level was studied for Maharashtra given the ready availability of sub-district shapefiles required for such analysis. The analysis also explores the seasonal variations in stillbirths at all-India level. A granular intra-cluster spatial pattern of stillbirth was observed in all states analyzed, with a clear hotspot across a few districts in Odisha and Chhattisgarh (>20 stillbirths/1,000 total births in 2019-20). Even in the southern cluster, the hotspots (8-20 stillbirths/1,000 total births) were found. Availability of sub-district level data in Maharashtra helped to identify intra-state regional variations in stillbirth with high prevalence in certain district clusters. In temporal terms, stillbirths exhibit a regular peak during August-October and a dip during February-April which is inclined with the birth seasonality patterns. This review and analysis underscore the need for more granular data availability, regular analysis of such data by expert and program managers, more decentralized and context specific programme intervention both in locational and seasonal terms.

Keywords Stillbirths · Geo-spatial analysis · India · Newborn survival · Public health

Introduction

Stillbirth, the 'neglected tragedy' is a serious global public health issue with severe multifaceted consequences socially, emotionally and economically [1, 2]. United Nations Inter-agency Group for Child Mortality Estimation (UN-IGME) indicates that 1.9 million babies were stillborn globally in 2021 at a stillbirth rate (SBR) of 13.9 per 1,000 total births. The stillbirth rate in India was estimated at 12.2 per 1,000 total births [3]. Accurate identification of populations with high risk of stillbirths is essential to guide further prevention and intervention programs with quality healthcare during antepartum and intrapartum period [4]. In India, the estimates of SBR differ considerably between data sources. The Sample Registration System (SRS) has estimated SBR of 3.0 per 1,000 total births [5], while the Health Management Information System (HMIS) reports a SBR of 12.4 per 1,000 total births for the year 2019-20 [6]. The cross-sectional data from the Annual Health Survey (2010-2013) among 9 states of India has reported an SBR of 10 (95% CI, 9.8 to 10.3) [7]. For a diverse country such as India, the national level aggregates have a wide sub-national variation. A recent study reported regional variation across the country using the HMIS database and has identified two distinct clusters of high and low stillbirth rates across the 9 Indian states [4]. The present analysis has carried a granular,

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district-level geo-spatial analysis in these 9 states of India. A sub-district level analysis was done for Maharashtra state. The seasonal variation of stillbirths has also been analyzed as this is highly needed for implementing appropriate corrective programmatic and preventive actions.

Database and Data Extraction

The analysis used data from the HMIS that provides facility-level monthly data at a granular (sub-district) level in the public domain (https://hmis.nhp.gov.in, downloaded on: 10th November, 2020; currently available at https://hmis.mohfw.gov.in). The online HMIS portal covers around 200,000 government facilities that upload health service delivery data on reproductive, maternal and child health-related services [8]. Present analysis considers stillbirth and total birth data in the public domain for three financial years of 2017-18, 2018-19 and 2019-20. The data downloaded from the HMIS portal was converted into a structured format through various steps of data wrangling and cleaning using python pandas [9] and stored in the PostgreSQL database [10].

Geo-Spatial Analysis

The contiguous districts of high and low burden clusters of stillbirths reported in a previous analysis [4] were selected for further micro-level investigation (Fig. 1) using HMIS data of 2019-20. The high burden OMRC cluster includes Odisha, Madhya Pradesh, Rajasthan and Chhattisgarh and low burden cluster includes the five southern states Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Telangana.

The variation at sub-district level was studied for Maharashtra as sub-district shapefiles required for the analysis were available only for this state. The sub-district level analysis was done to highlight the changes in clusters from 2018-19 to 2019-20 as well.

Choropleth map was used to provide an easy way to visualize how stillbirth rate varied within a region. This shows the district wise variation of SBR in high and low burden cluster as well as sub-district wise variation within the state of Maharashtra. QGIS software (version 3.22.11) [11] was used for drawing the choropleth map for the SBR prevalence.

Geospatial techniques of local indicator of spatial association (LISA) were applied to identify the spatial distribution of the stillbirth burden at the district level for OMRC and southern states as well as at the sub-district level for Maharashtra. These regions were divided into hotspots and cold spots using univariate LISA performed with SBR as the relevant variable. When the values for a random variable

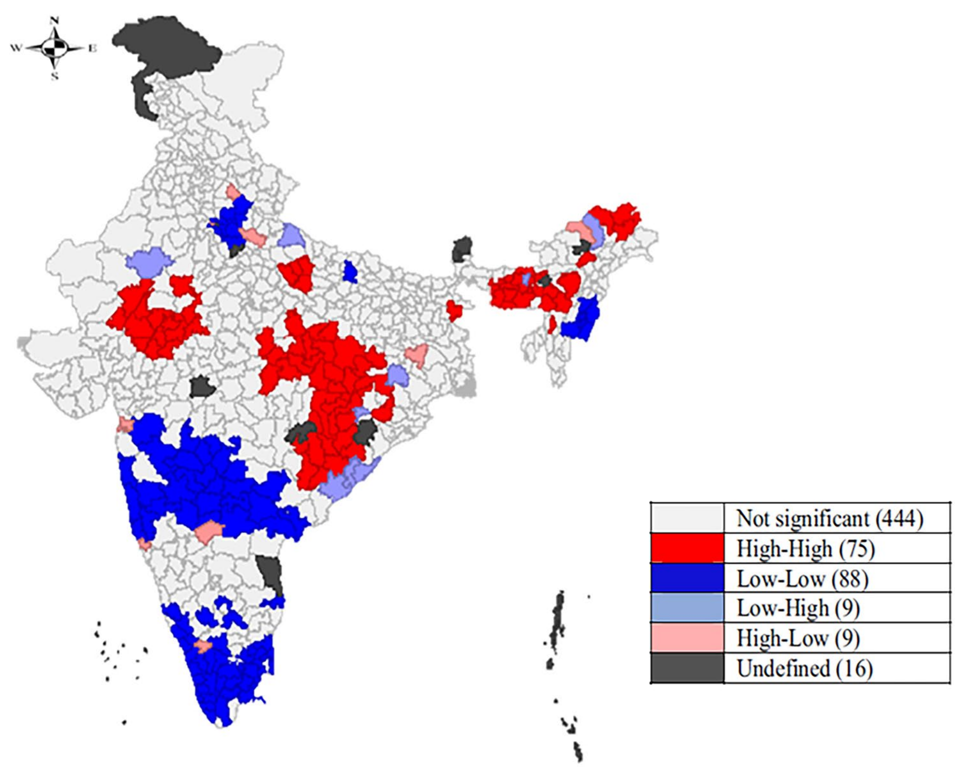

Fig. 1 Univariate LISA cluster map of stillbirth rates across the districts in India, HMIS 2019-20 (Moran's I: 0.372, $p = 0.1$) [4]. *HMIS* Health Management Information System, *LISA* Local indicator of spatial association

tend to cluster in space, it is termed positive spatial autocorrelation and when a region tends to be surrounded by neighbors with very different values, it is termed as a negative spatial autocorrelation. The neighbors were identified using the 'Queen contiguity' based on shared vertices and boundaries. The spatial weight matrix was computed by giving a value of 1 and 0 to the neighbors and non-neighbors, respectively. Similarly, the spatial lag variables were generated by summing the products of these spatial weights and each of the neighborhood values. The degree of spatial autocorrelation that exists in a dataset across the geographical unit was quantified by Moran's I, an indicator whose value ranges from −1 to +1; a value close to +1 signifies clustering, zero represents randomness, and a value close to −1 implies dispersion [12–14].

Univariate LISA was conducted to generate a cluster map and a significance map. The cluster map identifies four types of clusters. The first category, high-high or hotspots, implies that a particular region and its surrounding neighborhood have a high prevalence of the parameter being analyzed. In low-low clusters or cold spots, the prevalence is low in the region and its neighborhood. The high-low category has a high prevalence of the parameter in the area surrounded by low prevalence, while low-high is the opposite to it. The significance maps reveal if the clusters are statistically significant or not. The authors have used $p = 0.1$ to judge the statistical significance.

Seasonal Variation

The analysis on seasonal variation was done to explore the trend of peaks and dips of the reported live births and stillbirths at all-India as well as regional level (state of Maharashtra) for 36 months during 2017 to 2020. The primary outcome variables of this analysis were the 'Total Live Births' and 'Stillbirths' examined as the absolute counts. The state wise extent of variations in births have been studied by actual numbers as well as by calculating and mapping the standard deviations for each state.

Results

The spatial differences and clustering are very much evident within each of the regions of high burden OMRC cluster (5-39 stillbirths per 1,000 total births) as well as low burden southern states cluster (0-20 stillbirths per 1,000 total births) (Fig. 2).

Intra-region variation is observed in both the clusters (Supplementary Fig. S1a, S1b, S2a and S2b) each of which account for more than 15% proportion of Indian population. OMRC cluster accounts 17% and southern state cluster accounts 21% of population size as per census 2011 [15]. The middle part of the central belt in OMRC cluster was found to have a relatively lower incidence of stillbirth while a clear hotspot can be seen towards the south-east part which has more than 20 stillbirths per 1,000 total births in

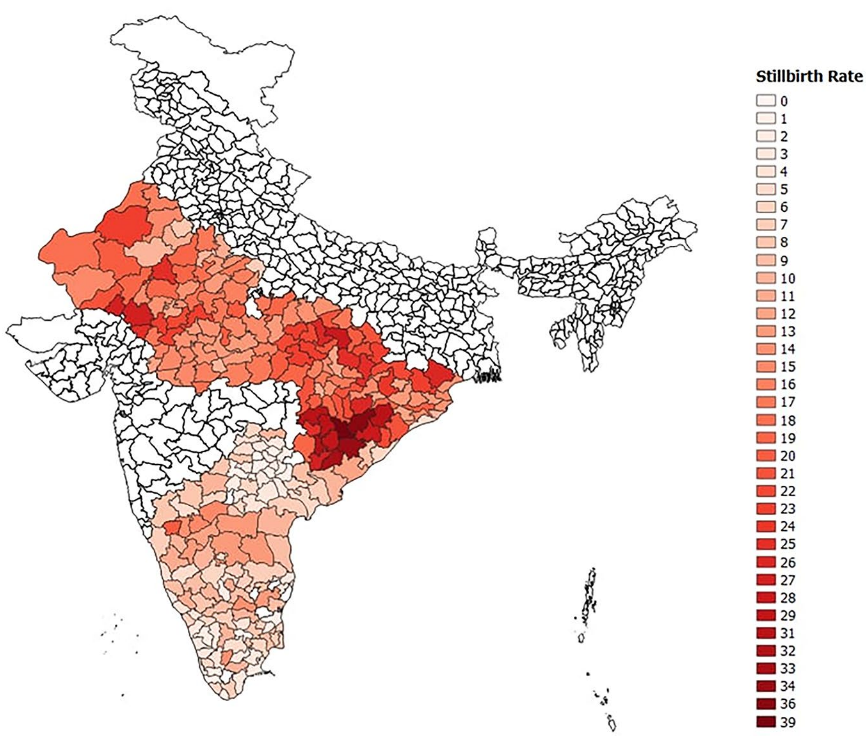

Fig. 2 Prevalence of stillbirth rates across the districts in OMRC cluster and southern states cluster, HMIS 2019-20. *HMIS* Health Management Information System

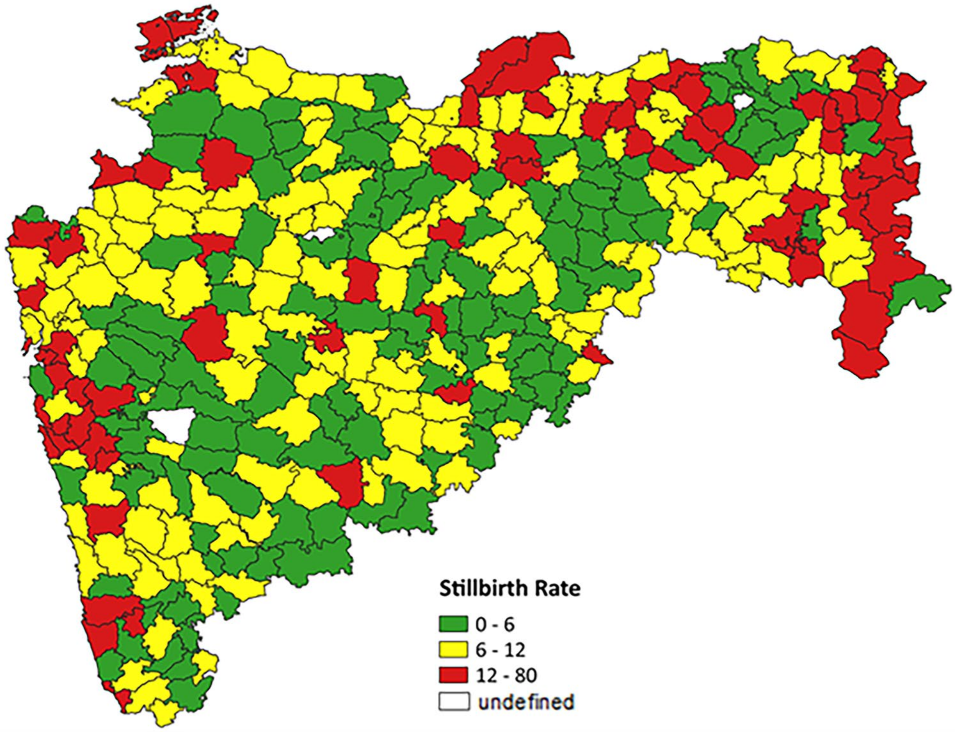

Fig. 3a Prevalence map of stillbirth rates across the sub-districts of Maharashtra, HMIS 2019-20. *HMIS* Health Management Information System

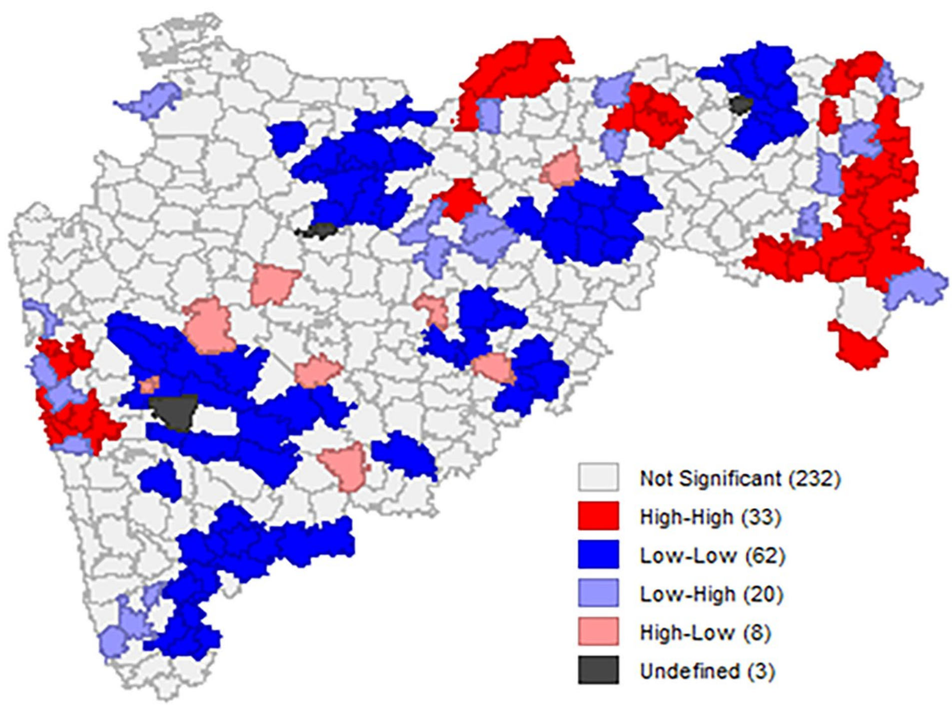

Fig. 3b Univariate LISA of stillbirth rates across the sub-districts of Maharashtra, HMIS 2019- 20 (Moran's I: 0.208, $p = 0.1$). *HMIS* Health Management Information System, *LISA* Local indicator of spatial association

2019-20, majorly in the state of Odisha (Supplementary Fig. S1a and S1b).

In the low burden southern states cluster, hotspot districts with 8-20 stillbirths per 1,000 total births were found (Supplementary Fig. S2a and S2b). The results were similar for the previous two financial years of 2017-18 and 2018-19 and therefore, not presented separately in this analysis.

Geo-spatial Variation of Stillbirth Rate at Sub-district Level

Though there was reduction in stillbirth rate over the years, a higher incidence of stillbirths continuously persists in a cluster of districts of Akola, Amravati, Bhandara, Chandrapur, Gadchiroli, Gondia, and Nandurbar (Supplementary Fig. S3a and S3b). A cluster of higher SBR can be seen in the eastern part of Maharashtra (Fig. 3a and 3b). Similar results were obtained for the financial years 2017-18 and 2018-19 (not presented for brevity).

Seasonal Variation

A peak in the total live births was observed during August-October and a dip during the February-April. Stillbirths also follow the similar trend of regular peaks in August-October and dips in February-April at the all-India level (Fig. 4).

The seasonality analysis was carried out for each Indian state. A similar trend of seasonal variations of live births and stillbirths was observed in twelve states (Bihar, Jharkhand, Uttar Pradesh, Uttarakhand, Haryana, Punjab, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Assam and West Bengal) (Supplementary Fig. S4a and S4b) even though the month of peaks and dips vary from state to state. Eleven states such as Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Goa in south; Arunachal Pradesh, Manipur, Meghalaya in north-east; Odisha and Chhattisgarh in the central-eastern part and Himachal Pradesh follow a pattern where the live birth and stillbirth peaks moderately differ from each other. Both live birth and stillbirth peaks differ significantly in Mizoram, Sikkim, Telangana and Tripura which may warrant a closer scrutiny. Maharashtra shows a similar trend to that of all-India level birth seasonality (Supplementary Fig. S5, S6).

Discussion

The inter-state and inter-district variations have regularly been noted in various health programs in India [16, 17]. The utility and usefulness of such data is widely known. However, the focused use of such granular analysis of data continues to remain limited.

The foregoing analysis raises four distinct issues for consideration. The first relates to the double-digit figures of the stillbirth rates revealed in the HMIS *vis a vis* a much lower figure from the SRS. Possible reason for this difference is that the SRS is a sample data while HMIS is the entire population data from the facilities that are reporting under the HMIS. More importantly, though HMIS will give the floor level stillbirth rate, the actual rate may be more than it but cannot be less. The divergence between the SRS and the HMIS figures merit a closer scrutiny. Whether higher stillbirth rate be attributed to misclassification, i.e. children dying within few hours of births also getting classified as stillborn. Such an argument cannot explain the intra-cluster variation or intra-state variation as seen in the analysis above because, at the very least, the reporting practices stay uniform within a given state. More importantly, the perinatal deaths cannot explain away the gap between the low burden and the high burden regions, their numbers being relatively small. It could also be argued that the low SBR cluster of the five southern states, could be on account of the significant share of the private sector healthcare in these states. All these private facilities rarely send reports under the HMIS. However, one must note that authors are considering only that data which has been received from the participating facilities. Hence, data from the non-reporting facilities does not enter in the estimation of stillbirth rates either in the denominator or the numerator.

The second issue relates to the large variation in the SBRs and emergence of the clusters of high and low SBRs at the district and the sub-district level. This highlights the need for a more granular data along with its regular, timely and nuanced analysis at the regional level so that, such information can be used for local and decentralized planning.

The third issue relates to the seasonality aspects. There are state-level variations in seasonality of stillbirths. Where

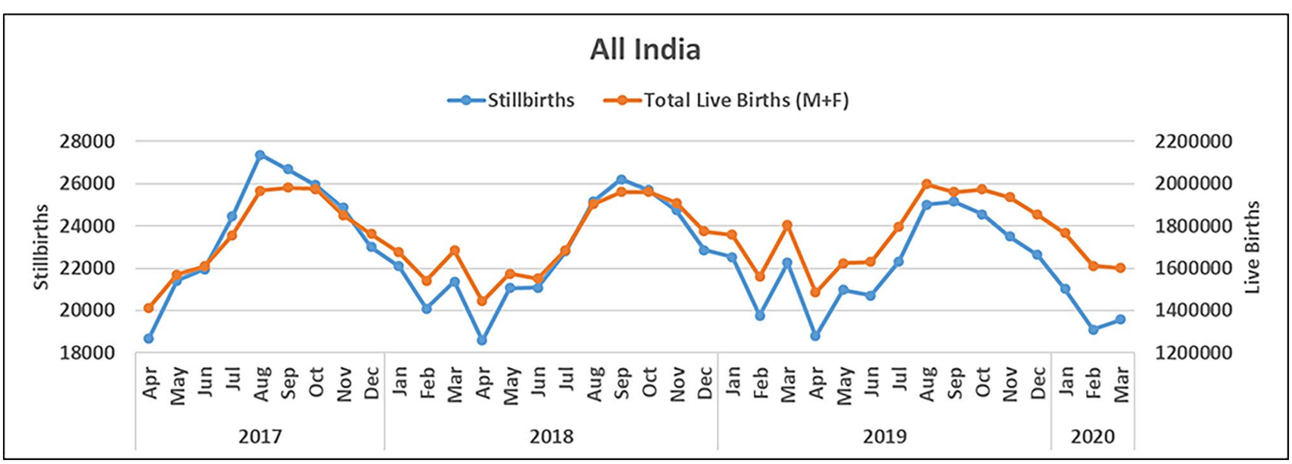

Fig. 4 Stillbirths and live births seasonality in India, HMIS 2017-20. *HMIS* Health Management Information System

the seasonality in the stillbirth is found to converge with the seasonal pattern of total birth, a consistent stillbirth is observed. However, where the stillbirths show peaks or dips, the matter needs a closer scrutiny in terms of the correlates of the high and low stillbirths and its implications on the service delivery and the logistics chain in the maternal-child healthcare.

Finally, the seasonal, and more importantly the regional variation in the stillbirths warrant a study of its correlates. It is important to identify and prioritize the factors that matter significantly among maternal factors, community factors, infrastructure factors or the governance factors. This will be a serious agenda if we wish to achieve a single-digit SBR for which Kerala already has set an example.

Such an analysis of the correlates has a bearing on the program. The Indian government had announced the aspirational districts program to focus upon various socio-economic indicators. In the union budget 2023-24, the aspirational block program with focus on 500 blocks across Indian states on social and development indicators have been proposed. A granular analysis at the sub-district level could be extremely useful for corrective and targeted interventions [18].

More important is how such analysis can be effectively used for programmatic interventions. The authors see a few opportunities. First, Indian government has already conducted a mid-term review of India Newborn Action Plan (2014-20) in 2022 and new approaches to accelerate progress towards stillbirth reductions are being proposed [19]. Also, the health and wellness centre under Ayushman Bharat Program in India intend to strengthen facility-level capacity in data entry and use for programmatic actions [20, 21]. India is also focusing upon maternal and perinatal deaths surveillance and response. The Indian Council of Medical Research in 2022 had made a call for research on various aspects of stillbirth in the country [22]. All of these opportunities should be used to strengthen data recording and reporting.

Conclusions

Stillbirth rates in India remain a serious issue. It is further confounded by the considerable regional variation across the country as well as variations within a state. There is persistence of high burden clusters which needs intervention. In this context, identification of low burden clusters can also provide the examples of good practices. The analysis and evidence call for a systematic identification of the hotspots and cold spots of the stillbirth rate, as well as identification of their correlates. This necessitates the need for more granular data availability, regular analysis of such data by experts and program managers and more decentralized and context-specific program intervention both in locational and seasonal terms [23]. There is a role of academic and research institutions which can support the government by conducting detailed and granular analysis. The government needs to make programmatic data available to academic institutions for such purpose.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12098-023-04711-9.

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Authors' contributions DBI and AP did the analysis; DBI and DRC wrote and edited the draft; CL shared critical inputs and edited the draft; SBA conceptualized and mentored the study as well as edited the draft. SBA will act as the guarantor for this manuscript.

Data Availability The HMIS data utilized in the study is publicly available and downloadable at https://hmis.mohfw.gov.in/#!/standardReports.

Declarations

Conflict of Interest None.

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