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Trends of infant mortality and its determinants in India from 2011 to 2015: Findings from National Family Health Survey

R.N. Kundu[1*], S. Bharati[2], and P. Bharati[3]

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[1]Ramendra Nath Kundu, Former Senior Research Fellow (UGC-NET), Department of Anthropology, West Bengal State University, West Bengal, India, (ramensky91@gmail.com)
[2]Susmita Bharati, Sociological Research Unit, Indian Statistical Institute, Kolkata, West Bengal, India, (susmitabharati60@gmail.com)
[3]Premananda Bharati, Biological Anthropology Unit, Indian Statistical Institute, Kolkata, West Bengal, India, (pbharati@gmail.com)

Corresponding author: [1*]Former Senior Research Fellow (UGC-NET), Department of Anthropology, West Bengal State University, West Bengal, India, (ramensky91@gmail.com)

ABSTRACT

Objective: The purpose of this study is to examine the regional distribution and trends in infant mortality, as well as the factors that influence it, using data from the National Family Health Survey.
Materials and Methods: The study used nationally representative data from NFHS-4, and included a total of 244486 live births for statistical analysis. Infant mortality rate (IMR) as the outcome variable, and birth-related, maternal, and socio-economic characteristics were used as explanatory factors. Binary logistic regression was used to identify significant predictors of mortality.
Results: Results indicate that IMR differed by State, with Chhattisgarh and Uttar Pradesh having the highest trend. The notable findings in this study show that IMR in India has increased overall from 2011 (38.97 per 1000) to 2015 (44.01 per 1000). Infant mortality was associated with maternal and child health care, as a lack of mother education (AOR 1.38, CI 1.16, 1.64), lack of postnatal checkup (AOR 1.58, CI 1.44, 1.72), and low birth weight (AOR 2.68, CI 2.47, 2.91). The poor families had a higher prevalence of IMR (AOR 1.42, CI 1.26, 1.60).
Conclusion: The study shows that multiple factors can influence infant mortality. These factors differ by region, hence planning must be done from the perspective of that region in order to deal with infant mortality effectively. Public health interventions must be implemented to improve the family's socioeconomic condition and expand mothers' access to health care. Furthermore, enhancing postnatal care and maternal health is pivotal in India, to reduce infant mortality.

Keywords: Infant mortality, Sustainable Development Goals, Socioeconomic factors, Scheduled Castes, India

INTRODUCTION

The infant mortality rate (IMR) is a key indicator of population health, human welfare and development, and it may also be used to evaluate the extent of socioeconomic disparities in a population (Bugelli et al., 2021; Jaramillo et al., 2019). In India, IMR has been progressively decreasing as a result of the implementation of several Child Health Programs (CHP) that has a favourable impact on the population's health, yet there are considerable regional inequalities. However, the declining trend in IMR has been noted to slow down at times, as evidenced by the changes from 1993 to 1998, which dropped from 74 to 72, and from 2003 to 2006, which dropped from 60 to 57 (Lahariya & Paul, 2010). The WHO estimates, that global infant mortality has decreased from 65 deaths in 1990 to 29 deaths in 2018 (WHO 2022), despite India having a higher rate of 32 deaths in 2018 (Chaurasia, 2020).

Birth-related, maternal and socioeconomic -covariates were reported to be responsible for infant mortality worldwide in studies from various countries. Birth abnormalities, low birth weight (LBW), and delayed caregiving have all been established as leading causes of newborn mortality in rural North India (Rai et al., 2017). A study in Ethiopia found that educated or highly educated mothers aged 25-29 had a lower risk of their child's death (Weldearegawi et al., 2015). Researchers found a relationship between racism and infant mortality in the United States (Bishop-Royse et al., 2021; Pabayo et al., 2019; Wallace et al., 2017). Infant mortality in Iran, Greece, Bangladesh, and Nepal, were influenced by socioeconomic inequalities (Damghanian et al., 2014; Huda et al., 2016; Khadka et al., 2015; Zilidis & Hadjichristodoulou, 2020). Preterm birth, childbirth-related complications, and infections comprise the majority of neonatal mortality, while pneumonia, diarrhoea, birth deformities, and malaria were the primary causes of death beyond the neonatal period, according to the WHO (WHO, 2022).

The Ministry of Health & Family Welfare of the Government of India has taken two recent initiatives, which are directly related to the health of children and mothers. The ‘Rashtriya Bal Swasthya Karyakram (RBSK)’ has undertaken special programs to improve the overall quality of life and health of children from birth to 18 years of age (Gupta et al., 2013). Initiatives have been taken to cover more than 12 million women under the ‘Janani Shishu Suraksha Karyakaram (JSSK)’, where government health facilities for delivery of pregnant women will be provided (MHFW, 2011). Future studies will look into how this child welfare programme has reduced infant mortality rates. For this matter, such a study must be continued, and the probable cause of infant mortality must be identified.

The current study examined the distribution and trend of infant mortality rates in different parts of India, from 2011 to 2015. The study also aimed to determine the effect of mother, child, and socioeconomic factors as a comprehensive perspective for determining infant mortality. Such study will help India in taking special measures to reduce infant mortality and progress toward the Sustainable Development Goals.

METHODS

Data source:

The unit-level data were taken from the National Family Health Survey, a systematic household survey in India that specially focused on child and mother health, mortality, and socioeconomic characteristics. The NFHS-4 data was chosen with the purpose of better understanding infant mortality between 2011 and 2015. In accordance with the principles of Demographic and Health Surveys (DHS), the NFHS used standardised questionnaires, sampling designs, and field methodologies. The survey methodologies were evaluated by the International Institute for Population Sciences (IIPS), a recognised nodal organization in the country. A total of 244486 births were included for statistical analysis, the following flow chart in figure 1 shows the data inclusion and exclusion criteria.

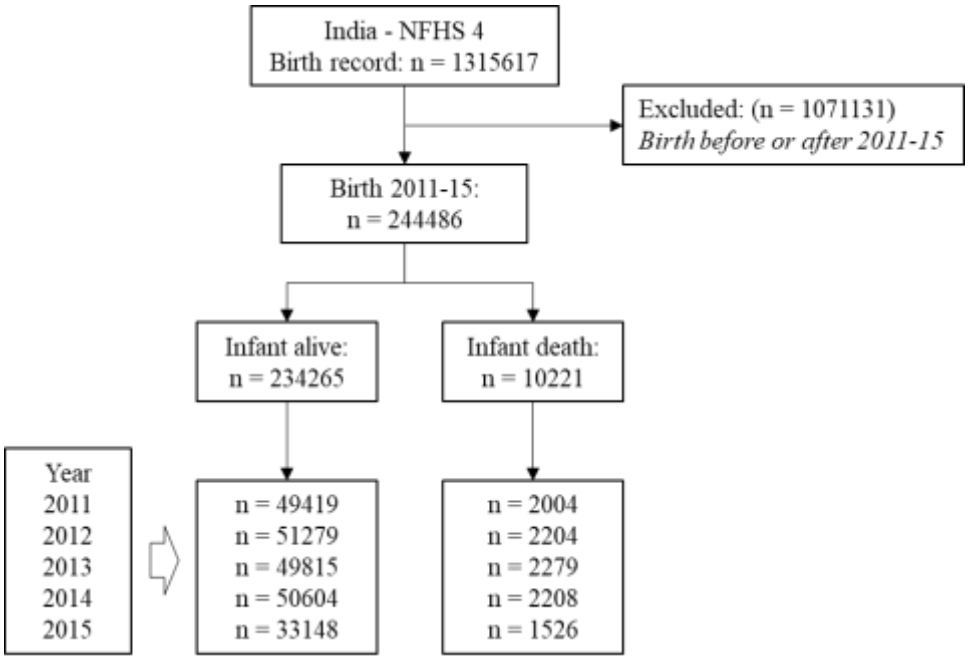

Figure 1: Flow chart of sample selection for the analysis of Infant Mortality in India from 2011 to 2015

Study variables:

Outcome variable: In this study, infant mortality was the outcome variable. It was defined as children who died before reaching the age of one year (364 days). The infant mortality rate (IMR) was calculated as the number of newborn deaths under the age of one per 1000 live births (Pol & Thomas, 2001; Thomas, 2018). The equation, IMR = $(D_0/B) \times 1000$, where D_0 was the number of infant deaths in a given year and B was the number of live births in that year (Lundquist et al., 2015). In the NFHS, it was asked whether the child was alive or dead at the time of the survey, and the age of death was noted for dead children. We computed the 5-year infant mortality rate for each state of India from 2011 to 2015. The data was analysed using a dichotomous division, with 1 indicating infant death and 0 indicating that the child was alive.

Explanatory variables: The study examined a variety of maternal, child, and socioeconomic characteristics as potential determinants of infant mortality. The explanatory variables were classified using the categories described by van Soest & Saha (2018), Sheikh et al. (2018, 2020), Sultana et al. (2019), Aguilera et al., (2020), and Tesema et al., (2021). The child factors includes, low birth weight, which was defined based on WHOs (2004) proposed cut-offs of <2500gm for low birth weight and ≥2500gm for non-low birth weight (UNICEF/WHO, 2004); birth order number (first, second, third, fourth & more), gender (girls, boys) and place of delivery (home, institution). The maternal factors includes, age of mother (15-17, 18-34, 35-49 years), education of mother (no education & primary, secondary, higher), antenatal care visits (less than four times, four times & above), and baby's postnatal check within 2 months (yes, no). The variables of socioeconomic factors includes, place of residence (rural, urban), social category (schedule tribe, schedule caste, OBC, general) and wealth index (poor, middle and rich).

Statistical analysis:

Descriptive analysis was used to calculate frequency and percentages for qualitative variables. The association between discrete/qualitative variables was assessed using the chi-square (χ^2) test. The hierarchical cluster analysis was based on a similarity matrix of infant mortality rate, calculated using the Complete-linkage coefficient method. The Euclidean distance has been used to measure the similarity between the States. The dendrogram shows the clustering results, which are divided into four groups based on the prevalence of IMR. To identify significant determinants of infant mortality, binary logistic regression (BLR) was applied. After a multicollinearity test, independent variables were chosen, and the variance inflation factor

(VIF) was considered as less than 5. The p-value of less than 0.05 was considered significant. Multiple Correspondence Analysis (MCA) was used to visualise the nature of the relationship between more than two categorical variables, such as maternal, child, and socioeconomic characteristics conditioning regional variation in infant mortality. The MCA was an unsupervised learning algorithm for displaying patterns in multi-dimensional categorical data. The MCA was represented by a two-dimensional graph. The total variance, or inertia, was calculated using the weighted sum of the squared chi-square distance. All statistical analysis was conducted using Microsoft Excel, R-software (version 4.2.0), and the Statistical Package for the Social Sciences (SPSS, version 25.0)

Ethical approval:

Secondary data from the Demographic and Health Surveys (DHS) was used in this study, which was obtained through online registration following their instructions. The survey procedures and participant confidentiality have been evaluated and approved by the ICF Institutional Review Board (IRB) and the International Institute for Population Sciences (IIPS) in India, a nodal agency of the host country. The ICF IRB follows the guidelines established by the US Department of Health and Human Services for the protection of human subjects and the confidentiality of participants. So, the DHS data was ethically approved and no further ethical permission was required.

RESULTS

The annual trend of infant mortality rate (IMR) in India from 2011 to 2015 was displayed through the maps in **Figure 2**. Among the States or Union territories IMR varies, and maximum IMR was found 73.53 per 1000 live birth in 2015 from Dadra and Nagar Haveli. The highest IMR in 2011 was found in Daman and Diu, Uttar Pradesh, and Chhattisgarh, while Andaman and Nicobar Islands, Dadra and Nagar Haveli and Kerala had the lowest respectively. In 2012, the highest IMR was found in Mizoram, Chhattisgarh, and Uttar Pradesh, while Andaman and Nicobar Islands, Lakshadweep, and Kerala had the lowest respectively. In 2013, Uttar Pradesh, Chhattisgarh, and Madhya Pradesh had the highest IMR, while Goa, Kerala, and Andaman and Nicobar Islands had the lowest respectively. In 2014, Lakshadweep, Uttar Pradesh, and Mizoram had the highest IMR, while Daman and Diu, Goa, and Kerala had the lowest respectively. In 2015, Dadra and Nagar Haveli, Uttar Pradesh, and Chhattisgarh had the highest IMR, while Andaman and Nicobar Islands, Goa, and Kerala had the lowest respectively.

Overall IMR from 2011 to 2015, highest being Uttar Pradesh (62.41), Chhattisgarh (55.50), and Madhya Pradesh (49.98), and lowest being Andaman and Nicobar Islands (5.23), Kerala (8.03), Goa (14.16).

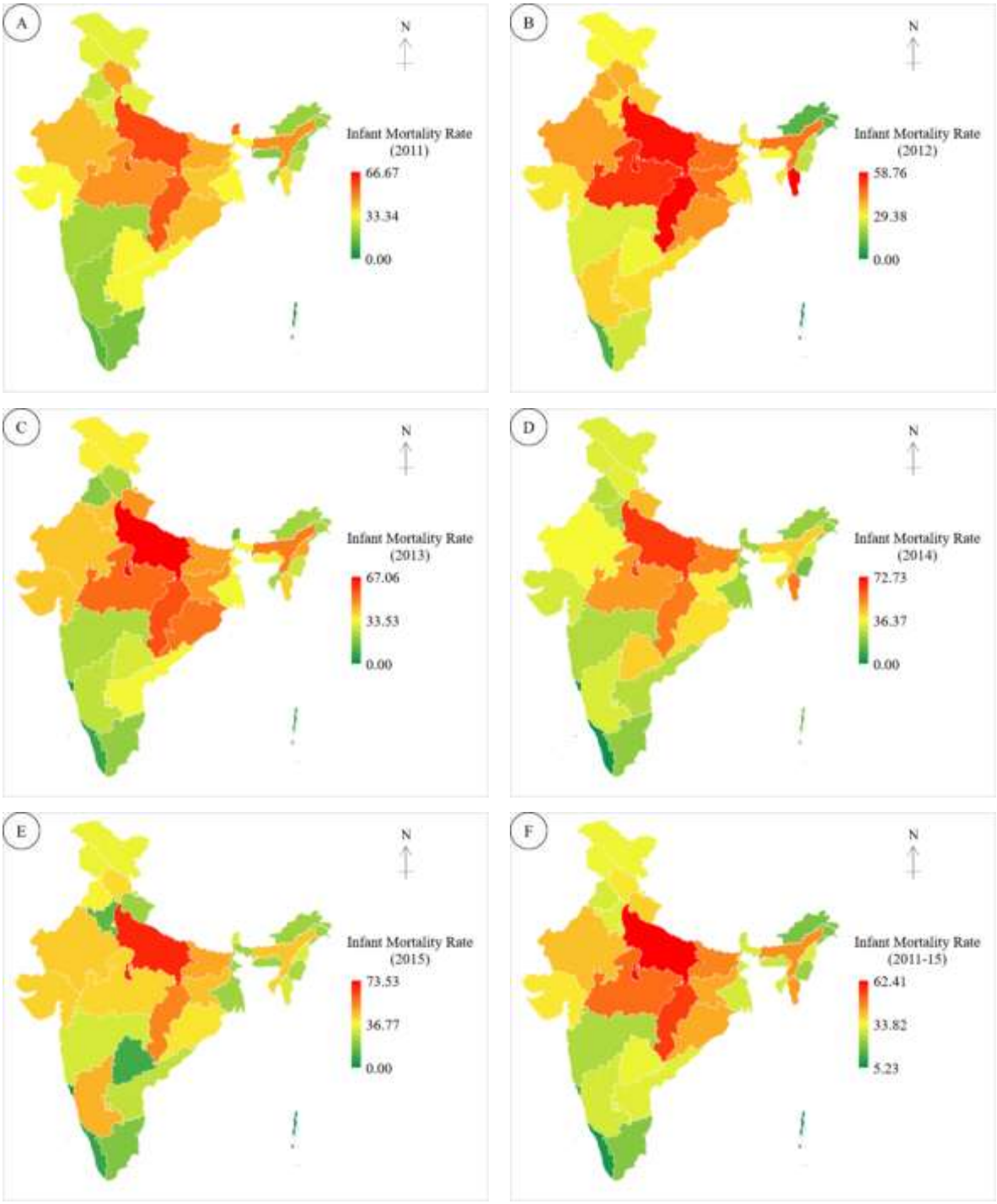

Figure 2: Prevalence of IMR across 36 states/ union territories of India from 2011 to 2015, (A) IMR 2011, (B) IMR 2012, (C) IMR 2013, (D) IMR 2014, (E) IMR 2015, (F) IMR 2011-15

The Euclidean distance matrix of the infant mortality rate from 2011 to 2015 was used to calculate the Complete-linkage for hierarchical clustering (**Figure 3**). The four-cluster solution was elected as the optimum based on the distance of IMR between different States in the dendrogram. Cluster-I was related to the maximum IMR, which was classified as Vulnerable-states. Cluster II was classified as Poor-states, whereas Cluster IV was classified as Fair-states with a higher IMR and fluctuation in nature. Cluster III was considered as a Relatively Good-states with a low IMR.

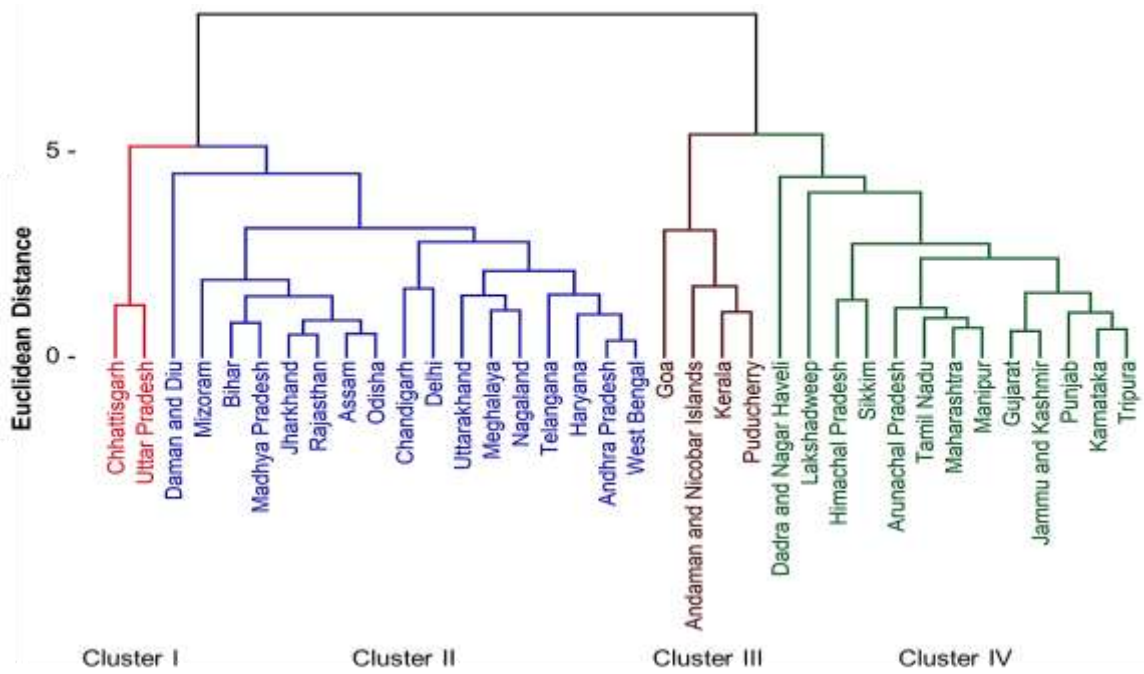

Figure 3: Hierarchical clustering using complete-linkage of Indian states based on IMR from 2011 to 15

Chhattisgarh, Madhya Pradesh and Uttar Pradesh, these three states were located in the central region of India, due to which the mortality rate in Central India was the highest in terms of regional distribution (**Figure 4**). South India was relatively well, but its rate gradually rose by 3.94 from 2011 to 2015. The highest increase in IMR from 2011 to 2015 was found in West (11.99) and Central (8.25) part of India, whereas the lowest increase was found in East (2.18) and Northeast (2.68). In 2015, IMR was better in northeast (-0.16) and critical in west (9.39), compared to the average IMR from 2011 to 2015. In India as a whole, the infant mortality rate increased by 5.04 from 2011 to 2015, and this increase was gradual. By region, from 2011-15, the highest IMR was in Central India (57.74), followed by East (43.57), North (35.61), Northeast (33.99), West (30.05), and South (23.69).

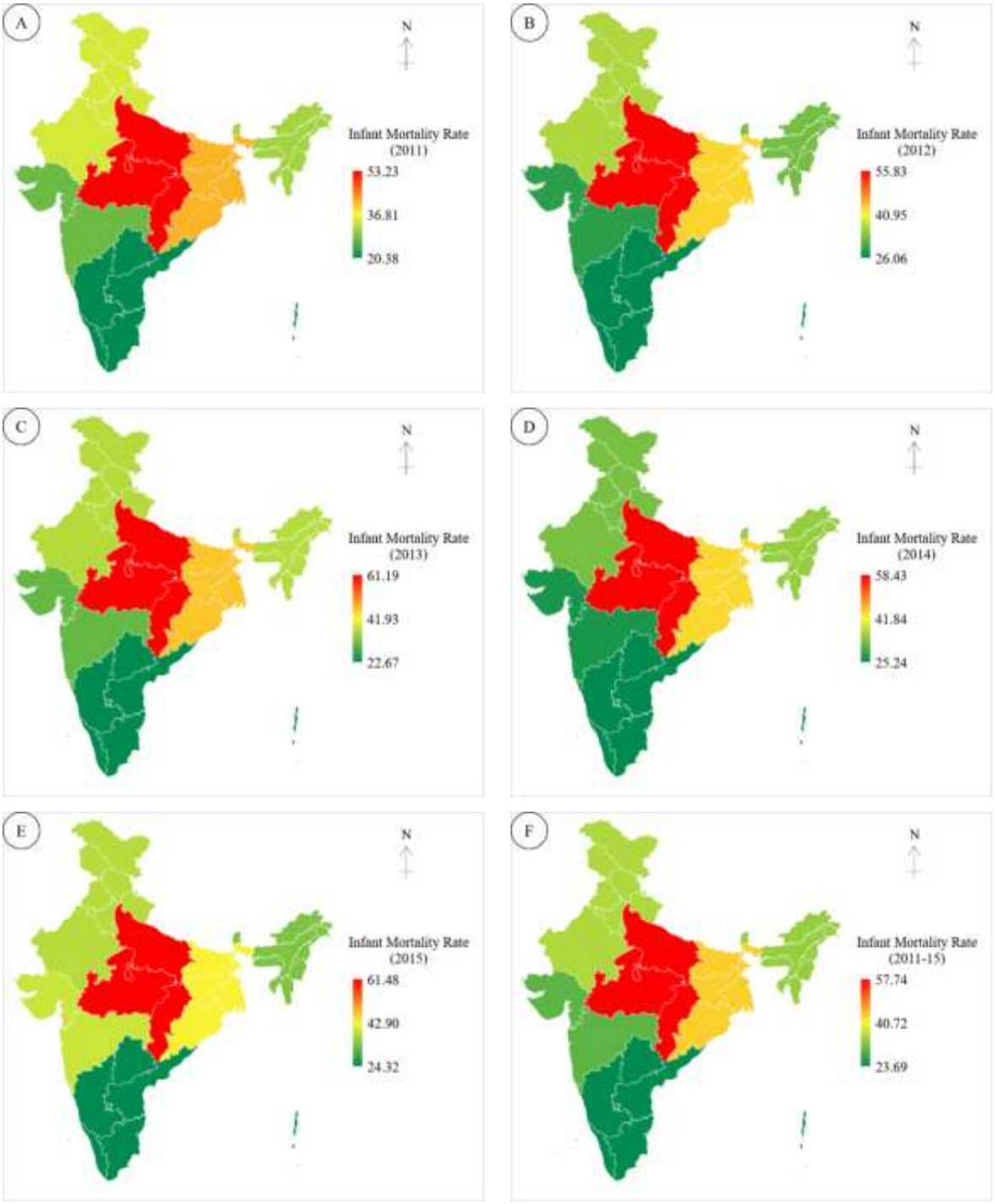

Figure 4: Prevalence of IMR across 6 regional parts of India from 2011 to 2015, (A) IMR 2011, (B) IMR 2012, (C) IMR 2013, (D) IMR 2014, (E) IMR 2015, (F) IMR 2011-15

Distribution of infant mortality by explanatory factors:

Table 1 shows that the frequency of infant mortality differs significantly (χ^2, $p < 0.05$) from each explanatory factor, except for the birth order, place of delivery, place of residence, social category in west India, gender in north India, and social category in northeast India. Here,

infant mortality denoted by only 'mortality'. Prevalence of mortality was found in low birth weight (under 2500 gram), with about a maximum of one-third (684/1868) being found in Central India. In comparison to the first and second birth, infant mortality was higher in the third, fourth, and even higher birth orders. Boys had a greater mortality rate than girls. An infant born at home had a higher prevalence of mortality than those born in institutions. Mortality was considerably different depending on the mother's age, with mortality being more frequent in mothers under 25 and over 34 years old. In comparison, mortality was higher among less-educated mothers. The prevalence of mortality was higher in the absence of antenatal and postnatal care throughout the country. Rural areas were found to have higher mortality than urban areas, with the maximum percentage finding in central India. Mortality was higher among the schedule caste throughout India, with the exception of the south, where Schedule tribes were more vulnerable. Infants from families with a lower household wealth index have a higher death rate across the country.

Table 1: Association among explanatory factors and Infant mortality in India by 2011-15

Explanatory factors	India	Regional parts of India					
		North	Central	East	Northeast	West	South
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Low Birth Weight (<2500gm)							
Yes	1868 (6.02)	374 (5.41)	684 (7.52)	350 (6.14)	151 (6.02)	154 (5.02)	155 (4.14)
No	3226 (2.23)	529 (1.87)	1146 (3.26)	668 (2.27)	440 (2.13)	190 (1.52)	253 (1.37)
χ^2 - value	1302.91***	277.38***	331.20***	255.68***	136.26***	140.51***	132.87***
Birth order							
First & Second	6434 (3.89)	1097 (3.27)	2390 (5.48)	1412 (4.35)	702 (3.06)	393 (2.97)	440 (2.24)
Third	1574 (4.00)	262 (3.53)	609 (5.12)	341 (3.84)	216 (3.65)	73 (2.84)	73 (2.76)
Forth & more	2213 (5.57)	319 (5.15)	1027 (7.21)	458 (4.88)	315 (4.25)	57 (3.59)	37 (4.14)
χ^2 - value	230.65***	53.65***	70.45***	11.78**	25.51***	2.16	15.38***
Gender							
Girls	4566 (3.89)	769 (3.47)	1840 (5.54)	969 (3.96)	542 (3.06)	209 (2.51)	237 (2.09)
Boys	5655 (4.44)	909 (3.64)	2186 (5.99)	1242 (4.73)	691 (3.72)	314 (3.46)	313 (2.63)
χ^2 - value	46.19***	1.07	6.50*	18.32***	11.85**	13.66***	7.28**
Place of delivery							
Home	2956 (5.19)	352 (4.40)	1257 (6.71)	741 (5.23)	511 (3.89)	63 (3.18)	32 (3.55)
Institution	6684 (3.77)	1221 (3.32)	2599 (5.37)	1327 (3.88)	641 (3.02)	411 (2.76)	485 (2.20)
χ^2 - value	222.78***	22.59***	44.74***	44.62***	19.13***	1.10	7.11**
Mother's age (years)							
15-24	3713 (4.70)	552 (3.97)	1465 (6.49)	886 (4.95)	347 (3.63)	240 (3.75)	223 (2.58)
25-34	5261 (3.75)	951 (3.30)	2084 (5.17)	1082 (3.89)	628 (3.11)	236 (2.41)	280 (2.11)
35-49	1247 (4.91)	175 (3.98)	477 (6.93)	243 (4.83)	258 (3.95)	47 (3.89)	47 (3.56)
χ^2 - value	150.92***	14.64**	64.75***	31.99***	12.74**	27.14***	13.64**
Mother's education							
No education & Primary	5770 (5.15)	906 (4.39)	2459 (6.46)	1442 (4.94)	568 (4.07)	195 (3.58)	200 (4.13)
Secondary	3946 (3.59)	660 (3.20)	1347 (5.25)	715 (3.75)	623 (3.11)	293 (2.85)	308 (2.17)
Higher	505 (2.25)	112 (1.92)	220 (3.69)	54 (2.15)	42 (1.81)	35 (2.08)	42 (1.00)

χ^2 - value	566.55***	94.65***	93.37***	70.44***	42.15***	12.00**	101.40***
Antenatal care (ANC) visits							
Less than four times	3146 (3.45)	438 (2.79)	1368 (4.33)	751 (3.31)	391 (2.80)	106 (2.83)	92 (2.55)
Four times & above	1679 (2.05)	326 (1.89)	482 (3.02)	268 (2.07)	216 (1.75)	150 (1.66)	237 (1.65)
χ^2 - value	311.58***	29.63***	48.89***	45.29***	32.18***	18.66***	13.02***
Baby's Postnatal check							
Yes	1087 (1.77)	181 (1.57)	459 (2.72)	203 (1.56)	112 (1.59)	57 (1.20)	75 (0.93)
No	3676 (3.25)	582 (2.68)	1386 (4.48)	798 (3.51)	486 (2.48)	190 (2.34)	234 (2.31)
χ^2 - value	324.95***	41.32***	92.03***	115.12***	18.59***	20.85***	51.10***
Place of residence							
Rural	8315 (4.46)	1298 (3.72)	3231 (6.04)	1984 (4.58)	1047 (3.64)	359 (3.12)	396 (2.73)
Urban	1906 (3.29)	380 (3.12)	795 (4.91)	227 (3.05)	186 (2.47)	164 (2.78)	154 (1.76)
χ^2 - value	151.58***	9.41**	29.24***	35.78***	24.95***	1.53	22.06***
Social category							
Schedule tribe	2030 (4.05)	186 (3.71)	576 (5.86)	405 (4.94)	686 (3.16)	116 (3.21)	61 (3.40)
Schedule caste	2209 (4.81)	442 (4.05)	918 (6.34)	533 (4.98)	76 (3.60)	87 (3.63)	153 (2.90)
OBC	4075 (4.30)	555 (3.85)	1947 (5.64)	1001 (4.28)	134 (3.52)	168 (2.84)	270 (2.11)
General	1492 (3.51)	359 (2.76)	547 (5.37)	220 (3.16)	188 (3.77)	131 (2.69)	47 (1.95)
χ^2 - value	97.39***	35.91***	12.89**	40.22***	5.81	5.9	20.12***
Wealth index							
Poor	6266 (5.12)	657 (4.61)	2580 (6.47)	1809 (4.81)	785 (4.02)	235 (3.89)	200 (3.92)
Middle	1897 (3.90)	401 (3.98)	678 (5.75)	241 (3.39)	263 (2.99)	126 (3.01)	188 (2.79)
Rich	2058 (2.80)	620 (2.72)	768 (4.25)	161 (2.65)	185 (2.32)	162 (2.25)	162 (1.42)
χ^2 - value	630.00***	97.53***	113.48***	76.95***	55.90***	30.32***	102.23***

Significant, ***p<0.001, **p<0.01, *p<0.05

Effects of explanatory factors on infant mortality:

The effect of explanatory factors on infant mortality in India from 2011 to 2015 was shown in **Table 2** using binary logistic regression. Infants who had been alive for at least 12 months were used as the reference category (coded as 0) for the counterpart of infant death (coded as 1) in the logistic regression. Omnibus chi-Square for India (χ^2 981.78), North (χ^2 185.65), Central (χ^2 287.97), East (χ^2 179.82), Northeast (χ^2 119.26), West (χ^2 114.23), and South (χ^2 164.01), all had a significant level at $p<0.001$. Hosmer and Lemeshow chi-square for India (χ^2 10.78), North (χ^2 9.21), Central (χ^2 6.67), East (χ^2 14.30), Northeast (χ^2 4.03), West (χ^2 8.58), and South (χ^2 4.94), all showed a significant level at $p \geq 0.05$. Both of these facts show that the models for India and each regional division fit the data well. The following facts were revealed from the logistic regression model.

In India, as a whole, Infant mortality was 2.68 times higher among low birth weight babies than normal weighted babies. Mortality was 1.53 times more likely in the fourth or more birth order compared to the first and second child. Age of mothers below 25 and above 34 years were 1.29 times more have a higher infant mortality rate than 25-34 years during the first year of

life. Maternal education had a detrimental impact on infant mortality, with infants born to mothers who were non-educated or less-educated dying at a younger age than higher educated mothers. Infant mortality was 1.10 times more among mothers who had received antenatal care less than four times, and 1.58 times more likely among babies who had not gotten any postnatal check-up within two months after birth. Infant mortality was higher in children among poor and middle wealth index households compare to those belonging in rich wealth index families. From zone-wise distribution, it was found in north and northeast zone, IMR was directly related with birth order i.e. it was 1.31 times higher for the third child and 1.50 times higher for the fourth and above compare to 1^{st} and 2^{nd} child in the north. Infants who did not receive a postnatal check-up after birth were 1.41 times more likely to die before reaching the age of one year. Schedule caste children were 1.37 times more infant mortality compared to general caste children. Infant mortality was more prevalent among children of poor wealth index households. In central India, infant mortality was 2.42 times more among low birth weights babies and 1.73 times more in four above birth ordered children. Infant mortality was 1.43 times more among mothers under the age of 25. A child who did not receive any postnatal check-up after birth was 1.35 times more likely to die before turning one year old. The wealth index was adversely associated with infant mortality both poor and middle household wealth index. In the eastern zone, infant mortality was 2.48 times more among low birth weight babies than normal babies and 1.56 times higher among infants who were born in private health centers and the mother's age was above 34 years. When an infant was born in less educated mothers were dying more than highly educated mothers. An infant who has not received any postnatal check-up was 1.98 times more likely to die. In northeast zone**,** Infant mortality was 2.95 times more among low birth weight babies and 1.43 times more among third children or above. An infant born among illiterate or less educated mothers were more likely to die than highly educated mothers. Infant mortality was 1.35 times more in mothers who have received antenatal care less than four times and 1.45 times more prevalent among babies who had not gotten any postnatal check-up after birth. In west zone**,** Infant mortality was 3.29 times more among low birth weight babies and 1.76 times more among fourth and above birth orders. Mothers below 25 and above 34 years, had infant mortality rate 1.83 times and 1.73 times more than 25-34 years. An infant without a postnatal check-up after birth was 1.61 times more prone to die and wealth index was directly related to infant mortality. In southern zone, Infant mortality was 3.14 times more among low birth weight babies, and less-educated mothers and it was directly related to postnatal check-up and wealth index of the family.

Table 2: Binary logistic regression model that indicates the role of explanatory factors on Infant Mortality from the year 2011-15 in India

Explanatory factors	India	Regional parts of India					
		North	Central	East	Northeast	West	South
	AOR (95% C.I.)	AOR (95% C.I.)	AOR (95% C.I.)	AOR (95% C.I.)	AOR (95% C.I.)	AOR (95% C.I.)	AOR (95% C.I.)
Low Birth Weight (Ref. No)							
Yes	2.68 (2.47, 2.91)***	2.74 (2.25, 3.33)***	2.42 (2.11, 2.77)***	2.48 (2.05, 3.01)***	2.95 (2.23, 3.91)***	3.29 (2.44, 4.44)***	3.14 (2.41, 4.10)***
Birth order (Ref. First & second)							
Third	1.11 (0.99, 1.24)	1.31 (1.00, 1.71)*	0.97 (0.78, 1.19)	0.93 (0.72, 1.21)	1.43 (1.04, 1.97)*	1.14 (0.73, 1.78)	1.01 (0.69, 1.49)
Fourth and more	1.53 (1.35, 1.73)***	1.50 (1.09, 2.05)*	1.73 (1.42, 2.12)***	1.03 (0.78, 1.36)	1.39 (0.98, 1.97)	1.76 (1.06, 2.93)*	1.44 (0.84, 2.47)
Gender (Ref. Boys)							
Girls	0.95 (0.87, 1.02)	0.94 (0.78, 1.14)	1.05 (0.92, 1.19)	0.93 (0.78, 1.10)	0.80 (0.64, 1.01)	1.01 (0.76, 1.36)	0.85 (0.65, 1.10)
Place of delivery (Ref. Institution)							
Home	1.01 (0.88, 1.17)	1.07 (0.74, 1.54)	1.10 (0.88, 1.39)	0.97 (0.73, 1.29)	1.09 (0.78, 1.53)	0.57 (0.28, 1.14)	0.87 (0.42, 1.81)
Mother's age (Ref. 25-34)							
15-24	1.29 (1.17, 1.41)***	1.23 (0.98, 1.53)	1.43 (1.22, 1.68)***	1.15 (0.93, 1.42)	0.91 (0.67, 1.23)	1.83 (1.31, 2.56)***	1.22 (0.92, 1.61)
35-49	1.29 (1.13, 1.48)***	1.20 (0.85, 1.70)	1.25 (0.99, 1.57)	1.56 (1.16, 2.08)**	1.23 (0.90, 1.68)	1.73 (1.02, 2.92)*	0.97 (0.55, 1.71)
Mother's education (Ref. Higher)							
No Edu. & Primary	1.38 (1.16, 1.64)***	1.10 (0.75, 1.60)	1.07 (0.81, 1.39)	2.14 (1.25, 3.67)**	2.56 (1.34, 4.89)**	0.80 (0.43, 1.47)	2.76 (1.60, 4.76)***
Secondary	1.18 (1.01, 1.39)*	1.17 (0.83, 1.63)	0.97 (0.76, 1.25)	1.61 (0.96, 2.70)	2.16 (1.18, 3.95)*	0.78 (0.46, 1.32)	1.77 (1.09, 2.89)*
ANC visits (Ref. Four times & above)							
Less than four times	1.10 (1.01, 1.20)*	0.96 (0.79, 1.17)	0.99 (0.86, 1.14)	1.02 (0.84, 1.24)	1.35 (1.06, 1.72)*	1.33 (0.97, 1.82)	0.77 (0.56, 1.07)
Baby's Postnatal check (Ref. Yes)							
No	1.58 (1.44, 1.72)***	1.41 (1.15, 1.74)**	1.35 (1.17, 1.56)***	1.98 (1.61, 2.43)***	1.45 (1.10, 1.90)**	1.61 (1.15, 2.24)**	2.31 (1.72, 3.10)***
Place of residence (Ref. Urban)							
Rural	1.01 (0.91, 1.12)	1.23 (0.97, 1.57)	0.94 (0.78, 1.12)	1.23 (0.92, 1.64)	0.94 (0.70, 1.27)	0.81 (0.57, 1.14)	1.02 (0.75, 1.37)
Social category (Ref. General)							
Schedule tribe	0.98 (0.86, 1.12)	0.81 (0.54, 1.21)	0.80 (0.62, 1.04)	1.05 (0.75, 1.47)	1.27 (0.92, 1.76)	0.69 (0.42, 1.14)	1.18 (0.65, 2.14)
Schedule caste	1.13 (1.00, 1.29)	1.37 (1.05, 1.79)*	1.02 (0.81, 1.27)	1.02 (0.75, 1.40)	0.92 (0.55, 1.55)	1.39 (0.91, 2.13)	1.12 (0.68, 1.84)
OBC	1.02 (0.91, 1.14)	1.26 (0.97, 1.63)	0.84 (0.69, 1.02)	1.09 (0.83, 1.44)	0.90 (0.58, 1.39)	0.96 (0.66, 1.39)	1.06 (0.67, 1.67)
Wealth index (Ref. Rich)							
Poor	1.42 (1.26, 1.60)***	1.66 (1.26, 2.19)***	1.45 (1.17, 1.80)**	1.22 (0.85, 1.75)	1.16 (0.82, 1.64)	1.75 (1.12, 2.73)*	1.69 (1.16, 2.48)**
Middle	1.29 (1.14, 1.45)***	1.40 (1.08, 1.82)*	1.45 (1.16, 1.81)**	1.14 (0.78, 1.67)	0.92 (0.65, 1.29)	1.62 (1.08, 2.44)*	1.33 (0.94, 1.88)

AOR = Adjusted odds ratio, CI = Confidence interval; Significant *** p<0.001, **p<0.01, *p<0.05

DISCUSSION

This study examines changes of infant mortality rate in India from 2011 to 2015, taking into account the diversity of states in terms of child-related, maternal-related, and socio-demographic characteristics. Regional distributions of the states show that the IMR has fluctuated over time, while there has been an increasing trend in the country as a whole, from 38.97 in 2011 to 44.01 in 2015 (**Figure 5**). Between 2011 and 2015, the western region had the highest growth rate of 11.99 while the eastern region had the lowest growth rate of 2.18 in India. The five-year average mortality rate in India was highest in the central region (36.30) and lowest in the southern region (19.78).

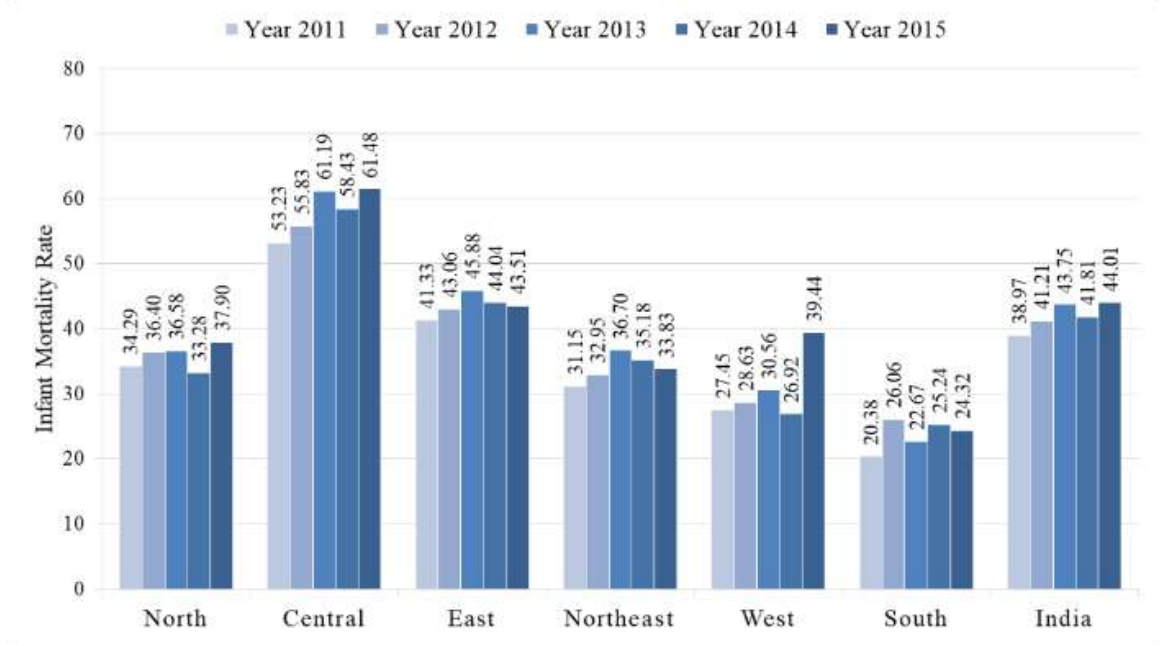

Figure 5: Trend of Infant mortality rate from 2011 to 2015 across the regional parts of India

Following multiple correspondence analysis (MCA) shows the regional distribution of the various causes of infant mortality, with the main focus being on the visualisation of the factors' associations by region (**Figure 6**). Based on the results in Table 2, independent variables were chosen for this MCA, considering only those predictors that had a common factor of at least 3 regions out of 6. The variance obtained by MCA, which determined cumulatively 71.77% of total inertia, with 51.65% (eigenvalue: 0.004) for dimension 1 and 20.12% (eigenvalue: 0.001) for dimension 2. Low maternal education, fourth or more birth order, and poor wealth index were the variables with the strongest discriminating effect in the first dimension, while the second dimension was characterised by the low birth weight. The MCA clearly shows that the eastern and western parts of India belong to a common quadrant and were associated with

secondary maternal education, lower maternal age, and birth order up to two children. Northern and southern regions were found to be closely aligned and associated with higher maternal age, four-and-more birth order, and poor wealth index. Lack of postnatal checkups, lower maternal education, and low birth weight have all been associated with the northeastern region.

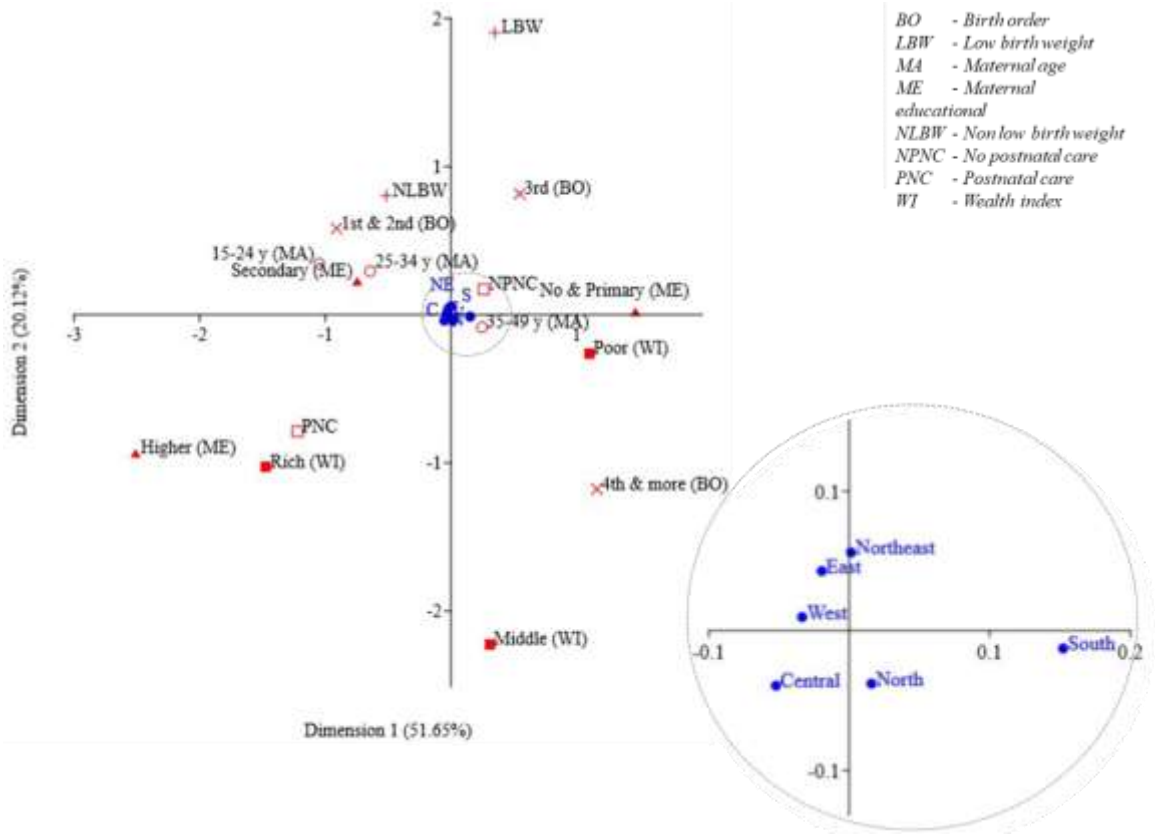

Figure 6: MCA plot in 2 dimensions, association of regional variation with maternal, child, and socio-demographic characteristics

The following factors affecting infant mortality in India:

***Child and birth-related factors*:** Low birth weight has been identified as one of the leading causes of infant mortality in studies conducted in the United States (Gage et al., 2013), China(Lin et al., 2015), Gabon (Zoleko-Manego et al., 2021), Brazil (Vilanova et al., 2019) and sub-Saharan Africa (Ngandu et al., 2020). This study found a similar pattern in every region of the country, a newborn born weighing less than 2.5 kilograms had a higher chance of dying before reaching the age of one year. In the western and central regions, the prevalence of mortality was higher among the fourth and subsequent infants.

***Maternal-related factors*:** In central, eastern, and western India, maternal age has been found as a common factor, with lower and higher maternal age at delivery being responsible for infant

mortality. Similar findings were obtained in a study of 67 low- and middle-income nations; with studies indicating that older mothers have a higher risk of infant mortality (Wu et al., 2021). Maternal education has been found to be a common predictor in eastern, northeastern, and southern regions of India, with less-educated mothers having a higher risk of infant death than more educated mothers. Low maternal education and infant mortality have been linked in other research conducted in California (Ratnasiri et al., 2020), Ethiopia (Kiross et al., 2019), and Brazil (Bugelli et al., 2021). Infant mortality rates were higher in the Northeast among mothers who visited for antenatal care for less than four times. In every region of India, postnatal care was the most critical concern, and mothers who did not get postnatal care within two months of giving birth had a higher risk of losing their infants. A study in Ethiopia suggests that improvements in maternal health care services appear to have reduced infant mortality among them (Kiross et al., 2021).

***Socioeconomic factors*:** In the northern region, social groups had an impact on infant mortality; infant mortality was more common in the scheduled castes community, and they account for 23.6% of the northern population. Infant mortality was more prevalent in impoverished families from the northern, central, western and southern regions than in wealthy families. Similar trends have been reported in underdeveloped and developing countries like Iran (Madadi et al., 2021), Angola (Shibre, 2020), China (Wang & Wu, 2020), Nigeria (Adewuyi et al., 2017), and sub-Saharan Africa (Ngandu et al., 2020).

CONCLUSION

In conclusion, the study revealed that there was no substantial change in the infant mortality rate in India between 2011 and 2015. During this period, the infant mortality rate varied by states, with Chhattisgarh and Uttar Pradesh in central India representing the highest prevalence. Multiple factors have been recognized as the primary determinants of infant mortality. Low birth weight and lack of postnatal checkups as the leading causes of IMR in all states, whereas in some states IMR coexists with maternal age, maternal education and poor household wealth index.

To prevent infant mortality, the government should improve healthcare facilities and maternal education as soon as possible. The disparity in access to medical facilities, education, and wealth must be minimised to the greatest extent possible. Mothers must raise awareness about the importance of postnatal checkups across the country. The government should priorities

increases in the household wealth index. In addition, the country's Scheduled Castes should be given priority in northern region of India.

Further research is required in the future, and subsequent studies must focus on the changes that occurred between 2016 and 2020. The present research will benefit the country in achieving six Sustainable Development Goals of the United Nations: No Poverty, Zero Hunger, Good Health and Well-Being, Quality Education, and Reduced Inequality (UN, 2015).

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