A Bayesian Geo-Additive Modeling of Childhood Anemia in India

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Research article

Keywords: Spatial effects, Geo-additive logistic regression, P-splines, Childhood anaemia

DOI: https://doi.org/10.21203/rs.3.rs-551263/v1

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Title: “A Bayesian Geo-Additive Modeling of Childhood Anemia in India”

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Abstract

Background: The geographical differences that caused anaemia can be partially explained by the variability in environmental factors, particularly nutrition and infections. The studies failed to explain the non-linear effect of the continuous covariates on childhood anaemia. The present paper aimed to investigate the risk factors of childhood anaemia in India with focus on geographical spatial effect.

Methods: Geo-additive logistic regression models were fitted to the data to understand fixed as well as spatial effects of childhood anaemia. Logistic regression was fitted for the categorical variable with outcomes (anaemia (Hb<11) and no anaemia (Hb≥11)). Continuous covariates were modelled by the penalized spline and spatial effects were smoothed by the two-dimensional spline.

Results: At 95% posterior credible interval, the influence of unobserved factors on childhood anaemia is very strong in the Northern and Central part of India. However, most of the states in North Eastern part of India showed negative spatial effects. A U-shape non-linear relationship was observed between childhood anaemia and mother’s age. This indicates that mothers of young and old ages are more likely to have children who are anaemic; in particular mothers aged 15 years to about 25 years. Then the risk of childhood anaemia starts declining after the age of 25 years and it continues till the age of around 37 years, thereafter again starts increasing. Further, the non-linear effects of duration of breastfeeding on childhood anaemia show that the risk of childhood anaemia decreases till 29 months thereafter increases.
Conclusion: Strong evidence of residual spatial effect to childhood anaemia in India. Government child health programme should gear up in treating childhood anaemia by focusing on known measurable factors such as mother’s education, mother’s anaemia status, family wealth status, child fever, stunting, underweight, and wasting which have been found to be significant in this study, attention should also be given to effects of unknown or unmeasured factors to childhood anaemia at the community level. Special attention to these unmeasurable factors should be focused in the states of central and northern India which have shown significant positive spatial effects.

Keywords: Spatial effects, Geo-additive logistic regression, P-splines, Childhood anaemia.

Background

Anemia among children is still a major public health concern in both developed and developing countries. Anemia is a condition in which the number and size of red blood cells or haemoglobin concentration is lower than the established cut-off value (1). Haemoglobin is essential to carry oxygen and if the body has abnormal or low red blood cells or not enough haemoglobin level, there will be a reduced capacity of the blood to carry oxygen to the body tissues. Globally, anemia affects 1.6 billion people, of which 47.4% were preschool-age children (2). According to the World Health Organization (WHO), anemia is considered a severe public health problem if the prevalence is 40 percent or more (2). In India, 58.5% percent of children between the age of 6 months to 5 years were anemic during 2015-2016 (3). Moreover, studies have acknowledged the high prevalence of anaemia in low and middle-income countries (4), with 67.6% and 65.6% preschool-age children in Africa and South-East Asia suffered from anaemia (2).
Iron is an essential element of haemoglobin, and iron deficiency is the most common cause of anaemia. However, deficiency in micronutrient-rich diet, Vitamin A, and Vitamin B12 could be the reason for iron deficiency (5). Also, disease like diarrhea (6), malaria (7), helminth infection, and hookworms (5) increased the risk of anemia. In India, due to various socio-economic, cultural, and religious beliefs, dietary food habits also vary amongst the population. Dietary pattern is an essential factor associated with iron intake and absorption. For example, a vegetarian diet may increase the risk of anemia due to the lack of iron fortification (8). Existing literature have also shown that socio-economic factors such as lower maternal education, low economic status (9), and demographic factors such as age and sex of a child (10) affect anaemia. Maternal health status during pregnancy had a significant impact on the health and nutritional status of the child. Evidence from previous studies reported that maternal anaemia, and child nutritional statuses such as wasting, stunting and underweight increased the risk of anaemia (11,12). During the first 5 years of life, children are most vulnerable to iron-deficiency anaemia because of the increased iron requirements due to their rapid growth (13). Iron deficiency anaemia in children is a serious concern because it may increase childhood morbidity, impaired growth development, and have long term effects on cognitive development and school performance (13).

Accounting for geographical heterogeneity of anaemia and the possible cause of heterogeneity is vital for the allocation of health resources to prevent and control anaemia. According to Koissi & Högnäs, (2013) ignorance of geographical heterogeneity due to unobserved characteristics could lead to biased estimation of the parameters (14). Geographical heterogeneity could be the effect of the unmeasured factors, which means that the geographical differences of factors that caused anaemia can be partially explained by the variability in environmental (15). Malaria which caused anaemia are known to be associated with altitude and weather conditions such as temperature and rainfall (16). Similarly, soil-
transmitted helminth infection, which caused anaemia is influence by the distance to water bodies, surface temperature, index of vegetation and rainfall (17). There are a number of studies using different statistical models such as multilevel and spatial mixed model to determine the effect of geographical heterogeneity on childhood anaemia in India (9,10); however, all these studies have overlooked the advantage of using the bivariate spline in modelling geographical heterogeneity. Specifically, the above model failed to explain the non-linear effect of the continuous covariates on childhood anaemia.

Thus, the pioneering contribution of this study would be to explore the spatial variation of anaemia among children aged 6 to 59 months using the spatial mixed model by assuming the flexible approach of bivariate splines. More, specifically we want to explore the spatial effects on childhood anaemia which arise due to the unmeasured factors. Identifying the spatial clustering of anaemia and its associated risk factors may help improving the allocation of health resources.

**Methods**

*Study area and data*

The study used the fourth round of the Indian National Family and Health Survey (2015-2016) which adopted a multi-stage stratified cluster sampling design (18). A total of 699686 eligible women between 15-49 years of age completed the interview. The whole data for the present study use child as the unit of analysis, rather than the mother itself. Information was available on 259627 children born in the last five years preceding the survey. The present study excluded the two union territories, Andaman & Nicobar and Lakswdeep as their borders are not connected to the map of India as this will create problem in the estimation of
spatial effects. Children with missing haemoglobin level were dropped from the analysis. With this criterion the final analytical sample size of children was 208707.

The covariates in the present study were selected based on previous study (15). The outcome variable used in the analysis was based on the categorization of haemoglobin level of children adjusted for altitude giving a binary variable where children whose haemoglobin level was less than 11Hb was categorised as being anaemic otherwise not anaemic. Mother educational level, household wealth index, child cough, child fever, received vitamin A, mother anaemia status, child stunting, wasting, underweight, child birth weight, child birth order, family size, child age, mother age. Duration of breast feeding, child age, and mother age were treated as continuous variables. However, the standard -2SD cut off values of z-scores categorization of height for age, weight for height, and weight for age were used to characterize stunting, wasting and underweight respectively.

**Statistical analysis**

Multiple logistic regression model was employed to select potential covariates for childhood anaemia prior to spatial analysis. A significance level of 20% was set for the selection of potential covariates to allow for selection of more variables to be used in the further analysis of spatial modelling.

Geo-additive logistic regression models were fitted to the data to understand fixed as well as spatial effects of childhood anaemia. If \( p_{ij} \) is the probability that child \( j \) from location \( i \) being anaemic, then child anaemic status which is binary is distributed as \( \text{Bernoulli}(p_{ij}) \). The following models were fitted to estimate fixed and spatial effects.

\[
M_0: \text{logit}(p_{ij}) = z_i \beta
\]
All categorical and continuous variables were treated as fixed effects in $M_0$. In case of $M_1$, categorical variables were employed as fixed effects and continuous variables were modelled by non-parametric smooth functions $f_j$. Model $M_2$ included a spatial effect of the state where a child belongs in addition to the fixed effects of categorical variables. Finally, $M_3$ was a combination of $M_1$ and $M_2$. The smooth functions $f_j$ were assigned with P-spline priors and the spatial component $f_{\text{spatial}}(s_i)$ with Markov random field prior (19,20). A fully integrated Bayesian approach was adopted to estimate the parameters and the estimated posterior odds ratio (OR) can be interpreted as the odds ratio from the logistic regression models. The models were fitted using the freely available package `bamlss` (21) in R (R Core Team, 2020).

A total of 40,000 MCMC iterations and 10,000 number of burn in samples were used in the analysis. Convergence of models were checked through autocorrelations and sampling paths. Finally, models were compared by Deviance Information Criterion (DIC) values (22), where the model with the smallest value is the preferred one. The DIC is calculated as $DIC = \bar{D} + p_D$, where $\bar{D}$ is the posterior mean of the model deviance, which gives a measure of goodness of fit, and $p_D$ is the effective number of parameters describing the complexity of the model and controls for penalty for model over fitting.

**Results**

**Descriptive results**
Table 1 provides prevalence of childhood anaemia according to region and states in India. Northern, central and, eastern regions show high prevalence of anaemia compared to other regions. The prevalence is above 60% in these three regions. The states of Chandigarh and Haryana show relatively high prevalence of anaemia of about 73% and 72% in northern region. In the central region, Madhya Pradesh and Uttar Pradesh show relatively high prevalence of anaemia. Jharkhand and Bihar are the states in eastern region having relatively high prevalence of anaemia of about 70% and 64% respectively. Most of the states in the north-eastern region show comparatively low prevalence of anaemia ranging from 24% to 57%. The states of Karnataka and Telangana show relatively high prevalence of anaemia above 60%. The overall prevalence of anaemia in India is about 58%.

Table 1: State variation of childhood anaemia

| Region/State         | Percentage of children (Anaemic) | Number of cases with anaemic children |
|----------------------|----------------------------------|--------------------------------------|
| **Northern**         |                                  |                                      |
| Chandigarh           | 62.2                             | 21,765                               |
| Haryana              | 72.3                             | 4,725                                |
| Himachal Pradesh     | 58.1                             | 1,324                                |
| Jammu and Kashmir   | 59.6                             | 3,986                                |
| Delhi                | 61.3                             | 627                                  |
| Punjab               | 57.3                             | 2,544                                |
| Rajasthan            | 60.9                             | 8,447                                |
| **Central**          |                                  |                                      |
| Chhattisgarh         | 42.9                             | 3,060                                |
| Madhya Pradesh       | 69.7                             | 14,015                               |
| Uttar Pradesh        | 63.8                             | 21,468                               |
| Uttarakhand          | 59.1                             | 2,808                                |
| **Eastern**          |                                  |                                      |
| Bihar                | 63.6                             | 13,332                               |
| Jharkhand            | 70.1                             | 7,002                                |
| Odisha               | 48.6                             | 4,393                                |
| West Bengal          | 55.6                             | 2,431                                |
| **North-Eastern**    |                                  |                                      |
| Arunachal Pradesh    | 53.3                             | 1,956                                |
| Assam                | 35.7                             | 2,838                                |
| Manipur              | 24.2                             | 1,153                                |
| Meghalaya            | 48.7                             | 1,706                                |
| Mizoram              | 23.9                             | 975                                  |
| Nagaland             | 26.2                             | 908                                  |
| Sikkim               | 56.6                             | 457                                  |
Table 2 provides a comparison of childhood anaemia across categorical covariates and a test of significance difference between categories of each covariate by chi-square test. It is evident that children from rural, mother with low education, household of poor economic condition show higher prevalence of anaemia than respective counterparts. There is a clear significant difference in childhood anaemia between levels of place of residence, mother’s education and household wealth. But the sex of child does not show any significance difference in childhood anaemia. Children with fever shows a tendency of higher prevalence of anaemia. It can also be seen that consumption of vitamin A supplement during childhood is helpful to reduce prevalence of anaemia. Under nutrition of children also shows an increase in prevalence of anaemia. At 5% level of significance the categorical variables, place of residence, mother’s education, household economic status, child fever, vitamin A, stunting, wasting, underweight and, mother’s anaemic status are all associated with childhood anaemic without controlling for other covariates. The categorical variables child birth order, household size, child birth weight show a non-significant effect on childhood anaemia at 20% level of significance in the preliminary analysis. Therefore, only categorical variables listed in Table 2 are included in the spatial logistic regression model in Table 4.
| Factor                  | N (%)       | \( P^* \) | Effect coding |
|------------------------|-------------|-----------|---------------|
| Place of residence     |             |           |               |
| Urban                  | 27,338 (55.2) | <0.001   | 1             |
| Rural                  | 92,770 (58.3)| 0.644    | -1^R          |
| Sex of the child       |             |           |               |
| Male                   | 62,486 (57.5) | <0.001   | 1             |
| Female                 | 57,622 (57.6)| 0.644    | -1^R          |
| Mother’s education     |             |           |               |
| Primary                | 17,845 (58.3)| <0.001   | 1             |
| Secondary              | 50,460 (54.1)| 0.644    | 2             |
| Higher                 | 9,467 (50.1)| <0.001   | 3             |
| No education           | 42,336 (64.3)| 0.644    | -1^R          |
| Wealth index           |             |           |               |
| Poor                   | 28,395 (57.6)| <0.001   | 1             |
| Middle                 | 23,422 (56.2)| 0.644    | 2             |
| Rich                   | 18,677 (53.9)| 0.644    | 3             |
| Richest                | 14,804 (52.9)| 0.644    | 4             |
| Poorest                | 34,810 (63.2)| 0.644    | -1^R          |
| Fever                  |             |           |               |
| Yes                    | 16,729 (60.9)| <0.001   | 1             |
| No                     | 103,295 (57.1)| 0.644    | -1^R          |
| Missing                | 84 (52.8)   | 0.220     |               |
| Cough                  |             |           |               |
| Yes                    | 13,887 (57.1)| <0.001   | 1             |
| No                     | 106,159 (57.6)| 0.644    | -1^R          |
| Missing                | 62 (54.9)   |           |               |
| Child received vitamin |             |           |               |
| A                      |             |           |               |
| Yes                    | 38,674 (58.1)| >0.001   | 1             |
| No                     | 80,003 (57.3)| >0.001   | -1^R          |
| Missing                | 1,431 (57.1)|           |               |
| Stunting               |             |           |               |
| Yes                    | 50,438 (62.7)| <0.001   | 1             |
| No                     | 64,015 (53.6)| <0.001   | -1^R          |
| Missing                | 5,655 (63.9)|           |               |
| Underweight            |             |           |               |
| Yes                    | 45,252 (63.7)| <0.001   | 1             |
| No                     | 69,201 (53.7)| <0.001   | -1^R          |
| Missing                | 5,655 (63.9)|           |               |
| Wasting                |             |           |               |
| Yes                    | 8,814 (64.1)| <0.001   | 1             |
| No                     | 105,639 (56.8)| <0.001  | -1^R          |
| Missing                | 5,655 (63.9)|           |               |
| Mother anaemic         |             |           |               |
| Yes                    | 48,928 (67.8)| <0.001   | 1             |
| No                     | 70,787 (52.1)| <0.001   | -1^R          |
| Missing                | 393 (58.1)  |           |               |

^R: Reference category; ^*: \( p \)-value of chi-square test of independence.
Model selection

The selection of the most preferred model is based on the deviance information criterion (DIC) and deviance values. Model with the smallest values of DIC and deviance is the preferred model. With this criteria, model \( M3 \) is the preferred model (Table 3). Therefore, interpretations of results (Table 4) and discussions are based on model \( M3 \).

### Table 3: Model comparison by deviance information criterion (DIC)

| Model Fit | Deviance | pD | DIC   |
|-----------|----------|----|-------|
| M0        | 171173.90| 19.79| 171154.10 |
| M1        | 170885.30| 37.71| 170847.60 |
| M2        | 165233.90| 51.77| 165182.10 |
| M3        | 164909.50| 69.92| 164839.60 |

3.3 Fixed effects

Table 4 shows fixed effects to childhood anaemia. Place of residence, mother’s education, poorest, rich, richest categories of household wealth, fever, cough, child under nutrition and mother’s anaemic status are fixed effects variables which are significant to childhood anaemia. The fixed effects coefficient for fever is positive, which indicates that children with fever are likely to increase the risk of childhood anaemia. Children who take vitamin A supplement decrease the likelihood of becoming anaemic. Children from rich or richest quintile of household wealth also have lesser risk of childhood anaemia than those who belong to poorest quintile. Children who are malnourished increase the risk of childhood anaemia. Mother’s anaemic status has a positive effect on childhood anaemia. This means that children whose mothers are anaemic have higher risk of being anaemic than those whose mothers are not anaemic.

### Table 4: Fixed effects on children anaemia in India

| Variable                  | Mean | SD  | 10%  | Median | 90%  |
|---------------------------|------|-----|------|--------|------|
| Place of residence        |      |     |      |        |      |
| Category                | Rural  R | Urban | Sex of child | Female  R | Male         | Mother’s education | No education | Primary | 0.0563* | 0.014 | 0.0386 | 0.0564 | 0.0740 |
|-------------------------|---------|-------|--------------|----------|--------------|--------------------|--------------|---------|---------|-------|--------|--------|--------|
|                         |         |       | Female       | 0.0074   | 0.06         | -0.0003            | 0.0075       | 0.0148  |
|                         |         |       | Male         | 0.010    | -0.0481      | -0.0361            | -0.0229      |
| Wealth index            |         |       | Poorest      | 0.0740   | 0.012        | 0.0585             | 0.0736       | 0.0893  |
|                         | 0.0069  | 0.012 | Poor         | -0.0079  | 0.0016       | -0.2056            | -0.1844      | -0.1625 |
|                         | -0.0904*| 0.013 | Middle       | -0.1072  | 0.017        | -0.1548            | -0.1330      |
|                         | -0.1332*| 0.017 | Rich         | -0.0723  | 0.010        | -0.0596            | -0.0466      |
|                         |         |       | Richest      | 0.1000   | 0.007        | 0.0125             | 0.0042       |
|                         |         |       |              | 0.0903   |              |                    |                |
|                         |         |       |              | 0.0999*  |              |                    |                |
|                         |         |       |              | 0.0797*  |              |                    |                |
|                         |         |       |              | 0.0387*  |              |                    |                |
| Child had fever         |         |       | No           | 0.0326   | 0.010        | 0.0200             | 0.0327       | 0.0451  |
|                         |         |       | Yes          | -0.0594* | 0.010        | -0.0723            | -0.0596      |
|                         |         |       | Child had cough |        |              |                    |                |
|                         |         |       | No           | -0.0041  | 0.007        | -0.0125            | -0.0042      | 0.0042  |
|                         |         |       | Yes          | 0.0999*  | 0.007        | 0.0903             | 0.1000       | 0.1091  |
|                         |         |       | Child received vitamin A |         |              |                    |                |
|                         |         |       | No           | 0.0797*  | 0.008        | 0.0698             | 0.0795       | 0.0899  |
|                         |         |       | Yes          | 0.0387*  | 0.012        | 0.0235             | 0.0387       | 0.0541  |
|                         |         |       | Child underweight |        |              |                    |                |
|                         |         |       | No           | 0.2715*  | 0.007        | 0.2632             | 0.2714       | 0.2803  |
|                         |         |       | Yes          |          |              |                    |                |
|                         |         |       | Child wasted |          |              |                    |                |
|                         |         |       | No           |          |              |                    |                |
|                         |         |       | Yes          | 0.0387*  | 0.012        | 0.0235             | 0.0387       |
| Mother anaemic         |         |       | No           |          |              |                    |                |
|                         |         |       | Yes          | 0.2715*  | 0.007        | 0.2632             | 0.2714       |

1 R: Reference category. *: Statistically significant at 5% alpha.

2 Non-linear effects

3 Another reason behind the geo-additive modelling is the ability to incorporate non-linear effects of continuous variables. In the present study, we incorporated non-linear effects of age of child, mother’s age and, duration of breast feeding.
Child age has non-linear effect to childhood anaemia (Fig 1). It is evident from Fig 1 that as child age increases, its effect on child anaemia decreases, which indicates, older children are less likely to have the risk of childhood anaemia. The risk of having anaemia is much higher in younger children aged about 6 months to about 15 months and decreases thereafter.

Fig 1. Non linear effect of child age to childhood anaemia. Lower and Upper lines indicate 95% confidence interval

Mother age also has a non-linear effect to childhood anaemia (Fig 2). The functional relationship between childhood anaemia and mother age depicts almost a U shape. This indicates that mothers of young and old ages are more likely to have children who are anaemic; in particular mothers aged 15 years to about 25 years. Then the risk of childhood anaemia starts declining after the age of 25 years and it continuous till the age of around 37 years, thereafter again starts increasing.

Fig 2. Non linear effect of mother age to childhood anaemia. Lower and Upper lines indicate 95% confidence interval

Fig 3 shows the non-linear effects of duration of breast feeding on childhood anaemia. The risk of childhood anaemia decreases till 29 months, thereafter increases. This indicates improvement in childhood anaemia with increase in duration of breast feeding. The credible intervals are wider at extreme ages because of small cases of observations.

Fig 3. Non linear effect of duration of breast feeding to childhood anaemia. Lower and Upper lines indicate 95% confidence interval.

Spatial effects

Fig 4 displays the estimates of the spatial effects of childhood anaemia, with colour range goes from black to white representing low to high risk of childhood anaemia. Spatial effects represent unobserved influences, such as environmental and climatic factors, availability of good transport facility, and access to good services for child health. The figure clearly shows evidence of residual spatial effects of childhood anaemia in India with most of states show
significant positive/negative effects with respect to the 95% posterior credible interval map (Fig 5). With respect to 80% posterior credible interval more states show significant spatial effects (Fig 6). Most of states in northern and central regions show significant positive spatial effects with respect to 95% credible interval. However, almost all states in north-eastern region of India show significant negative spatial effects with regard to the 80% credible interval (Fig 6).

Discussion

In India Childhood anaemia cuts across all the sections of society with varying intensity. Its prevalence as per the WHO classification is the indication that it is a severe public health problem for India. Except for Mizoram, Manipur, Nagaland, Assam, and Kerala for all the states and union territories (UTs,) anaemia is a matter of concern, whereas for states like Haryana, Jharkhand, and Madhya Pradesh it is of extremely serious concern. These three states need to revisit existing programs targeting to address the child health in general and anaemia in particular.

Anaemia has a close link with the food habit. Food habit is closely associated with culture and the nature. Geographical settings decide the nature of food supply and the micronutrients. Within the same geographical settings culture may encourage or discourage some group of population to consume or avoid certain nutritious food. For example tribal culture of northeast India approves consumption of varieties of insects, whereas for non-tribals
consumption of such insects is considered as taboo. Probably because of this reason the tribal
dominated states like Mizoram, Manipur, and Nagaland have very low prevalence of anaemic
children. However, our finding contradicts other studies in India that children from lowest
socioeconomic strata have more likelihood of suffering from anaemia (9,23) and Nepal (24).

The prevalence of anaemia among children in rural areas is comparatively higher than their
counter part in India. Rural mass in India might be less aware about the balanced diet which
has potentials to improve the hemoglobin count. Because as high as one third of rural
population in India are illiterate. Ignorance of food items relating to iron content food staff
may also add to the problem of anaemia in rural areas. This indicates that mass media
campaign to address anaemia should emphasize pictorial and or audio-visual means, rather
than on the written leaflets. A distinct negative relationship between wealth quintile and child
anaemia is quite evident. This is indicative of the fact that economically poorer households
may not be able to afford to procure nutritious food. This calls for better public distribution
system which provides subsidized food in India. The system need to keep an eye on
regularity, quantity, quality, etc.

Uneducated mothers are less equipped with knowledge of hygiene and proper knowledge of
child care. Unhealthy feeding habit can lead to various types of food related health problems.
Feeding practice is closely associated with diarrhoeal disease and studies exhibit that there is
positive relationship between diarrhoea and anemia. Unlike earlier studies (8,10) no
significant association is noted between sex of the child and prevalence of anaemia in the
present study. Children who take vitamin A supplement decrease the likelihood of becoming
anaemic. But earlier study (8) did not find significant statistical association between vitamin
A intake and childhood anaemia. In India, poor and illiterate families leave their baby on the
mud floor. The crawling baby in absence of any care taker may put to mouth anything it comes to his hand. Such activities may lead to various infections, morbidities, that is why younger children have more likelihood of suffering from anaemia. Other studies also indicate that younger children have more chances of having anaemia (15,24). Very young mothers definitely are less educated and relatively old mothers might take child rearing for granted, as they may already have older children. Other study also indicates U-shape relationship between mother’s age and the childhood anaemia (15) and others (10,25) found children born to young mothers are more likely to be anaemic.

In India usually the educated and rich women, due to various reasons, do not practice exclusive breast feeding. Exclusive breast feeding in India is usually practiced among the less educated and poor women, as a result a positive association between exclusive breast feeding and childhood anaemia is observed. However, this finding contradicts studies conducted elsewhere (26).

**Conclusions**

There is strong evidence of residual spatial effect to childhood anaemia in India. Government child health programme should gear up in treating childhood anaemia by focusing on known measurable factors such as mother’s education, mother’s anaemia status, family wealth status, child fever, stunting, underweight, and wasting which have been found to be significant in this study, attention should also be given to effects of unknown or unmeasured factors to childhood anaemia at the community level. Special attention to these unmeasurable factors should be focused in the states of central and northern India which have shown significant positive spatial effects.
List of Abbreviation

DIC - Deviance Information Criterion
WHO - World Health Organisation
OR - Odds Ratio
UTs - Union Territories
HSC - Holendro Singh Chungkham
SPM - Strong P Marbaniang
PKN - Pralip Kumar Narzary

Declarations

Ethical approval and consent to participate: The 2015-16 Indian Demographic Health Survey data are available to the public by request from the DHS website https://dhsprogram.com/methodology/survey/survey-display-355.cfm. We submitted a request to the DHS by mentioning the objectives of this study and thereafter was granted the permission to download the dataset.

Consent for publication: Not applicable

Availability of data and materials: The datasets generated and/or analysed during the current study are available in the Website of Demographic Health Survey https://dhsprogram.com/methodology/survey/survey-display-355.cfm

Competing interest: The authors declare that they have no competing interests

Funding: Not applicable

Author’s contributions: HSC, SPM conceived the study, involved in the study design, data analysis, interpret the data, drafted the manuscript. PKN drafted the manuscript. All authors read and agreed on the submitted final manuscript.

Acknowledgement: Not applicable

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Figures

Figure 1

Non linear effect of child age to childhood anaemia. Lower and Upper lines indicate 95% confidence interval.
Figure 2

Non linear effect of mother age to childhood anaemia. Lower and Upper lines indicate 95% confidence interval.
Figure 3

Non linear effect of duration of breast feeding to childhood anaemia. Lower and Upper lines indicate 95% confidence interval.
Figure 4

Residual spatial effect to childhood anaemia. Colour ranges from black to white representing low to high risk of childhood anaemia. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Figure 5

The 95% credible intervals map for prevalence of anaemia. White: negative effect; light black: insignificant effect; black: positive effect. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area o bbnhjr of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Figure 6

The 80% credible intervals map for prevalence of anaemia. White: negative effect; light black: insignificant effect; black: positive effect. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.