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RESEARCH ARTICLE

Short birth interval and associated factors in rural India: A cross-sectional study

Sourav Chowdhury[1*], Aditya Singh[2], Nuruzzaman Kasemi[1], Mahashweta Chakrabarty[2] and Shivani Singh[3]

[1]Department of Geography, Raiganj University, Raiganj, West Bengal, India, [2]Department of Geography, Banaras Hindu University, Varanasi, Uttar Pradesh, India and [3]India Health Action Trust, Lucknow, India
*Corresponding author. Email: souraaavvv@gmail.com

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Abstract

Short Birth Interval (SBI) is one of the main causes of adverse maternal and child health outcomes. A 33-month birth-to-birth interval between two successive live births should be followed to minimize the risk of adverse maternal and child health. This study aimed to examine the prevalence of SBI and the associated factors in rural India. Information on 98,522 rural mothers from the fourth round of National Family Health Survey data was analyzed. Bivariate statistics, logistic regression, Moran's *I*, and Cluster and Outlier Analysis have been used to assess the prevalence and spatial pattern of SBI in rural India. Results revealed that about half of the mothers in rural India had experienced SBI. Rural Indian mothers whose child was not alive (OR = 1.76, 95% CI = 1.63–1.90), were not using any contraceptive methods (OR = 1.42, 95 % CI = 1.37–1.48) and not breastfeeding (OR = 2.73, 95% CI = 2.50–2.97) were more likely to experience SBI. On the other hand, rural mothers from the middle, richer and richest wealth quintiles (OR = 0.91, 95% CI = 0.86–0.97; OR = 0.84, 95% CI = 0.80–0.92; OR = 0.60, 95% CI = 0.55–0.66) and of age over 30 years (OR = 0.38., 95% CI = 0.36–0.39) were less likely to experience SBI. Analysis of spatial patterns revealed clear east-west differences in the prevalence of SBI. There was strong clustering of high values of SBI in most districts across the central, northern, western, and southern regions. The study suggests the need to introduce appropriate interventions and programs focused on reducing the prevalence of SBI in rural India.

Keywords: Short birth interval; Inter-birth spacing; National Family Health Survey 4; India

Background

The time between live birth and the start of the second pregnancy is referred to as the birth-to-pregnancy interval. World Health Organization (WHO) recommends that this period be at least 24 months to minimize the risk of adverse maternal, perinatal and child outcomes (WHO, 2005). When the average gestation period, which is on average nine months, is added to it, it becomes what is known as the birth-to-birth interval or birth interval (Exavery *et al.*, 2012). Thus, the optimum birth intervals should be 33 months long. Any birth interval shorter than this is therefore considered a 'short' birth interval. Short birth interval (SBI) has been linked to a high risk of several adverse outcomes such as preterm birth, labour dystocia, small gestational age, intrauterine growth retardation, low birth weight, folate deficiency, hormonal dysfunction in the postpartum phase, lactation stress, maternal and child morbidity and mortality (Gubhaju, 1986; Zhu, 2005; Bhalotra, van Soest and Soest, 2008; Williams *et al.*, 2008; Grisaru-Granovsky *et al.*, 2009; Dejonge *et al.*, 2014; Ewemade, Akinyemi and Dewet, 2019).

Over the past decades, the Government of India has implemented several policies and programs, such as Safe Motherhood, Reproductive and Child Health (RCH), and National Health Mission (NHM), to improve the health of mothers and children in the country, but maternal and infant mortality is still significantly high in India (Vora *et al.*, 2009; Singh *et al.*, 2011; Kumar and Singh, 2016; Paul and Chouhan, 2020).

The maternal mortality rate is 130 deaths per 100,000 live births, considerably higher than many sub-Saharan African countries (Registrar General of India, 2020). Neonatal mortality, too, is a cause of concern. Globally, millions of neonates die every year. In 2019, globally, an estimated 2.4 million children died in their first month, roughly a third of all neonatal mortality occurring during the first day of life and almost three-quarters occurring within the first week (UNICEF, 2020b). The situation is worse in India's rural areas (36 deaths per 1000 live births in rural areas versus 23 in urban areas) (Office of the Registrar General & Census Commissioner, 2020; UNICEF, 2020a). The length of the birth interval is one of the most important factors that explain this high mortality (Zhu, 2005; Ramarao, Townsend and Askew, 2006; Conde-Agudelo, Rosas-Bermúdez and Kafury-Goeta, 2007; Bhalotra, van Soest and Soest, 2008; Williams *et al.*, 2008; Grisaru-Granovsky *et al.*, 2009; Singh *et al.*, 2012; Shahjada *et al.*, 2014; Schwandt *et al.*, 2017). It is therefore important to study birth intervals as it may provide an opportunity to reveal possible situations leading to the inappropriate birth interval, which may have a beneficial effect on pregnancy, child, and maternal health (Dewey and Cohen, 2007).

Several previous studies have examined SBI and identified various risk factors that explain the variation in the length of birth intervals. Previous research in many developing countries has shown that birth intervals of 3 to 5 years are better for both mother and child than birth intervals shorter than two years. (Ronsmans, 1996; Exavery *et al.*, 2012; Schwandt *et al.*, 2017; Yadav and Pandey, 2018). Many studies have reported a positive association between the breastfeeding period and the birth interval length (Ginneken, 1974; Miller *et al.*, 1992; Gray, 1994; Yohannes *et al.*, 2011; Singh *et al.*, 2012). The sex of the index child has also been considered a determinant of birth intervals. Some studies have noted that mothers with a prior birth of a female child generally have a shorter birth interval (Nath, 1994; Gray and Evans, 2005; Singh, Singh and Narendra, 2011; Singh *et al.*, 2012). The short length of the birth interval has also been found to be associated with the mortality of the previous infant (Ronsmans, 1996; Williams *et al.*, 2008; Kumar, 2009; Singh, Singh and Narendra, 2011). Several studies have highlighted the effect of place of residence (e.g., rural versus urban) on the birth interval length (Nath, 1994; Exavery *et al.*, 2012; Das and Roy, 2021).

Data from the National Family Health Survey (NFHS-4) suggests that the prevalence of SBI is higher among mothers from rural India, where about 69% of the total population lives (Office of the Registrar General & Census Commissioner, 2011; International Institute for Population Sciences (IIPS) and ICF, 2017). However, none of the previous Indian studies on this issue has focused exclusively on the rural population. Previous studies are mostly small-scale studies with a limited number of variables (Singh, Singh and Narendra, 2011; Singh *et al.*, 2012). Though small-scale studies provide important insights into people's health behaviour, their findings are not generalisable to a larger population because of their inadequate geographic coverage and small sample constricting their power. The review of previous literature also reveals that geographical disparities in the prevalence of SBI at the district level in India have not been explored, possibly due to the unavailability of district-level data until recently. This study, therefore, aims to examine the prevalence and correlates of SBI in rural India using data from the latest round of NFHS.

Data and methods

Data source

This study uses survey data from the NFHS-4, conducted during 2015-16 (International Institute for Population Sciences (IIPS) and ICF, 2017). NFHS is a nationally representative cross-sectional

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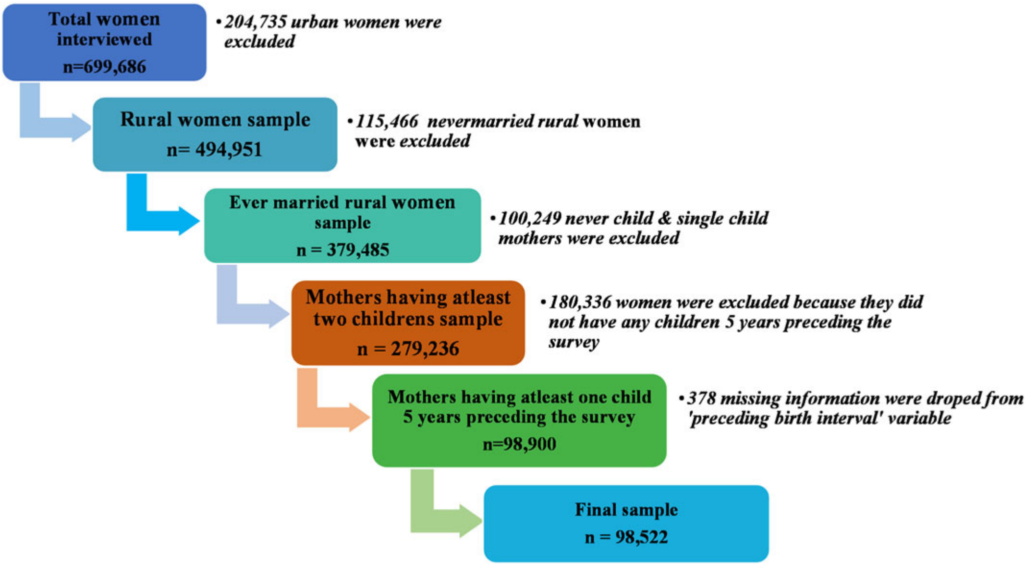

Figure 1. Flow chart showing the process of selection of mothers from the NFHS-4 dataset.

survey offering evidence on various demographic, socioeconomic, maternal and child welfare, reproductive health, and family planning outcomes. The dataset used in this study is anonymous and available for public use at https://dhsprogram.com. More information about this survey is available in the NFHS-4 national report (International Institute for Population Sciences (IIPS) and ICF, 2017).

Sampling design and sample size

In the NFHS-4, 699,686 mothers aged 15-49 were interviewed using a two-stage stratified sampling. The response rate of NFHS-4 was 97%. Urban, unmarried, single child mothers and mothers with no children were excluded from the sample. Figure 1 describes the process of selection of the study sample. For this study, the birth intervals start with the most recent births that fall within the last five years preceding the survey, and the prior births could occur either within these five years or at any time before it. Mothers whose most recent births did not fall within the past five years preceding the survey were excluded from the study. The reason behind this exclusion of these mothers was that the information on many variables to be included in our multivariable analysis was unavailable in the dataset.

Dependent Variable

The dependent variable for this study is short birth interval or SBI. The SBI in this study is defined based on the WHO's Technical Consultation on Birth Interval recommendations. The WHO recommends 24 months as a healthy 'birth-to-pregnancy' interval (WHO, 2005). The gestational period on average takes nine months. Therefore, the 'birth-to-birth' interval would be of 33 months (24 months of 'birth-to-pregnancy interval and nine months of gestational period). This 33-month long birth-to-birth interval is considered the optimum birth interval.

In this study, a mother with a birth-to-birth interval of fewer than 33 months is considered to have experienced a short birth interval. The rest of the mothers (with a birth-to-birth interval of 33 months or more) are considered to have experienced an optimum or adequate birth interval. The

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variable SBI had two categories – those with SBI were coded 1 (Yes), and the rest of the mothers were coded 0 (No).

Independent Variables

Based on an extensive review of the previous literature on this issue, we tried to incorporate in the analysis a wide range of socioeconomic, bio-demographic, geographic, and family planning-related factors (Zhenzhen, 2000; Razzaque *et al.*, 2005; Ramarao, Townsend and Askew, 2006; Williams *et al.*, 2008; Singh, Singh and Narendra, 2011; Yohannes *et al.*, 2011; Saha and van Soest, 2013; Jatrana and Pasupuleti, 2015; Barclay and Kolk, 2017; Yadav and Pandey, 2018; Chowdhury, Singh, Kasemi and Chakrabarty, 2022). Wealth Index served as a proxy measure of the household's economic status, whereas membership of a social group (based on caste or tribe of a person) served as a proxy for the social status of a household.

Mother's education level, age, ever use of contraceptives, breastfeeding status (ever breastfed), the desired number of sons, and survival status of the previous child were some other variables that were included in the analysis as these have been found to affect the outcome of interest. Region of residence as a variable was included in the analysis to capture geographical heterogeneity in the dependent variable. These variables have also been used in previous studies (Singh, Singh and Narendra, 2011; Exavery *et al.*, 2012; Jatrana and Pasupuleti, 2015; Chowdhury, Singh, Kasemi, Chakrabarty, *et al.*, 2022). Detailed information and coding of these independent variables have been given in Table 1.

Statistical analysis

At the outset, we provide a glimpse into the distribution of sampled mothers from rural India. The prevalence of SBI by background characteristics of mothers is calculated then. After that, we identify the correlates of SBI among rural mothers in India. For this purpose, we employ binary logistic regression because the dependent variable is dichotomous (i.e., binary) in nature (Wright, 1995). Before running the regression model with all independent variables, the one-to-one relationship between the dependent variable and each independent variable is checked by running a logistic regression with only one predictor variable at a time. The odds ratios thus obtained are labeled as 'unadjusted' odds ratios. This is done to eliminate any variables that do not have a statistically significant one-to-one relationship with the dependent variable. All those variables found to have a significant one-to-one relationship are put in the final model together. The odds ratios thus obtained are labeled as 'adjusted' odds ratios. These odds ratios have been used to conclude the effect of the independent variables on the dependent variable.

The possibility of multicollinearity affecting our regression results is checked using the variance inflation factor (VIF), which measures how much the variance of a regression coefficient is inflated due to multicollinearity in the model (Miles, 2014). The general rule of thumb is that VIFs exceeding four warrant further investigation, while VIFs exceeding 10 are signs of serious multicollinearity requiring correction. A low overall VIF (1.62) for our regression model suggests that multicollinearity was not a problem. The logistic regression model results have been presented as odds ratios with p-values and 95% confidence intervals (CI). The data analysis was conducted in Stata16 statistical software (StataCorp, 2019).

Since 'region of residence' turns out to be a statistically significant predictor of SBI in the regression analysis, we have extended our analysis to examine spatial variation in the prevalence of SBI at the district level. For this, the prevalence of SBI for each district is computed separately by dividing the total number of mothers with SBI in the district by the total number of mothers in that district. This district-level prevalence is then mapped to detect spatial patterns/clustering in the outcome variable.

Table 1. Description of independent variables

Independent Variable	Description	Coding
Wealth Index	The wealth index is a composite index of household amenities and assets. It represents a household's socioeconomic status. It is used as a proxy for the income of the household. Many previous studies on NFHS and DHS data have used it. It has five categories (quintiles).	Poorest (1), Poorer (2), Middle (3), Richer (4), Richest (5)
Mother's level of education	A mother's level of education is classified into four categories depending on years of schooling: illiterate = no years of schooling; primary = 1–5 years of schooling; secondary = 6–10 years of schooling; and higher = more than ten years of schooling.	Illiterate (1), Primary (2), Secondary (3), Higher (4)
Social groups	Social groups have been categorized as Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward Classes (OBC) and Others (General)	SC (1), ST (2), OBC (3), Others (4)
Maternal age groups (years)	This variable has been categorized as below 30 years and more than 30 years of mothers' current age	<30(1), >30 (2)
Survival status of the previous child	It denotes whether or not the previous or current child is alive	Dead (1), Alive (2)
Desired number of sons	The number of sons the respondent wishes to have over her life. This variable has three categories, i.e., no sons, only one son, and two or more sons.	0 (1), 1 (2), ≥ 2 (3)
Use of any contraceptive method	Whether or not the couple is practicing any method of birth control.	No (1), Yes (2)
Breastfeeding of the previous child (LAM)	Whether or not mothers have previously breastfed their children. This variable is also known as Lactation Amenorrhea Method (LAM). Because breastfeeding reduces the likelihood of conception, it is natural contraception. This variable has two categories.	No (1), Yes (2)
Mass media exposure on family planning (FP) methods	Mass media has three sources in NFHS-4 - a) print media like newspapers and magazines, b) radio, and c) television. The variable "Mass media exposure on FP methods" has two categories: 'exposed' that is, the respondent has heard about family planning from any of the mass media mentioned above, and 'non-exposed' that is, the respondent did not hear about family planning from any of the mass media mentioned above.	No exposure (1), Exposure (2)
Region of residence	Indian states have been regrouped into six 'regions' based on their geographical and cultural characteristics. Many previous studies from India have used this reclassification of states into regions. The six regions are - I. Northern region (Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Chandigarh, Rajasthan, and Delhi), II. Central region (Uttar Pradesh, Madhya Pradesh, Chhattisgarh and Uttarakhand), III. Eastern Region (Bihar, Jharkhand, West Bengal, and Orissa), IV. Western region (Gujarat, Maharashtra, Goa, Dadra & Nagar Haveli, and Daman & Diu), V. Southern region (Andhra Pradesh, Karnataka,	Northern (1), Central (2), Eastern (3), Western (4), Southern (5), Northeastern (6)

(*Continued*)

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Table 1. (*Continued*)

Independent Variable	Description	Coding
	Kerala, Tamil Nadu, Puducherry, Telangana, Andaman & Nicobar Islands, Lakshadweep), VI. Northeastern region (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).	

Although we can discern clustered districts from non-clustered districts just by simply looking at a prevalence map, it not always easy to tell the difference. Also, a qualitative description may not always be sufficient for a scientific study. It is therefore suggested to statistically test whether districts of similar (or dissimilar) values are clustered and if they are clustered, what their location is on the map. To test the existence of clustering, we use a popular spatial autocorrelation test, the Moran's *I* test. The term "spatial autocorrelation" refers to the study of how well things in a given spatial area correlate with each other. Positive autocorrelation occurs when many similar values are located near each other, while negative correlation is common where very different results are found near each other. Moran's *I* statistic is the correlation coefficient for the relationship between a variable (like SBI) in a spatial unit (district) and its value in the surrounding districts (Anselin, Syabri and Kho, 2009).

We use 'Global Moran's *I*' to examine the presence of clustering in SBI across the districts of India. Global Moran's *I* is called 'Global' because it does not pinpoint specific locations on a map where the measured autocorrelation is strongest. It simply tells us that the map data are spatially autocorrelated (clustered) but does not tell us where are those areas (clusters) on the map. To determine the location and magnitude of local spatial autocorrelation, we calculate another statistic called 'Local Moran *I*' (Anselin, 1995). It identifies spatial clusters of features with high or low values. The Appendix of this paper provides a detailed description of these indicators, their calculation, and interpretation. This spatial analysis has been carried out in ArcGIS 10.8 software package (ESRI, 2020).

Results

The analysis revealed that 50,606 out of 98,522 rural mothers aged 15–49 years in India between 2010 and 2015 experienced SBI, equivalent to 51% of the total sample. About 26% of rural mothers had 'very short' birth intervals (less than 24 months), and about 25% had 'short' birth intervals (24-32 months). About 35% of rural mothers had birth intervals between 33 and 59 months, and 13% of rural mothers had birth intervals of more than 60 months.

Sample characteristics

Table 2 presents the sample distribution of rural mothers across all variables. About two-thirds of rural mothers were in the bottom two quintiles suggesting poverty was pervasive. Over two-fifths of mothers in the sample were illiterate. Around a third were using contraceptives at the time of the survey. Nearly half of the sampled mothers reported that they were exposed to FP messages through mass media.

Prevalence of short birth interval by background characteristics

Table 3 presents the prevalence of SBI by background characteristics of mothers. SBI varied only slightly across various socioeconomic variables such as wealth index, education of the mother, and social group. The prevalence of SBI among mothers aged less than 30 years was about twice higher

Table 2. Distribution of mothers by background characteristics, rural India, NFHS-4 (2015-16)

Background characteristics	Mothers in the sample (number)	Mothers in the sample (%)
Socioeconomic		
Wealth Index		
Poorest	35377	35.9
Poorer	26584	27.0
Middle	19547	19.8
Richer	11762	11.9
Richest	5252	5.3
Mother's level of education		
Illiterate	40023	40.6
Primary	16074	16.3
Secondary	38159	38.7
Higher	4265	4.3
Social group		
Scheduled Castes	22718	23.1
Scheduled Tribes	12754	12.9
Other Backward Classes	43461	44.1
Others	19590	19.9
Bio-demographic		
Maternal age groups (years)		
<30	63386	64.3
>=30	35136	35.7
Survival status of the previous child		
Dead	6275	6.4
Alive	92247	93.6
Desired number of sons		
0	9502	9.6
1	52178	53.0
>=2	36842	37.4
Family planning		
Use of any contraceptive method		
No	65268	66.2
Yes	33254	33.8
Breast feeding of the previous child (LAM)		
No	6189	6.3
Yes	92333	93.7

(*Continued*)

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Table 2. (Continued)

Background characteristics	Mothers in the sample (number)	Mothers in the sample (%)
Mass media exposure on FP methods		
Non-exposure	50263	51.0
Exposure	48259	49.0
Geographical		
Region of residence		
Northern	10883	11.0
Central	30614	31.1
Eastern	29197	29.6
Western	9848	10.0
Southern	13832	14.0
Northeastern	4148	4.2
India	**98522**	**100.0**

Notes: All percentages have been calculated using women's national weight provided in NFHS-4 (variable V005), LAM: Lactation Amenorrhea Method, FP: Family Planning

than among those over 30 years of age. SBI was higher among those mothers whose previous child was dead. SBI was less prevalent among those mothers who breastfed their previous child than those who did not. The occurrence of SBI was less common among contraceptive users than non-users. As compared with any other region of India, the prevalence of SBI was significantly lower in the northeast region.

Correlates of short birth interval

A multivariable logistic regression model was applied to assess the independent effect of variables affecting SBI, and its results were presented in the form of odds ratios (see Table 4). The results of one-to-one regression revealed that all variables (except some categories of some variables) were statistically significantly associated with the dependent variable. Therefore, all of these variables were put together in one logistic regression model, and the 'adjusted' odds ratios were obtained. The adjusted odds ratios suggested that wealth index, social group, maternal age, survival status of the previous child, the desired number of sons, contraceptive use, breastfeeding of the previous child, and region of residence were associated with the likelihood of SBI among rural women in India.

The odds ratios of the SBI gradually decreased as one moved from the poorest wealth quintile to the richest. Mothers from the richer and richest quintiles were less likely (OR = 0.84, 95 % CI = 0.80–0.92; OR = 0.60, 95 % CI = 0.55–0.66) to have SBI as compared to the mothers of the poorest quintile. Mothers belonging to Scheduled Castes and Other Backward Classes were slightly more likely to experience SBI (OR = 1.08, 95 % CI = 1.02–1.14; OR = 1.13, 95 % CI = 1.07–1.18) than those belonging to 'Others' or general category.

The odds of having SBI among mothers aged 30 years and above were about 0.38 times (OR = 0.38, 95% CI = 0.36–0.39) that of those under 30. The death of the previous child turned out to be a significant predictor of SBI. Mothers whose previous child was dead were 76% more likely (OR = 1.76, 95% CI = 1.63–1.90) to experience SBI than mothers with a previous alive child. The odds of SBI among mothers with no desired number of sons were about 0.80 times less likely (OR = 0.79, 95% CI = 0.74–0.84) than those mothers who desired to have two or more sons. Mothers not using contraception were around one-and-a-half times more likely (OR = 1.42,

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Table 3. Prevalence of short birth interval across the background characteristics, rural India, NFHS-4 (2015-2016),

Background characteristics	Number of mothers with SBI	Prevalence of SBI (%)	95% CI	
			Upper	lower
Socioeconomic				
Wealth Index				
Poorest	18354	51.9	51.2	52.6
Poorer	13813	52.0	51.1	52.8
Middle	10325	52.8	51.8	53.8
Richer	5984	50.9	49.5	52.2
Richest	2130	40.6	38.9	42.3
Mother's level of education				
Illiterate	20209	50.5	49.9	51.1
Primary	8419	52.4	51.3	53.5
Secondary	20008	52.4	51.7	53.2
Higher	1970	46.2	44.2	48.2
Social group				
Scheduled Castes	11984	52.8	51.8	53.7
Scheduled Tribes	6396	50.2	49.0	51.3
Other Backward Classes	23122	53.2	52.6	53.9
Others	9103	46.5	45.4	47.5
Bio-demographic				
Maternal age groups (years)				
<30	37808	59.6	59.1	60.2
>=30	12798	36.4	35.8	37.1
Survival status of the previous child				
Dead	4216	67.2	65.7	68.7
Alive	46390	50.3	49.8	50.8
Desired number of sons				
0	4709	49.6	48.1	51.0
1	26394	50.6	49.9	51.2
>=2	19503	52.9	52.3	53.6
Family planning				
Use of any contraceptive method				
No	35751	54.8	54.2	55.3
Yes	14855	44.7	43.9	45.5
Breast feeding of the previous child (LAM)				
No	4746	76.7	75.2	78.1
Yes	45860	49.7	49.2	50.2
Mass media exposure on FP methods				

(*Continued*)

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Table 3. (*Continued*)

Background characteristics	Number of mothers with SBI	Prevalence of SBI (%)	95% CI	
			Upper	lower
Non-exposure	26027	51.8	51.2	52.4
Exposure	24579	50.9	50.3	51.6
Geographical				
Region of residence				
Northern	5906	54.3	53.3	55.3
Central	16444	53.7	53.0	54.4
Eastern	14064	48.2	47.2	49.1
Western	5259	53.4	51.6	55.2
Southern	7536	54.5	53.0	55.9
Northeastern	1397	33.7	32.4	35.0
India	**50606**	**51.4**		

Notes: All percentages have been calculated using women's national weight provided in NFHS-4 (variable V005); LAM: Lactation Amenorrhea Method, FP: Family Planning, CI: Confidence Interval

95 % CI = 1.37–1.48) to experience SBI than those using contraception. The odds of SBI were thrice higher among mothers who did not breastfeed their previous child (OR = 2.73, 95% CI = 2.50–2.97) than among those who did.

Region of residence also turned out to be a significant predictor of SBI. Mothers from north-eastern region were about 60% less likely to (OR = 0.40, 95% CI = 0.37–0.43) to experience SBI than mothers from mother of north region. The odds were also significantly lower in eastern region (OR = 0.61, 95% CI = 0.58–0.65), southern region (OR = 0.75, 95% CI = 0.72–0.83), western region and central region of India (OR = 0.83, 95% CI = 0.77–0.90; OR = 0.83, 95% CI = 0.79–0.88).

Spatial patterns of short birth interval

A spatial analysis was conducted to assess the spatial pattern of SBI in rural India. Figure 2 shows variation in the prevalence of SBI across the districts of rural India. The prevalence of SBI was over 60% in almost all the districts of Madhya Pradesh, western districts of Rajasthan, some eastern districts of Bihar, the northern district of Andhra Pradesh, and a few central districts of Karnataka. On the other hand, almost all the districts of Kerala, Odisha, Sikkim, Assam, Tripura and southern districts of West Bengal had a relatively lower prevalence (<40%) of SBI.

A simple look at the map of SBI does not reveal whether SBI is clustered, randomly distributed or dispersed across the districts of India. Therefore, we calculated Global Moran's *I* in which the districts of India were feature locations and the prevalence of SBI attribute values (Figure 3). The spatial autocorrelation (Global Moran's *I*) revealed that the spatial distribution of SBI in the study area had a clustering pattern, with a Moran's index of 0.19 (the respective p-value was <0.001). The matching Z-score was 40.90, meaning there was less than a 1% probability that the clustered pattern we see in the SBI prevalence map was caused by random chance.

Figure 4 shows the cluster and outlier map of the SBI. The cluster and outlier analysis identifies areas with significant Local Moran *I*, which are categorized according to the type of spatial autocorrelation (Anselin, 1995). Dark red denotes a high-high association, dark blue denotes a low-low association, light red denotes a high-low association, and light blue denotes a low-high association. For example, a high-high cluster indicates that districts with above-average SBI prevalence share

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Table 4. Unadjusted and adjusted odds ratios (with 95% confidence interval) of short birth interval, rural India, NFHS-4 (2015-16)

	Unadjusted				Adjusted			
		CI (95%)				CI (95%)		
Independent variables	OR	Lower	Upper	*P* value	OR	Lower	Upper	*P* value
Wealth Index								
Poorest®								
Poorer	1.00	0.96	1.05	0.876	0.95	0.90	0.99	0.019
Middle	1.04	0.99	1.09	0.113	0.91	0.86	0.97	0.002
Richer	0.96	0.91	1.02	0.163	0.84	0.80	0.92	<0.001
Richest	0.63	0.59	0.68	<0.001	0.60	0.55	0.66	<0.001
Mother's level of education								
Illiterate®								
Primary	1.08	1.03	1.13	0.002	1.03	0.97	1.08	0.332
Secondary	1.08	1.04	1.12	<0.001	1.07	1.02	1.12	0.115
Higher	0.84	0.77	0.91	<0.001	1.08	0.98	1.19	0.126
Social group								
Scheduled Castes	1.29	1.22	1.36	<0.001	1.08	1.02	1.14	0.008
Scheduled Tribes	1.16	1.09	1.23	<0.001	0.98	0.92	1.04	0.490
Other Backward Classes	1.31	1.25	1.37	<0.001	1.13	1.07	1.18	<0.001
Others®								
Maternal age groups (years)								
<30®								
>=30	0.39	0.37	0.40	<0.001	0.38	0.36	0.39	<0.001
Survival status of the previous child								
Dead	2.02	1.88	2.17	<0.001	1.76	1.63	1.90	<0.001
Alive®								
Desired number of sons								
0	0.87	0.82	0.93	<0.001	0.79	0.74	0.84	<0.001
1	0.91	0.88	0.94	<0.001	0.78	0.75	0.82	<0.001
>=2®								
Use of any contraceptive method								
No	1.50	1.45	1.55	<0.001	1.42	1.37	1.48	<0.001
Yes®								
Breastfeeding of the previous child (LAM)								
No	3.33	3.07	3.61	<0.001	2.73	2.50	2.97	<0.001
Yes®								
Mass media exposure on FP methods								
Exposure	0.97	0.94	1.00	0.043	0.97	0.94	1.01	0.163

(*Continued*)

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Table 4. (*Continued*)

Independent variables	Unadjusted				Adjusted			
		CI (95%)				CI (95%)		
	OR	Lower	Upper	*P* value	OR	Lower	Upper	*P* value
Non-exposure®								
Region of residence								
Northern®								
Central	0.98	0.93	1.02	0.335	0.83	0.79	0.88	<0.001
Eastern	0.78	0.75	0.82	<0.001	0.61	0.58	0.65	<0.001
Western	0.97	0.90	1.04	0.352	0.83	0.77	0.90	<0.001
Southern	1.01	0.95	1.08	0.79	0.75	0.72	0.83	<0.001
Northeastern	0.43	0.40	0.46	<0.001	0.40	0.37	0.43	<0.001

Notes: ® = reference category, OR = odds ratio, CI = confidence interval, LAM: Lactation Amenorrhea Method FP: Family Planning

borders with districts with the same prevalence. High-low, on the other hand, indicates that districts with above-average prevalence are surrounded by districts with below-average prevalence. High-high clusters are known as hot spots, and low-low clusters are known as cold spots. It is seen that districts in the central, northern, western, and southern zones of India had high-high clusters (hot spots) of the SBI, whereas districts in the eastern and northeastern zones had low-low clusters (cold spots). High-low outliers existed in the eastern part of the country and included districts from northern Bihar, Meghalaya, Nagaland, and northern Manipur.

Discussion

Findings of this study indicate that during two consecutive live births, more than half of the birth intervals in rural India were shortly spaced (less than 33 months). This corresponds to more than two out of every five mothers (results not shown) that did not comply with the optimum birth interval, meaning that a large proportion of mothers in rural India could be at risk of adverse maternal and newborn health effects due to SBI.

A range of factors associated with the SBI was identified in the study. Mothers of the richest wealth quintile were less likely to have SBI than mothers of the poorest wealth quintile. Prosperous mothers have enough money to pay for healthcare expenses, including postnatal consultations where counseling for healthy timing and spacing of pregnancy, as well as advice on proper family planning techniques for keeping adequate birth interval, are given. On the other hand, the poorer mothers are typically less educated and unemployed and struggle to pay for their children's healthcare. Their incomes are also quite low, and after investing in the necessities of life, they are often left with insufficient funds for healthcare (Singh, Kumar and Pranjali, 2014). The previous literature corroborates this finding on this issue (Williams *et al.*, 2008; Singh, Singh and Narendra, 2011; Yadav and Pandey, 2018).

Caste turned out to be a statistically significant predictor of SBI. SC mothers were more likely to experience SBI. In this regard, it is important to note that SC as a category consists predominantly of those castes who have historically been treated as untouchables. Mothers from these social groups are generally poor, less educated, and unaware of their reproductive health and healthy timing of birth interval (Kumar and Singh, 2016). Therefore, it is not surprising that SBI rates is higher among these mothers.

It was also noted in this study that older mothers were more likely to delay subsequent births as compared with younger mothers. It may be because older women are relatively less fertile, a

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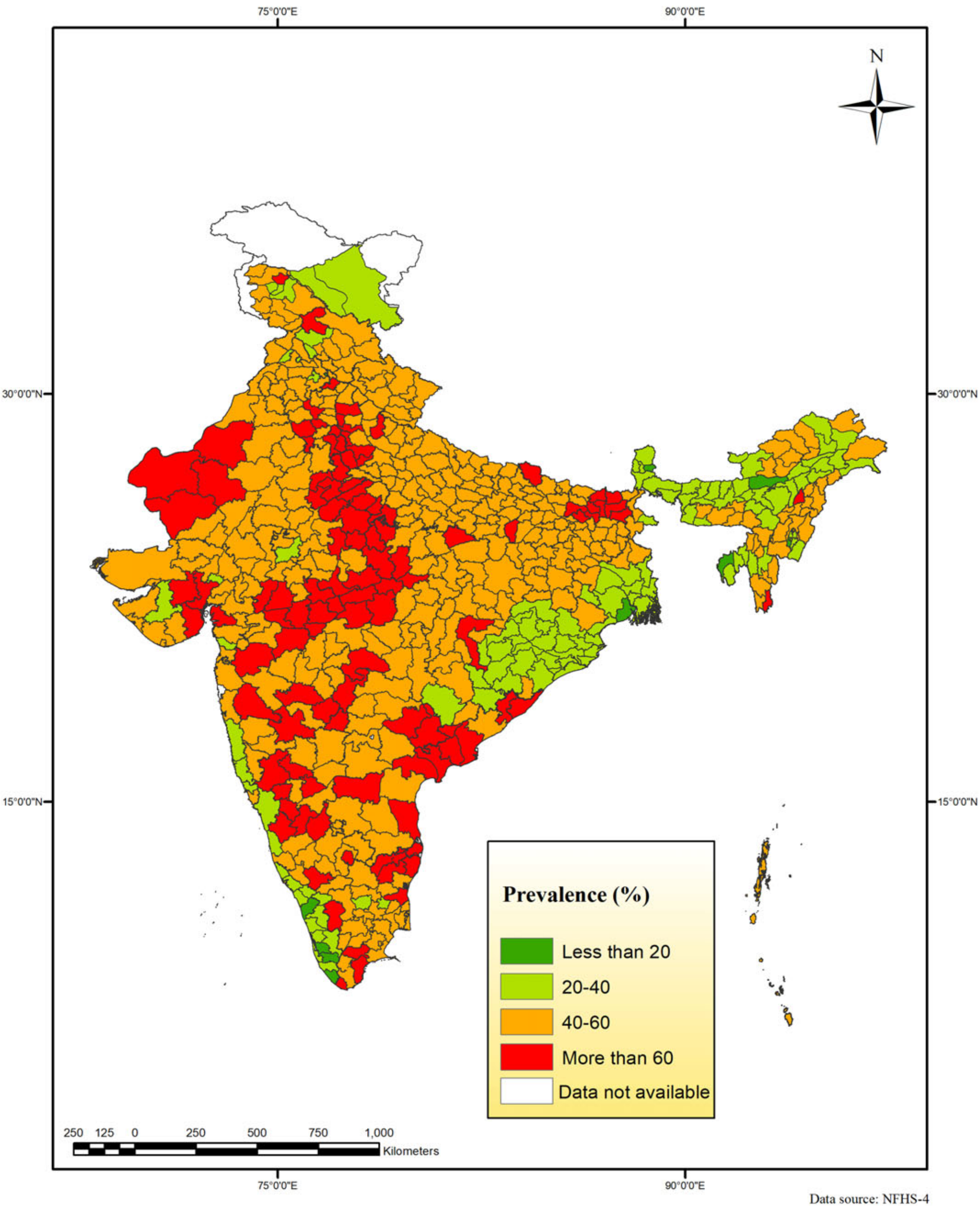

Figure 2. Spatial distribution of prevalence of short birth interval, rural India, 2015-2016.

condition that decreases their chance of pregnancy, thereby leading to a longer birth interval. The fecundity of women decreases gradually but significantly beginning approximately at age 32 years and decreases more rapidly after age 37 years. A healthy fertile 30-year-old mother has a 20% risk of getting pregnant each month she tries. That ensures 20 will be effective for every 100 fertile 30-year-old mothers in one cycle, and the other 80 will have to try again. By 40, the chances of becoming a mother are fewer than 5% per cycle, implying that less than 5 out of every 100 women will be

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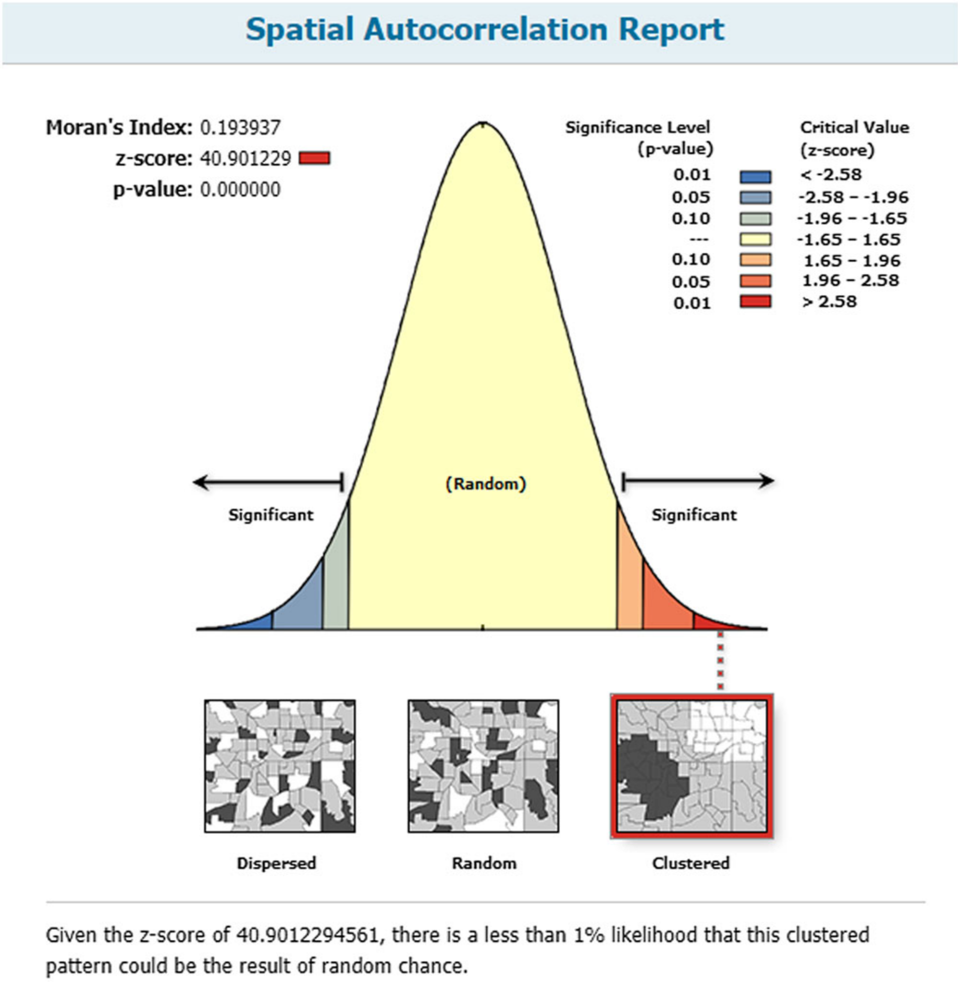

Figure 3. Spatial Autocorrelation Report.

successful each month (American Society for Reproductive Medicine, 2012). The average menopause age in India is about 46 years, but at some point, in their 40s, most Indian mothers become unlikely to have a healthy pregnancy. The age-related loss of female fertility occurs when the consistency and volume of eggs decrease over time (Ahuja, 2016). This finding is consistent with several previous studies that have similarly shown that older mothers tend to have longer birth intervals (Conde-Agudelo, Rosas-Bermúdez and Kafury-Goeta, 2006; Exavery *et al.*, 2012).

The survival status of the previous child was also important in determining birth interval patterns. There could be several social and biological reasons behind it. The societal explanation is that couples who have lost a child during infancy postpone contraception to have another child. The biological explanation is that the loss of a baby ends breastfeeding, which causes an early return to ovulation and increases the probability of subsequent early conception (Singh, Singh and Narendra, 2011).

This study also found that increasing the desired number of sons decreased the length of birth intervals. It could be because sons are traditionally valued highly by Indian parents as an economic asset and assurance of old age, as well as the bearer of the family name. These parents are less likely to consider contraception or other fertility control measures before having the desired number of

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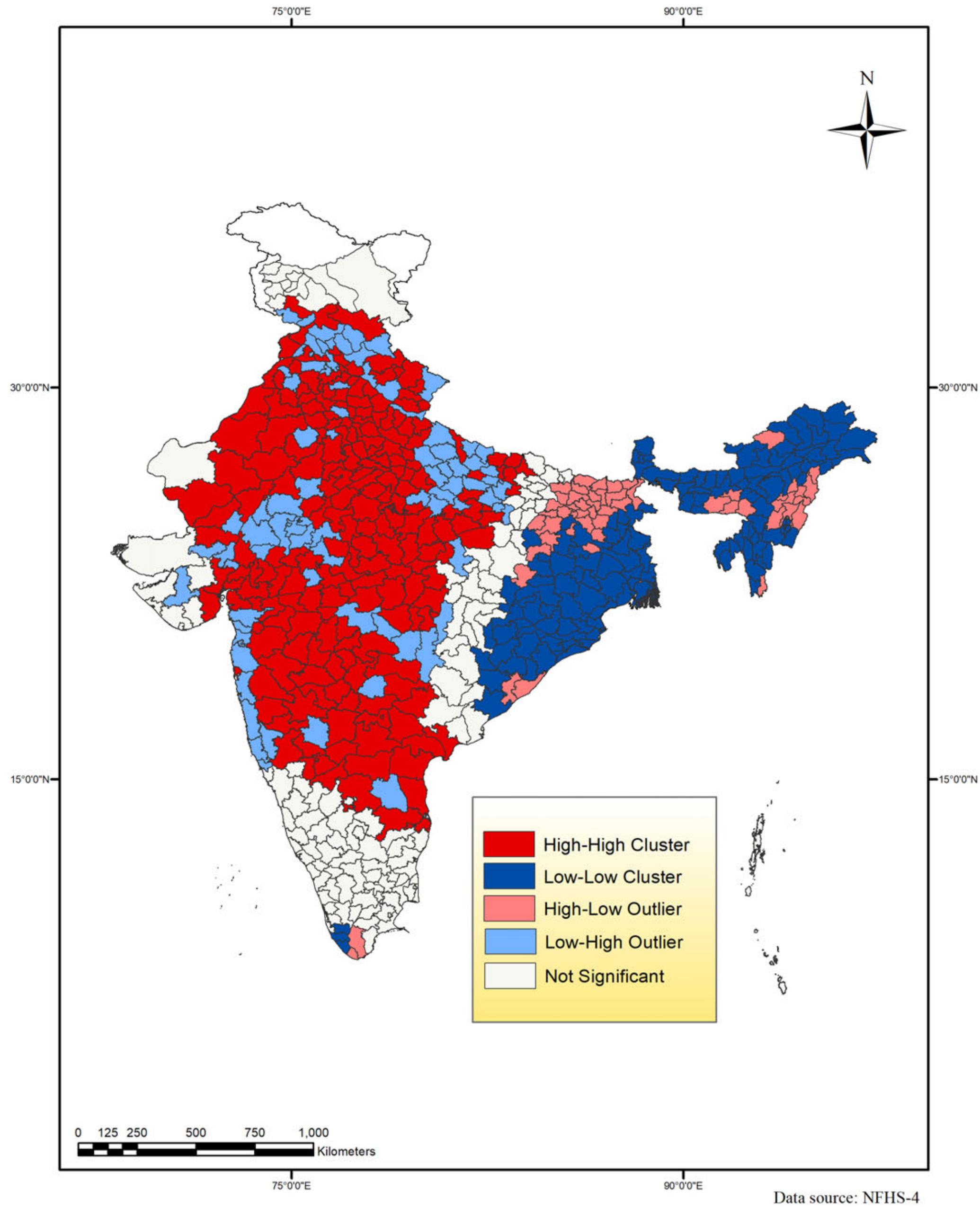

Figure 4. Cluster and outlier map of short birth interval, rural India, 2015-2016.

sons. Some prior researches confirm this finding (Chakraborty, Sharmin and Islam, 1996; Gray and Evans, 2005; Singh, Singh and Narendra, 2011).

The use of contraception was another important determinant of SBI. The prevalence of SBI increased due to a lack of contraception. Lack of discussion between couples, partner opposition, lack of awareness, and affordability of modern family planning methods could be reasons for lower contraceptive use (Saha and van Soest, 2013; Yadav and Pandey, 2018). Couple-focused

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family planning should receive special attention, with husbands encouraged to participate in family planning and contraception adoption discussions to reduce the occurrence of SBI,

This study finds breastfeeding is an important predictor of SBI in rural India. It is well-known that prolonged lactation primarily protects against conception by delaying the return of ovulation and menstruation. This finding is in tune with many previous studies (Miller *et al.*, 1992; Singh *et al.*, 2012; Dim, Ugwu and Iloghalu, 2013). Prolonged breastfeeding should be encouraged if SBI is to be reduced. Accredited Social Health Activists (ASHA) can play an important role in accomplishing this goal (Yadav and Pandey, 2018).

There are glaring geographical disparities in the prevalence of SBI in rural India. SBI was more common in rural mothers in the northern, central, western, and southern regions. It should be noted that most states in the northern, central, and western regions have one thing in common: a skewed child sex ratio. The child sex ratios in these states are significantly lower than the national average, with 919 girls for every 1000 boys (Office of the Registrar General & Census Commissioner, 2011). The skewed sex ratio is a natural expression of son preference, which may have significant implications for the number of children and birth interval length.

The high-high cluster of SBI mainly consists of those states that have contraceptive prevalence lower than the national average (54%), such as Madhya Pradesh (51%), Gujarat (47%), and Uttar Pradesh (40%). Similarly, the contraceptive prevalence in districts from high-low outliers was below the national average. The majority of these districts come from Bihar (24%), Meghalaya (24 %), and Manipur (24 %) (International Institute for Population Sciences (IIPS) and ICF, 2017). A large proportion of the population in the northeastern region consists of numerous tribal groups with a significant migrant population from the neighboring countries in some states. Contraceptive prevalence among these people is considerably low due to several reasons discussed in the literature (Dey and Goswami, 2009; Spoorenberg and Dommaraju, 2012). The child sex ratio in this region is also high as compared to the northern, central, and western regions (Office of the Registrar General & Census Commissioner, 2011). A higher child sex ratio may be a reflection of a lower desired number of sons (Dubuc and Sivia, 2018). These factors might have a role in forming hot and cold spots. Future research could explore in more detail the influencing factors that could have led to the formation of these hot spots.

The Government of India has recently launched '*Mission Parivaar Vikas*' to expand the availability of contraception and family planning in selected 146 high fertility districts located in the states of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, and Assam, which together account for 44% of the population of the country (Muttreja and Singh, 2018). Except for those in Assam and Jharkhand, most of these districts have a high prevalence of SBI. However, a higher prevalence of SBI is also noticeable in many districts from the states like Maharashtra, Karnataka, Telangana, and Tamil Nadu, which are not the focus of *Mission Parivar Vikas*. This higher prevalence suggests the need to expand this mission to many other districts with a higher prevalence of SBI to improve maternal and child health even further in these states.

The strength of this study is that our analysis not only examined the correlates of SBI but also mapped the clusters of occurrences of SBI. Determining a hot spot is important because it helps identify and pinpoint areas requiring more preventive measures. There are a few limitations. It was unable to incorporate the gestational period since the NFHS-4 does not contain any information about the gestational period of pregnancy; therefore, we considered the average gestational period of nine months, which was used in prior studies. It should also be noted that abortions and miscarriages may extend birth intervals, but for lack of data, this could not be considered in this research. We have considered only the most recent birth interval in this study due to the lack of data on many independent variables to be used in the regression analysis. We mapped hot spots of SBI but did not examine the contributing factors. Future research could explore in detail the influencing factors that could have led to the formation of these hot spots.

Conclusion

The analysis of birth intervals in rural India reveals that about half of mothers included in the sample experienced SBI, which indicates that SBI remains an issue that deserves urgent attention in rural India. There are wide geographic variations in SBI. Central, northern, western, and southern regions of rural India had high-high clusters (hot spots) of the SBI. Mothers from disadvantaged backgrounds (poor and illiterate) are more likely to experience SBI and suffer consequences. The desired number of sons, contraceptive use, and breastfeeding were significant predictors of SBI. These factors can be modified in the short term by introducing appropriate interventions and programs and may help reduce the prevalence of SBI in rural India.

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Author contributions. SC analyzed the raw data, prepared the map, wrote the draft, and reviewed and edited the manuscript. AS conceived and designed the study, wrote and edited the manuscript. NK reviewed and edited the manuscript. MC & SS read and edited the manuscript.

List of abbreviations. SBI: Short Birth Interval; WHO: World Health Organization; NFHS: National Family Health Survey; ASHA: Accredited Social Health Activists; LAM: Lactation Amenorrhea Method; CI: Confidence Interval; OR: Odds Ratio.

Declarations.

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Ethics approval and consent to participate. The present study used secondary data available in the public domain. The dataset had no identifiable information about the survey participants. Therefore, no ethical approval was required for conducting this study.

Consent for publication. Not applicable.

Availability of data and materials. The dataset used in the current study is available in the Demographic and Health Surveys (DHS) repository available online at https://dhsprogram.com

Competing interests. The authors declare no competing interests.

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Appendix

Spatial Autocorrelation

When a set of numbers has a pattern that allows values in the series to be predicted based on previous values, the set of numbers is said to have 'autocorrelation.' Serial correlation and serial dependence are other terms for the same thing. The 'auto' part of autocorrelation comes from the Greek word for 'self,' and autocorrelation refers to data that is correlated with itself rather than data that is correlated with something else.

According to the first law of geography given by geographer Waldo Tobler, near things are more related to each other than distant things. We refer to this as 'spatial dependency.' The degree of spatial dependency between the value of an observation of a spatial entity (area/district) and the values of observations of the same variable in the surrounding areas or districts is referred to as spatial autocorrelation. Simply put, spatial autocorrelation determines how closely the value of a variable in one location relates to the values of the same variable in locations surrounding it.

As per Tobler's Law of Geography, the geographic phenomenon is often distributed non-randomly, and closer things are often more related to near things than distant things. In other words, the phenomenon is clustered or dispersed in some locations over the space. This nonrandom geographical distribution of the values of a variable under study may significantly affect the accuracy of classical statistics. In conventional statistics, the observations in a sample are assumed to be independent of each other. However, in the presence of spatial autocorrelation or clustering, this assumption is violated as observations with similar values are spatially located nearby each other. This typically means that classical statistical tools cannot be directly employed while analyzing geographic data, as this would result in biased results. Hence, spatial autocorrelation analysis must be performed before conducting any conventional statistical analysis. Spatial autocorrelation analysis also reveals the location of high and low-value clusters helping the policymakers decide which areas to focus on and which to ignore in policy and program implementation.

A variety of diagnostic methods can be used to detect spatial autocorrelation. These measures are generally of two types depending on what they measure: Global or Local. 'Global' spatial autocorrelation measures estimate spatial autocorrelation using a single value to describe the pattern of the entire map (study area). Among the most widely used of these measures is the *Global Moran's I* statistic, the correlation coefficient for the relationship between a variable and its surrounding values. 'Local' spatial autocorrelation helps us detect and identify high and low values clusters. It is measured by *Local Moran's I*.

Moran's I index formula is as follows:

$$I = \frac{n}{\sum_i^n \sum_j^n w_{ij}} \frac{\sum_i^n \sum_j^n w_{ij}\,(x_i - \bar{x})\left(x_j - \bar{x}\right)}{\sum_i^n (x_i - \bar{x})^2} \tag{i}$$

Where,

n is the number of the spatial features

x_i is the attribute value of feature i (in spatial analysis, the terms 'variable' and 'attribute' refer to the same thing)

x_j is the attribute value of feature j

x is the mean of this attribute

w_{ij} is the spatial weight between feature i and j

$\sum_i^n \sum_j^n w_{ij}$ is the aggregation of all spatial weights

Moran's I is a statistical inference technique. It is statistically evaluated using a p-value and a z-score. It is interpreted based on the expected value calculated under the null hypothesis of no spatial autocorrelation (complete spatial randomness). For a random pattern, the expected value is

$$E(I) = \frac{-1}{n-1} \tag{ii}$$

Where n denotes the number of spatial entities, clustering and positive spatial autocorrelation are shown by positive Moran's I index values (observed) that are significantly larger than the expected value E(I). Negative Moran's I index values (observed) significantly less than E(I) imply negative spatial autocorrelation or no autocorrelation. The results are not statistically significant if the p-value is large (usually $p > 0.05$), and we cannot reject the null hypothesis. We can reject the null hypothesis of complete spatial randomness and accept that spatial autocorrelation exists if the p-value is low (usually <0.05).

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