Assessing Risk Factors for Short Birth Interval Hot Spots using Geographically Weighted Regression: Findings from a Nationally Representative Survey Data

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Abstract

Background

Short Birth Interval (SBI) is a public health problem in most low- and lower-middle-income countries. Understanding geographic variations in SBI, particularly SBI hot spots and associated factors, may help intervene with tailored programs. This study identified the geographical hot spots of SBI in Bangladesh and the factors associated with them. `

Methods

We analyzed women's data extracted from the 2017/18 Bangladesh Demographic and Health Survey and the healthcare facility data extracted from the 2017 Service Provision Assessment. Moran's I was used to examine the spatial variation of SBI in Bangladesh whereas the Getis-Ord G^*_i (d) was used to determine the hot spots of SBI. The Geographical Weighted Regression (GWR) was used to explore the spatial variation of SBI on explanatory variables. The explanatory variables included in the GWR were selected using the exploratory regression and ordinary least square regression model.

Results

Data of 5941 women were included in the analyses. Around 26% of the total births in Bangladesh had occurred in short intervals. A majority of the SBI hot spots were found in the Sylhet division, and almost all SBI cold spots were in the Rajshahi and Khulna divisions. No engagement with formal income-generating activities, high maternal parity, and history of experiencing the death of a child were significantly associated with SBI in the Sylhet region. Women's age of 34 years or less at the first birth was a protective factor of SBI in the Rajshahi and Khulna divisions.

Conclusion

The prevalence of SBI in Bangladesh is highly clustered in the Sylhet division. We recommend introducing tailored reproductive health care services in the hot spots instead of the existing uniform approach across the country.

Introduction

Despite the tremendous strides in improving maternal and child health, particularly in the Millennium Development Goals period of 2000–2015, maternal and child morbidity and mortality continue to be a major problem in low- and lower-middle-income countries (LMICs). Globally, almost 300,000 women die annually from causes related to pregnancy and childbirth, and 94% of these occur in LMICs [1]. Also, over 80% of 5.2 million global under-five mortality occurs in LMICs, although they only account for 52% of the global under-five population [2]. Around half of these deaths occur within the first 28 days of children's lives and an additional 1.5 million occur within 1–11 months of birth [2]. Anemia, placental abruption, placenta previa, uterine rupture, preterm birth, low birth weight and congenital malformations are some of the dominant causes for many of these deaths, and they are preventable [1–4]. Inadequate birth spacing is incontrovertibly linked to many of these adverse health outcomes [5,6]. The reason is the lack of sufficient time to return to the normal pregnancy metabolic state before the next pregnancy that affects women's nutritional, physical and emotional health [7]. Moreover, pregnancy in short intervals decreases maternal foetal concentrations, especially during the second and third trimesters, which can weaken connective tissue by preventing collagen cross-linking, thus increasing the risk of adverse pregnancy outcomes [8]. The World Health Organization recommends this interval to be at least 33 months. A shorter duration than this is identified as a short birth interval (SBI) [9]. Around one-fourth of pregnancies that end with live births in LMICs occur in SBIs [10–12].

Previous research on SBI in LMICs primarily focused on sociodemographic risk factors of mothers, children, and other members of households [10–14]. Another key variable of interest is the area-level difference in SBI rates, measured across geographical locations (e.g., urban/rural and administrative divisions) [10–14]. An important aspect of this variable is its ability to modify other risk factors of SBI, such as partners' educational attainments and children's survival status [15]. The reason is that in LMICs, socio-economically advantaged and disadvantaged people usually live in clusters. As a result, risk factors of SBIs could be different between various clusters in an area. However, in literature, these differences are not receiving the necessary attention and most researchers are often producing overall estimates for broader jurisdictions. This overall estimate masks the local-level variation and, thereby, limits our ability to formulate policies and programs targeting specific areas or segments of people where much-needed public health interventions are needed [15]. Consequently, in many LMICs, we see mismatches between service requirements and service availability and misuse of limited but valuable resources. This is particularly true for Bangladesh, where healthcare policies and programs are usually adopted nationally. This approach directly or indirectly considers a uniform situation across the country and does not account for local-level needs. With this study, using two nationally representative samples of Bangladesh, we aimed to determine the area-specific differences in SBI and explore their risk factors.

Methods

This study draws on data from the 2017/18 Bangladesh Demographic and Health Survey (BDHS), which is a nationally representative data source and provides estimates of reproductive health, maternal and child health. The survey is part of the Demographic and Health Survey Program conducted in 90 LMICs. In Bangladesh, the Ministry of Health and Family Welfare supervised the survey; its partner organizations, The National Institute of Population Research and Training along with Mitra and Associates (an independent research firm) implemented this survey at the field level. Several development partners, including UNFPA and UNDP, provided financial support for this survey.

Following a two-stage stratified random sampling approach, the survey collected data from women of 15–49 years old living in the selected households. At the first stage of sampling, the survey selected 675 Enumeration Areas (EAs, clusters) covering urban and rural areas as well as eight administrative divisions of Bangladesh. The EAs were selected randomly from a list of 293,579 EAs created by the Bangladesh Bureau of Statistics as part of conducting the 2011 National Population Census, the most recent population Census in Bangladesh. The household listing operation was conducted at the second stage of sampling and 30 households were selected from each EA through probability proportional to the sample size. A total of 20,160 households were selected, of which data collection was undertaken in 19,457 households with over 96% inclusion rate. There were 20,376 eligible women in the selected households. Of them, data was collected from 20,127 women with a response rate of 98.8%. Finally, data of 5,941 women were included in this study by applying the following inclusion criteria: (i) the woman had at least two pregnancies, of which the most recent one ended with live birth within five years of the survey date, (ii) the second most recent pregnancy ended with live birth or termination, and (ii) the end dates of both pregnancies and the interval were recorded.

The survey also collected the geographical location of each EA using the Global Positioning System (GPS). The GPS reading was made at the center of each EA, while efforts were made to ensure adequate satellite signal strength. For this, the data collectors ensured that they were not near any tall building or under any big tree. The points recorded were then randomly displaced to 5 kilometers in the rural area and 2 kilometers in the urban area. The DHS recorded those displaced EA points in a shapefile (geographical data file) and released it along with the survey data.

We also used geographical data of the 2017 Bangladesh Health Facility Survey (BHFS), a nationally representative survey of healthcare facilities. This dataset includes 1524 healthcare facilities selected randomly throughout the country covering primary, secondary and tertiary level healthcare facilities. A detailed description of the sampling procedure of both surveys has been published in their survey reports [16,17].

Outcome variable

The outcome variable is SBI, defined as an interval of at least 33 months between the two most recent births. The BDHS recorded this data in months by subtracting the date of birth of the most recent child to the date of birth or termination of the second most recent child. These dates were collected from the birth registration reports or immunization cards. If these were not available, mothers were requested to recall their memories. These women were referred to memorable events like the national or local election, flood to help them recall their memories to estimate the accurate date of births.

Explanatory variable

The explanatory variables considered in this study were identified through a comprehensive literature search in the following five databases: Medline, Embase, Web of Science, CINHAL, and Google Scholar. A pre-designed search strategy was used with relevant keywords, including birth interval, birth spacing, and short birth interval. To identify the key factors, special attention was paid to the five studies conducted in Bangladesh [13,14,18–20] and the studies conducted in some other LMICs [10–12]. The factors were age at birth (≤ 19, 20–34, ≥ 35), age at first childbirth (≤ 19, 20–34, ≥ 35), educational status of women and their husbands (no education, primary, secondary, higher), and women's employment status (employed, not employed), sex of households' head (male, female), women's exposure to mass media (little exposed, moderately exposed, highly exposed) and the number of children ever given birth (≤ 2, > 2). Survival (yes *vs* no) of the second most recent child was also considered. The average distances from respondents' houses to the nearest healthcare facilities that offer reproductive healthcare services were also considered an explanatory variable. The average distance was calculated at the divisional level using the administrative boundary link method based on the geographical variables of the 2017/18 BDHS and 2017 SPA datasets [21].

Statistical analysis

We first determined the variation in the prevalence of SBI across the places of residence and administrative divisions using the chi-square test. The proportions of SBI and the explanatory variables were estimated across the EAs (clusters). The survey weight was applied using STATA's *svy* command to calculate the proportions. The estimated proportions were then merged with the GPS cluster locations and examined whether any geographical difference persists in the distribution of SBI in Bangladesh. For this, the hot spot analysis was conducted with the Moran's I and Getis-Ord G*i (d)statistics to examine spatial variation and clustering of SBI across EAs, respectively. We considered a False Discovery Rate (FDR) correction while using the Getis-Ord G*i (d) statistics to account for multiple, dependent tests. The importance of considering the FDR correction method in DHS data has been described elsewhere [22]. We ran Ordinary Least Square Regression (OLS) to identify the predictors of observed spatial patterns of SBI in Bangladesh. We checked the model assumptions for OLS and multicollinearity [23,24]. For this, the variables included in the OLS were first determined carefully by using explanatory regression, a data mining tool was used to select the variables as Stepwise Regressions do. The explanatory regression model identifies the variables to be included in the OLS that meet the model's assumptions.

The OLS fits a linear regression to all of the data in the study area. Therefore, it did not answer the questions, (i) why clustering (if any) of SBI occurs in Bangladesh? and (ii) what factors are associated with the observed clustering? It is also important to know whether the relationships between the outcome variables and explanatory variables vary across areas and which explanatory variables show substantial influence. The GWR answers these questions. We ran GWR with the variables that met the assumptions of the OLS model, as recommended in the previous studies [25,26]. The advantage of this approach is that the model produces an estimate for each EA instead of an overall estimate for the entire area [26]. Statistical software Stata version 15.1 (Stata Corp, College Station, Texas, USA) and ArcGIS version 10.6.1 (ESRI. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute. 2011) were used for all statistical analyses.

Results

Background characteristics of the respondents

This study includes data of 5,941 women who came from 672 clusters in the 2017/18 BDHS. The crude and age-standardized characteristics of the study sample are shown in Table 1. The average age of participants at their most recent births was 25.93 years (SD ± 5.13). On average, they received 6.12 years of education (SD ± 3.70) and gave birth to 2.85 (± 1.18) children. More than a quarter of the total live births occurred in SBI (26.26%).

Table 1
Characteristics of the respondents (N = 5,941)

Characteristics	Crude estimate	Age-standardised estimate*
Maternal age at most recent pregnancy, mean years (± SD)	25.93 (5.13)	-
Maternal age at the first pregnancy (± SD)	1.26 (0.44)	-
Maternal education, mean years (± SD)	6.12 (3.70)	6.47 (3.73)
Children ever born, mean number (± SD)	2.85 (1.18)	2.13 (1.26)
Mother engaged in a formal job (prevalence (95% CI))	46.81 (44.39–49.24)	44.0 (22.2–24.2)
Birth interval		
Short birth interval (prevalence (95% CI))	26.26 (24.84–27.94)	25.6 (22.9–28.8)
Not short birth interval (prevalence (95% CI))	73.64 (72.06–75.16)	74.0 (41.2–75.8)

Note: *Age-standardisation was performed using the age structure of women of 15–49 years included in the 2011 Bangladesh National Census.

Geographical distribution of the prevalence of short birth interval

The geographical distribution of the prevalence of SBI in Bangladesh is presented in Table 2. We found a statistically significant difference in SBI prevalence across the places of residence and divisions. The prevalence of SBI in rural areas was around 27%, compared to 24% in urban areas. Among the eight administrative divisions, the Sylhet division sits on the top of the league table (46%), and the Khulna division sits on the bottom (19.99%).

Table 2
Weighted proportion of Short Birth Interval in Bangladesh by place of residence and administrative division, BDHS 2017/18 (N = 5,941)

	Short birth interval (weighted)		Chi-square test
	Yes (n = 1566)	No (n = 4,398)	
Place of residence			
Urban	1191 (75.66)	3207 (24.34)	*p* < 0.05
Rural	375 (72.93)	1191 (27.07)	
Division			
Barishal	72 (21.46)	262 (78.54)	*p* < 0.01
Chattogram	379 (28.86)	933 (71.14)	
Dhaka	352 (24.02)	1114 (75.98)	
Khulna	100 (19.99)	402 (80.01)	
Mymensingh	142 (28.08)	365 (71.92)	
Rajshahi	137 (21.39)	505 (78.61)	
Rangpur	130 (20.72)	496 (79.28)	
Sylhet	254 (45.99)	298 (54.01)	

Hot spots and cold spots of short birth interval in Bangladesh

We found evidence of statistically significant clustering of SBI in the study area (Moran's I = 0.330590, $p < 0.01$). The Getis-Ord G statistic revealed the high clustering across EAs ($p < 0.01$) (Fig. 1). A relatively high number of SBI hot spots were found in the Sylhet division, and SBI cold spots were found in parts of the Rajshahi and Khulna divisions.

Model comparisons: OLS and GWR

The results of the OLS model are presented in Table 3. The results demonstrate that five explanatory variables had a positive relationship with the SBI. None of the variables had multicollinearity. The adjusted R^2 was 0.62. The AIC was − 988.13.

The effects of the five variables selected for SBI hot spots and cold spots in the area level were determined using the GWR. The summary results of this model fit are presented in Table 4. Model's fitness was improved with the GWR over the OLS. The AIC value was − 988.13 for the OLS model and − 1024.23 for the GWR model. The reported adjusted R for the GWR model was 0.65, 3% higher than the OLS model.

Predictors of short birth interval: hot spots and cold spots

The cluster-wise coefficients of the GWR model are plotted in Fig. 2a-f. In the Sylhet division, where a majority of the SBI hotspots are located, the significant predictors of SBI are no formal education of husbands (Fig. 2c), women doing no formal jobs (Fig. 2d), having three or more children (Fig. 2e), and experiencing the death of a child (Fig. 2f). On the contrary, in the Rajshahi and Khulna divisions where most of the SBI coldspots were located, maternal age of 34 years or less at the first birth (Fig. 2b) was a significant protector of SBI.

Table 3
Ordinary least square regression model identifying significant factors of short birth interval in Bangladesh, BDHS 2017/18

Variable category	**Coefficient**	**Standard error**	**t-statistics**	**Probability**	**Robust std-error**	**Robust t-statistics**	**Robust probability**	**VIF**
Women's age at birth, ≤ 19 years	1.05	0.09	32.24	< 0.01	0.05	36.14	< 0.01	3.40
Women's age at birth, 20–34 years	0.92	0.06	29.12	< 0.01	0.03	34.12	< 0.01	1.95
Husbands did not receive formal education	1.13	0.23	41.12	< 0.01	0.07	42.34	< 0.01	3.12
Women not engaged in formal work	0.78	0.12	23.17	< 0.01	0.06	25.12	< 0.01	2.98
Gave birth to three or more children	0.34	0.07	21.12	< 0.01	0.03	14.12	< 0.01	1.93
The child born from the second most pregnancy died	0.41	0.06	7.00	< 0.01	0.04	6.00	< 0.01	1.40
Intercept	0.11	0.02	2.97	< 0.01	0.1	1.94	< 0.01	—
Model diagnostics								
Number of observation (EAs)	672	Akaike's Information Criterion (AIC):					-988.13	
Multiple R-squire	0.62	Adjusted R-square					0.62	
Joint F-Statistics	1824.14	Probability (> F), (6,672) degrees:					< 0.01	
Joint Wald Statistics	158.13	Probability (> chi-squared)					< 0.01	
Koenker (BP) Statistics	1892.14	Probability (> chi-squared)					< 0.01	

Variable category	Coefficient	Standard error	t-statistics	Probability	Robust std-error	Robust t-statistics	Robust probability	VIF
Jarque-Bera Statistics	0.86	Probability (> chi-squared)					< 0.01	

Table 4
Geographically weighted regression model assessing factors of short birth interval in Bangladesh, BDHS 2017/18

Explanatory variables	Women's age at first birth, ≤ 19 years, Women's age at first birth, 20–34 years, Husbands did not receive formal education, Women not engaged in formal work, Gave birth three or more children, Experienced death of a child
Residual squares	17.87
Effective number	81.24
Sigma	0.18
AIC	-1024.23
Multiple R-square	0.67
Adjusted R-square	0.65

Discussion

This study provides evidence that along with the socio-demographic factors known to be associated with a high prevalence of SBI in Bangladesh [14,19,27], area-level variations are also important. This is the first study in the Bangladesh context that explored the factors determining such area level variations, including factors responsible for SBI hot spots and cold spots. Unemployed women, those who gave birth to three or more children, experienced the death of a child, or whose husbands received no formal education were significantly more likely than others to be located in SBI hot spots. Women who gave their first birth at the age of 19 years or earlier and 20–34 years were significantly more likely to be living in SBI cold spots. These findings are robust as we have selected these variables following a proper statistical model-building technique. Therefore, we believe these findings are reliable and implications in designing policies and tailored programs.

The observed prevalence of SBI (26%) is consistent with the results of a nationally representative study conducted recently in Bangladesh [28] and in the range of SBI (19%-66%) reported in LMICs [29,30]. This study also found a relatively high prevalence of SBI in the Sylhet division, where a majority of SBI hot spots are located. On the other hand, SBI cold spots are mainly located in parts of the Rajshahi and Khulna divisions. This is a new observation for Bangladesh. These divisional variations in SBI hot spots and cold spots are due to the division-level variations in socio-demographic and cultural characteristics of women and their partners and their perceptions regarding the desired number of children.

Previous studies in Bangladesh consistently reported high rates of early marriage, relatively low age at first birth, and low rates of formal education in the Sylhet division [31,32]. These characteristics, both individually and together, can affect SBI. Our results also suggest that these factors are the significant predictors of SBI in the SBI hot spots area in the Sylhet division. A possible reason for such association is that couples with these characteristics are less likely to access maternal healthcare services, including intrapartum, birthing, and post-partum care [33–35]. Moreover, in the current form of maternal healthcare services delivery in Bangladesh, post-partum care visit on the fourth weeks of the live birth is dedicated to providing counselling regarding family planning and contraception [36]. This approach is not helpful in increasing family planning and contraception services because post-partum care visits at the fourth week of live birth are still very low in Bangladesh [36]. Indeed, many women in Bangladesh have a misapprehension that once a live birth has occurred, the issue of pregnancy is over, and it is unnecessary to visit a healthcare center for post-partum care, particularly at the fourth week of live birth. This tendency is even higher among women of disadvantaged backgrounds. Consequently, many women end up with another pregnancy in a short interval. Additionally, women with these characteristics are less likely to receive family planning counselling which is offered at the household level by family planning workers [37].

Although the underlying reasons for such low use of services in the Sylhet division have yet not been explored, we believe this is mainly due to inadequate knowledge of reproductive goals [37]. Moreover, there are studies in Bangladesh, including the Sylhet division, that found women of disadvantaged backgrounds are highly influenced by religious misconceptions. For instance, many couples believe that the religion Islam (the religion of over 90% of the population in Bangladesh) supports *taking children as many as they want, and* contraception use is comparable to the *killing of humans* [37–39]. Consequently, the current approach to family planning services, including visits to women's homes by family planning workers every 14 days to provide reproductive counselling and contraception, may not work effectively in this division. Indeed, several recent studies reported a high prevalence of unmet need for contraception and particularly modern contraception in Sylhet compared to the other divisions [40,41]. Also, the prevalence of unintended pregnancy in this division is higher than in other parts of Bangladesh [37,42], and most of them occur in shorter intervals of the previous births [27]. Also, a relatively high proportion of men in the Sylhet division is either migrated aboard or locally [43]. Women having migrated partners are less likely to receive maternal healthcare services, a finding reported in Nepal [44] and Bangladesh [45]. Consequently, they have inadequate knowledge regarding birth spacing.

Literature suggests that the prevalence of adverse pregnancy outcomes, including child mortality, is relatively high in the Sylhet division and low in the Rajshahi and Khulna divisions [46,47] and are aligned with the SBI hot spots and cold spots, respectively. There seems to be a two-way relationship between adverse pregnancy outcomes and SBI; adverse outcomes occur due to a relatively high number of births in shorter intervals and vice versa. Findings from the studies in other settings of LIMCs [48–50] demonstrate relatively high birth intervals among couples with fewer children. Couples experiencing the death of a child or even witnessing such an event among the neighbours, are usually motivated to take another child considering the uncertainty, often in a shorter interval [49]. Similarly, women who are not engaged in formal jobs are likely to take babies in short intervals [15].

The findings of this study highlight the need for tailored programs in Bangladesh in general and the Sylhet division in particular to reduce the prevalence of SBI. Strengthening reproductive healthcare service delivery, including intrapartum, delivery, postpartum, and postpartum contraceptive services should be prioritized. Providing integrated reproductive healthcare services may help improve the current service delivery. Also, tailoring service modality considering the divisional level barriers is needed [36], as it is not possible in the current uniform top-down policy approach [35,36].

As far we know, this is the first study that explored the hot spots and cold spots of SBI and its associated factors in Bangladesh. The explanatory variables considered in this study were chosen based on a comprehensive review of the existing literature and finally by following the proper statistical model building techniques. The data were collected from two nationally representative surveys conducted in the same year using validated questionnaires. However, the analysis of cross-sectional data means that the findings are correlational only. To ensure the privacy of the respondents, the BDHS displaced cluster locations that we used in plotting our results in maps, up to five km in rural and two km in urban areas. Thus, the areas plotted in the maps as SBI hot spots or cold spots are slightly different from the actual areas from where data were collected, although divisions of data collection were the same. However, the findings are still valid as our results only highlight the potential areas of SBI hot spots or cold spots. Moreover, besides the socio-demographic factors included in this study, area level and environmental factors could also be important predictors of SBI hot spots and cold spots in Bangladesh, but we could not consider those variables in our analysis as they were not available. However, our adjusted variables explained around 65% of the total occurrences of SBI hot spots and cold spots.

Conclusion

We found evidence of substantial geographical variations in SBI in Bangladesh. SBI hot spots are mainly located in the Sylhet division, and SBI cold spots are mainly located in parts of the Rajshahi and Khulna divisions. Divisional variations in socio-demographic characteristics of women and their husbands were the main reasons for such geographical variation in SBI hot spots and cold spots. Targeted and divisional level policies and programs to provide integrated intrapartum, birthing, and postpartum care, including postpartum contraception, are needed to reduce the prevalence of SBI in Bangladesh in general and in the Sylhet division in particular.

Declarations

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability:

The datasets used and analyzed in this study are available from the Measure DHS website: https://dhsprogram.com/data/available-datasets.cfm

Ethics declaration

We analysed secondary data obtained from the data custodian, the Demographic and Health Survey program of the USA. They obtained ethical approval from Bangladesh Medical Research Council and the ethical board of the Demography and Health Survey program. The data collected was distributed in non-identifiable form. We, therefore, don’t need any ethical approval.

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Authors’ contributions:

MNK and MZI designed the study, performed the data analysis, and wrote the first draft of this manuscript. MMI and MMR critically reviewed and edited the previous versions of the manuscript. All authors approved the final version of this manuscript.

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Figures

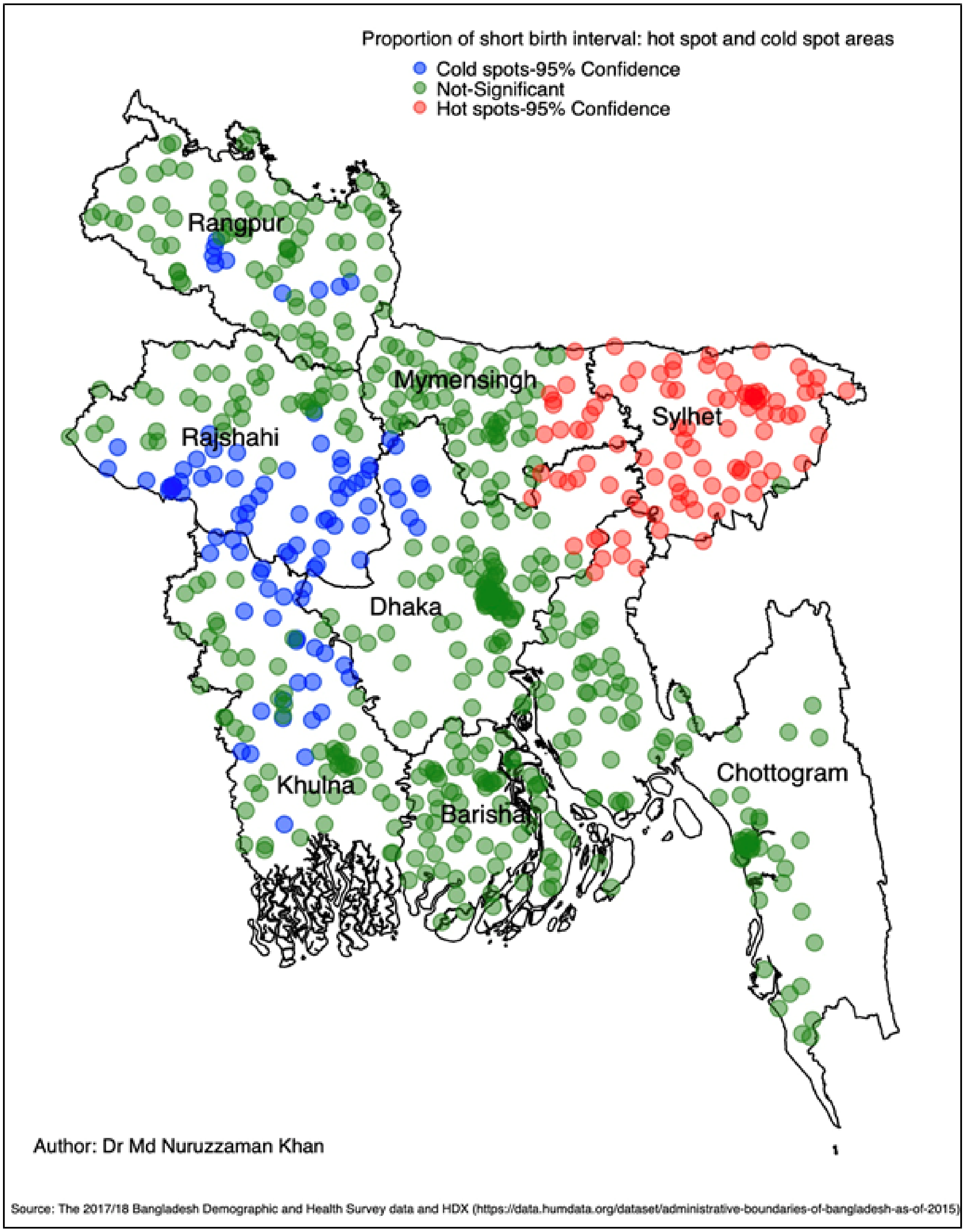

Figure 1

Hot spots and cold spots of short birth interval in Bangladesh 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.

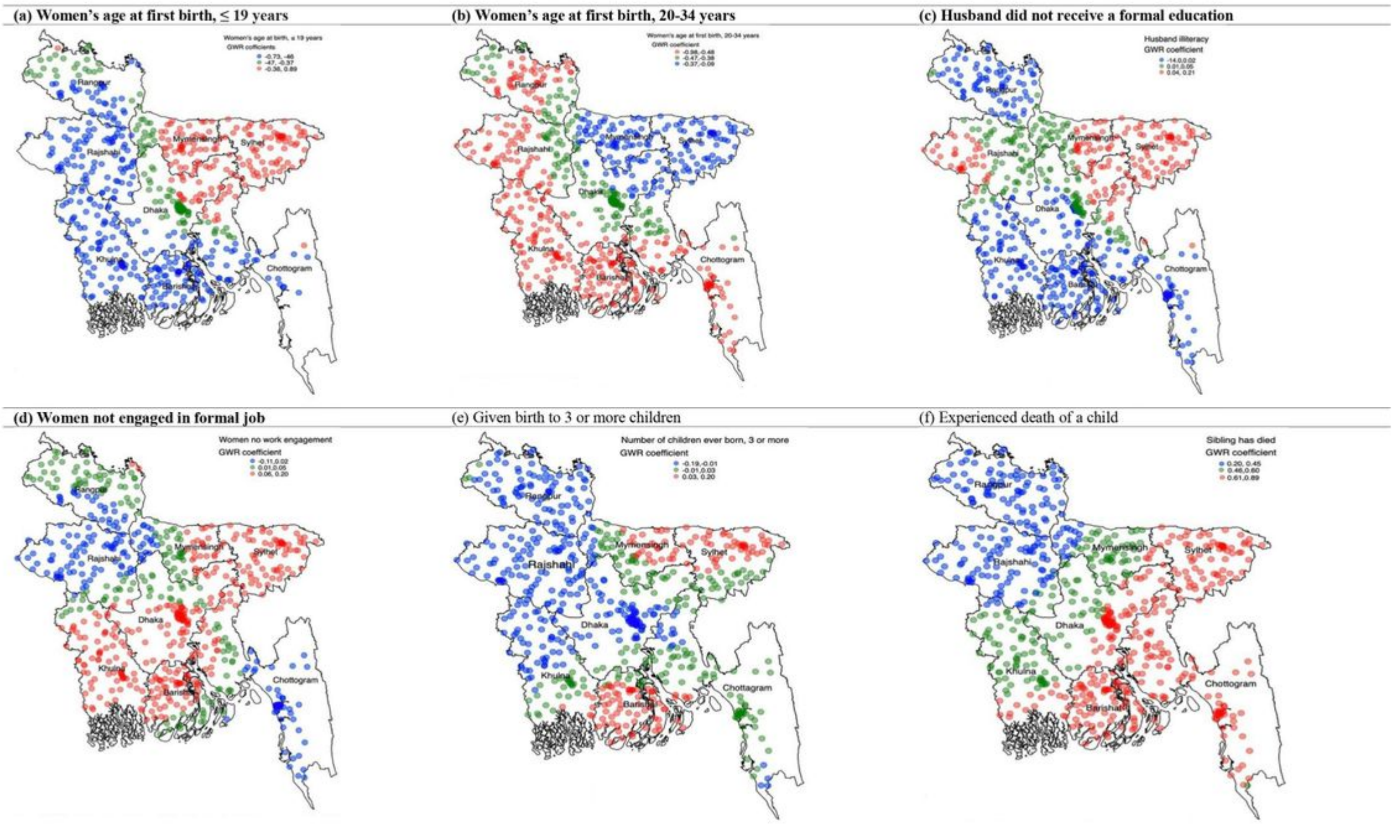

Figure 2

a-f: GWR coefficients predicting short birth interval in Bangladesh, BDHS 2017/18 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.