ORIGINAL ARTICLE

Do hot-spots of maternal mortality ratio exist in india? A district-level spatial analysis

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Abstract	Introduction	Methodology	Results	Conclusion	References	Citation	Tables / Figures

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Citation

Puranik A, Nair S, Binu VS, Biju S. Do hot-spots of maternal mortality ratio exist in india? A district-level spatial analysis. Indian J Comm Health. 2017; 29, 4: 369 – 375.

Source of Funding: Nil **Conflict of Interest:** None declared

Article Cycle

Received: 28/10/2017; **Revision:** 15/11/2017; **Accepted:** 20/12/2017; **Published:** 31/12/2017

Abstract

Background: Hot-spot detection of Maternal Mortality Ratio (MMR) can assist in identifying the exact geographic location of regions that need urgent attention. **Aims &Objectives**: To detect hot-spots of MMR at district level in the selected nine states of India and the observed pattern was further correlated with hot-spots of certain known risk factors of MMR in the same region. **Material &Methods**: Data on MMR was obtained from Annual Health Survey 2012-13. Moran's I was computed for MMR to quantify spatial autocorrelation. The hot-spot analysis of MMR and its potential risk factors were performed using Getis-Ord Gi* statistic, a measure of local indicators of spatial autocorrelation (LISA). The spatial analysis was based on queen's contiguity weight matrix and analyses were done using ArcGIS 10.3. **Results:** The Moran's I value of MMR was found to be 0.69 indicating a positive spatial autocorrelation. Districts with MMR hot-spotting was largely observed in Uttar Pradesh and Madhya Pradesh, followed by Assam, Bihar and Jharkhand. The hot-spot analysis unveiled an inverse relation of MMR with female literacy rate, mothers who received any antenatal check-up (%), mothers who utilized Janani Suraksha Yojana (%), safe delivery (%) and urbanization (%). Marriages among females below 18 years (%), total fertility rate and women with unmet need for spacing (%) had a direct relation with MMR. **Conclusion:** Information on hot-spots as depicted in this study can help locate the regions vulnerable to MMR and the potential risk factors, which in turn could aid in implementing targeted intervention programs.

Keywords

Maternal mortality; Moran's I; LISA; Hot-spots; Getis-Ord Gi*

Introduction

One third of global maternal death was contributed by India and Nigeria in the year 2010 (1). Among the South Asian countries, India ranks second in Maternal Mortality Ratio (MMR) superseded by Afghanistan (2). Although, India has succeeded in reducing MMR from 560 per 100 000 live births in 1990 to 190 per 100 000 live births in 2013, the country has fallen short in achieving the Millennium Development Goal of reducing MMR by 75% between 1990 and 2015 (3).

In order that scarce resources are utilized effectively, public health interventions need to be tailor made for a defined area based on prevailing problems and situations. Locating hot-spots of health events could help identify high risk geographical regions requiring interventions. Spatial data analytical methods are useful in detecting hot and cold-spots. Detecting hot-spots of MMR burden could facilitate mapping and identification of high risk regions which could in turn aid policy makers to channelize resources to the most needy.

A literature search for studies that assessed the spatial distribution of MMR resulted in very few studies that aimed at analyzing the spatio-temporal distribution of MMR. Studies were mostly from Brazil (4, 5) and there were no stated data from India.

Aims & Objectives

1. To detect hot-spots of MMR at the district level in nine selected states of India.
2. To correlate the observed pattern with hot-spots of certain known risk factors of MMR in the same region

Material & Methods

Study Type: Ecological study design. **Study Area:** Districts of nine states of India namely Bihar, Jharkhand, Uttar Pradesh, Uttarakhand, Madhya Pradesh, Chhattisgarh, Orissa, Rajasthan and Assam. These nine states constitute 59% of births, 70% of infant deaths, 75% of under-five deaths and 62% of the maternal deaths in India.

Data collection tools & measurements: Data on district level MMR in addition to information pertaining to female literacy rate, percentage of married females below the age of 18 years, percentage of mothers who received any antenatal check-up, percentage of mothers who utilized Janani Suraksha Yojana, percentage of safe delivery, total fertility rate (TFR), percentage of women with unmet need for spacing and percentage of urbanization was retrieved from the latest AHS (2012-13) reports of each state (6).

Data Analysis – statistical tests: Moran's I was computed for MMR to quantify spatial autocorrelation. Moran's I statistic quantifies the global autocorrelation which deciphers the clustering or dispersion of spatial data. Hot-spots of MMR and the potential risk factors were analyzed by means of local indicators of spatial autocorrelation (LISA) using ArcGIS 10.3 (ESRI, Redlands, CA). LISA is used to detect pockets of regions exhibiting homogeneous values that do not follow a global trend. The LISA statistic classifies regions based on the type of association and is depicted in the form of LISA maps. Getis-Ord Gi*, a measure of LISA was used to identify statistically significant hot-spots and cold-spots of MMR as well as the risk factors considered in the study. Gi* statistic follows normal distribution and the standardized Gi* statistic is given by

$$Z(G_i^*) = \frac{\sum_{j=1}^{n} w_{ij}x_j - \bar{x}\sum_{j=1}^{n} w_{ij}^2}{s\sqrt{\frac{n\sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2}{n-1}}}$$

where

xj = magnitude of variable X at a location j over all n

wij = value of weight to quantify spatial relationship between location i and j

The spatial analyses are unique since it exclusively accounts for the distance between the units of analysis in the form of the weight matrix. A spatial weight matrix defines the neighborhood set for each observation of the variable of interest and can be determined in various forms (7). In this study, we performed the spatial analysis based on queen's contiguity weight matrix. The standardized Z score value close to zero implies a random distribution of event of interest whereas positive and negative Z scores imply that high values and low values of event of interest produce clusters respectively. The calculated Z score greater than a threshold value associated with a statistical significance leads to the rejection of null hypothesis which imply that the cluster is a hot-spot. The hot-spot analysis map constructed using the Gi* scores depict significance of hot-spots at 1% (99% confidence), 5% (95% confidence) and 10% (90% confidence). Similar approach is followed for negative Gi* scores to detect significant cold-spots. The regions with calculated Z score close to zero indicate non-significant spatial clusters (P value > 0.1) (8).

Results

The nine states considered in this study are Bihar (MMR of 274 per 100 000 live births), Jharkhand (MMR of 245 per 100 000 live births), Uttar Pradesh (MMR of 258 per 100 000 live births), Uttarakhand (MMR of 165 per 100 000 live births), Madhya Pradesh (MMR of 227 per 100 000 live births), Chhattisgarh (MMR of 244 per 100 000 live births), Odisha (MMR of 230 per 100 000 live births), Rajasthan (MMR of 208 per 100 000 live births) and Assam (MMR of 301 per 100 000 live births) (6).

The Moran's I value of MMR was found to be 0.69 indicating a positive spatial autocorrelation. It could be inferred that the districts with high MMR are surrounded by districts with high MMR and districts with low MMR are surrounded by districts with low MMR which implies the existence of hot-spots and cold-spots respectively. Hence it was decided to further explore this relationship at the district level. Getis-Ord Gi* statistic was thereby used to detect the presence of hot and cold-spots of MMR in the districts of selected nine states of India. The red and blue regions in Figure 1 illustrate statistically significant hot-spots and cold-spots respectively. The map revealed the presence of three significant hot-spots. The districts forming hot-spots largely belonged to Uttar Pradesh and Madhya Pradesh followed by Assam, Bihar and Jharkhand. Few districts in Uttarakhand, Uttar Pradesh, Madhya Pradesh, Rajasthan and Jharkhand were identified as the cold-spots.

On correlating factor such as female literacy rate (Figure 2a), significant hot-spot formation was observed in the districts of Uttarakhand, Assam and Orissa. The districts of Uttarakhand where female literacy hot-spots exist were observed to have cold-spots of MMR. This indicates an inverse relation between female literacy rate and MMR in this region. Similar relation can be observed in Uttar Pradesh and Bihar where districts with cold-spots of female literacy rate were observed to have hot-spots of MMR. The districts of Assam however, showed hot-spots of both female literacy rate and MMR. A cold-spot of percentage of marriages among females below 18 years (Figure 2b) and MMR in Uttarakhand reveals a direct relation between the two factors. However, this relation was found to be inverted in few districts of Rajasthan and Madhya Pradesh.

The districts of Uttar Pradesh and Bihar formed cold-spots of percentage of mothers who received any antenatal check-up (Figure 2c) and formed hot-spots of MMR which implies that antenatal check-up has an inverse relation with MMR. However, this relation was not observed in Assam since hot-spots of both MMR and percentage of mothers who received any antenatal check-up existed. The districts of Uttar Pradesh that formed cold-spots of percentage of mothers who utilized JSY (Figure 2d) also formed cold-spots of MMR. In Madhya Pradesh, an opposite pattern was observed between these two variables.

The districts of Madhya Pradesh and Rajasthan that formed hot-spots for percentage of safe delivery (Figure 2e) showed cold-spots of MMR which indicates an inverse relation between these two variables. A similar inverse relation was observed in the bordering districts of Uttar Pradesh and Bihar that formed cold-spots of percentage of safe delivery and hot-spots of MMR. Hot-spots of TFR were observed in the bordering districts of Uttar Pradesh and Bihar which also formed hot-spots of MMR (Figure 2f). However, districts of Uttarakhand found to have cold-spots of both TFR and MMR while in Assam the districts that formed cold-spot of TFR also formed hot-spot of MMR.

Districts of Rajasthan and Uttarakhand (Figure 2g) illustrated cold-spots with regards to percentage of women with unmet need for spacing and MMR, thus depicting a direct relation between the two factors. In Assam however, this trend was reversed with districts displaying cold-spot for percentage of women with unmet need for spacing and a hot-spot for MMR. The districts of Madhya Pradesh implied an inverse relation between urbanization and MMR.

Discussion

This is the study that used spatial data analytical methods to explore the cold-spots as well as hot-spots of MMR and associated factors at district level in selected nine states of India. These nine states constitute 50% of the total population of India and contribute to more than 60% of all maternal deaths in the country. Large disparities in maternal deaths exist at the district level across these nine states and therefore a state level analysis can facade the spatial heterogeneity at district level. Also, these nine states are identified as poor performing states and it is important to determine the areas with high maternal deaths. Considering these requirements, we intended to analyze the spatial pattern of MMR and its known risk factors in the districts of selected nine states of India.

Among the various risk factors of MMR that was explored in this study, few were found to have a direct association while the others illustrated an inverse relation with MMR. The role of female literacy in reduction of MMR and improving maternal health has been demonstrated by studies in the recent past (9, 10). The present study observed a similar association in the districts of Uttarakhand, Uttar Pradesh and Bihar where lower female literacy rate correlated with higher rate of maternal mortality. Female literacy cold-spots observed in the border districts of Uttar Pradesh and Bihar probably reflects an additional influence of the bordering countries namely Nepal and Pakistan, where the female literacy rate is 57.4 and 48 respectively. Interestingly, hot-spots of female literacy and maternal mortality co-existed in Assam, indicating the role of factors above and beyond female literacy rate in influencing MMR in that region. For instance, timely access to medical facilities, availability of nutritional supplements and trained attendants are some of the related factors that our study did not account for due to non-availability of data at the district level in these nine states.

The importance of regular antenatal check-up in reducing MMR has been well established (11). One of the reasons for high MMR in the districts of Uttar Pradesh and Bihar has been attributed to the low percentage of mothers receiving antenatal check-ups. Conversely, the districts of Assam did not illustrate this relation since hot-spots of both factors existed in this region. Increase in percentage of antenatal check-ups in Assam could be attributed to Mamoni scheme introduced by Government of Assam to persuade pregnant women to undertake three antenatal check-ups (12).

In the year 2005, India launched JSY in all states and union territories with special focus on these nine states to increase the institutional births. This scheme provides cash incentives to pregnant women for institutional delivery (13-15). From our study we observed that the districts of Uttar Pradesh that had a lower utilization of JSY formed cold-spots of MMR. This pattern was not observed in Madhya Pradesh since there was an inverse relation between the two factors in this region. In few other districts of Madhya Pradesh, hot-spot of MMR was observed where cold-spot of JSY utilization existed. These patterns give an indication that JSY utilization alone was not related to increase or decrease in MMR in these regions (16). A study by Randive et al. indicated that JSY was successful in raising the proportion of institutional deliveries (17). However, in this study there was no significant relation observed between MMR and proportion of institutional births. This unleashes a paradigm that in addition to enforcing measures that promote institutional deliveries, there are many other drivers or reasons that need to be addressed to reduce the burden of MMR in the country. Safe delivery has been advocated as a key factor to reduce MMR by Shah et al. (18). The importance of safe delivery was observed in our study, where the districts of Madhya Pradesh and Rajasthan demonstrated hot-spots of safe delivery with cold-spots of MMR. A similar inverse relationship was observed in the border districts of Uttar Pradesh and Bihar that formed cold-spots of safe delivery with hot-spots of MMR.

An assessment of the situation of maternal mortality across 172 countries from 1990-2008 carried out by Brown et al. showed that greater fertility was associated with increased maternal mortality (19). In the present study, TFR and MMR depicted a direct relation as hot-spots of TFR in the bordering districts of Uttar Pradesh and Bihar correlated with hot-spots of MMR in the same regions. Like-wise cold-spots of TFR and MMR in Uttarakhand further indicated this direct association. However, Assam demonstrated an inverse relationship with a low TFR but hot-spots suggesting a high MMR. This further indicates to look beyond the established factors in this region that is notorious for its difficult and tough terrain.

Ahmed et al. stated that maternal mortality could be reduced by family planning i.e. reducing number of unwanted pregnancies by using contraceptive (20). Our study findings from the districts of Rajasthan and Uttarakhand concurred with this, while Assam showed an inverse relationship thus deviating from existing literature.

Montgomery et al. studied the distribution of maternal mortality among the poor and better off states of India from 2001–2003. They concluded that poor access and utilization of healthcare services was observed in rural parts of poorer states, which led to a higher prevalence of maternal mortality in these areas as compared to the urban areas where the access to medical services was easier (21). These findings were echoed in the study by Singh et al. (22). Our study illustrated a similar association in the districts of Madhya Pradesh, where cold-spots of MMR corresponded with hot-spots of urbanization.

Marriage at an early age leads to early pregnancy. A multi-country study by World Health Organization elucidated the elevated risk of adverse pregnancy outcomes in young mothers (23). This was typically illustrated in Uttarakhand wherein low percentage of marriages among females below 18 years of age corresponded with low MMR. Curiously few districts of Rajasthan and Madhya Pradesh did not concur with this finding as these regions documented hot-spots of early marriage but cold-spots of MMR. However, it should also be noted that some of these districts formed hot-spots of safe delivery and JSY utilization.

In addition to the factors considered in the study, various direct medical conditions such as sepsis, anaemia, pregnancy-induced hypertension and haemorrhage are potential causes of maternal deaths in India (24, 25) and these factors could not be explored due to paucity of data.

Conclusion

The present study attempted to detect hot-spots of MMR in the districts of the selected nine states of India. The hot-spots were found in Uttar Pradesh, Madhya Pradesh, Assam, Bihar and Jharkhand. This study also made an attempt to correlate the observed spatial pattern of MMR with that among various risk factors. An inverse relation of MMR with female literacy rate, mothers who received any antenatal check-up (%), mothers who utilized Janani Suraksha Yojana (%), safe delivery (%) and urbanization (%) was observed. Marriages among females below 18 years (%), total fertility rate and women with unmet need for spacing (%) had a direct relation with MMR.

Recommendation

Findings from this study could be used to scale up services in MMR vulnerable areas of the country thus helping programme managers to allocate sparse resources to those who really require it. The spatial analyses in this study showcase the benefits of identifying the hot-spots of maternal mortality in India and demonstrate the practicality of using spatial statistical methods on existing health data in identifying vulnerable areas.

Limitation of the study

Based as it is on aggregate level data rather than individual, there could be an ecological fallacy. Moreover, the findings of this study are limited to the selected nine states situated in the north, central and eastern part of the country. Considering the vast diversity that is India, it may not be appropriate to generalize these findings to the country as a whole.

Relevance of the study

The strength of this study is the district level analysis and the spatial methods used to decipher hot-spots of maternal mortality ratio in the selected nine states. This could help in investigating hitherto unknown factors associated with the increased and unequal distribution of MMR across the districts of India and thus aid policy makers for improved decision-making

Authors Contribution

BVS conceptualized the idea; AP conducted the literature search, acquired the data, performed statistical analysis, interpreted the results and prepared the manuscript. BVS, SN and SB provided input in interpreting the results, manuscript editing and review.

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Tables

TABLE 1 STATE-WISE SUMMARY OF EACH FACTOR CONSIDERED IN THE STUDY

Factors	BR	JH	UP	UK	MP	CG	OD	RJ	AS
	Min-max	Min-max	Min-max	Min-max	Min-max	Min-max	Min-max	Min-max	Min-max
Female literacy rate (%)	3.5-36.4	50.2-74.4	40.3-80.7	64.6-86.1	42.2-86.6	44.5-75.8	43.6-86.0	46.2-73.1	65.0-87.4
Marriages among females below 18 years (%)	3.5-36.4	4.7-24.3	0.4-28.9	0.7-5.3	1.1-27.1	1.4-11.9	6.0-16.0	3.1-37.0	3.8-18.2
Mothers who received antenatal check-up (%)	74.1-96.0	85.7-97.9	61.6-97.0	74.1-94.8	80.4-98.0	87.5-97.8	94.0-99.7	59.9-97.2	88.1-98.5
Mothers who utilized JSY (%)	23.2-57.2	13.3-44.4	15.7-70.4	17.8-57.6	48.6-88.1	21.4-67.3	47.4-81.3	35.3-84.2	34.0-78.5
Safe delivery (%)	42.9-83.1	38.5-75.8	39.1-90.8	49.9-85.4	61.9-97.9	42.8-80.9	56.9-96.2	60.8-94.8	44.1-90.5
TFR	2.6-4.6	2.2-3.7	2.1-5.5	1.7-2.7	2.0-4.1	2.3-3.6	1.8-3.5	2.4-4.4	1.9-3.7
Unmet need for spacing (%)	11.4-27.9	5.8-20.9	6.0-20.0	4.0-17.0	5.7-22.9	8.6-20.4	4.3-24.5	2.8-12.3	3.7-13.0
Urbanization (%)	1.0-33.7	4.8-56.9	2.0-71.9	0.5-51.5	8.0-84.6	4.8-41.5	3.8-43.4	4.3-46.8	2.7-56.9

BR-Bihar, JH-Jharkhand, UP-Uttar Pradesh, UK-Uttarakhand, MP-Madhya Pradesh, CG-Chhattisgarh, OD-Orissa, RJ-Rajasthan, AS-Assam

Figures

FIGURE 1 HOT-SPOT ANALYSIS MAP DEPICTING HOT-SPOTS AND COLD-SPOTS (ALONG WITH THE STATISTICAL SIGNIFICANCE) OF MMR IN THE DISTRICTS OF SELECTED NINE STATES OF INDIA

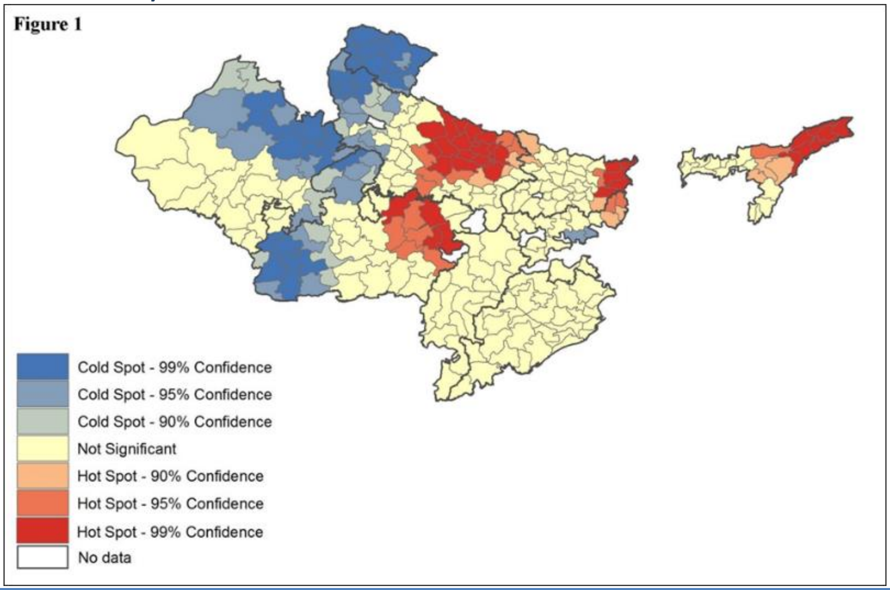

FIGURE 2HOT-SPOT ANALYSIS MAP DEPICTING HOT-SPOTS AND COLD-SPOTS (ALONG WITH THE STATISTICAL SIGNIFICANCE) OF A. FEMALE LITERACY RATE, B. MARRIAGES AMONG FEMALES BELOW 18 YEARS (%), C. MOTHERS WHO RECEIVED ANY ANTENATAL CHECK-UP (%), D. MOTHERS WHO UTILIZED JSY (%), E. SAFE DELIVERY (%), F. TFR, G. UNMET NEED FOR SPACING (%), H. URBANIZATION (%) IN DISTRICTS OF THE SELECTED NINE STATES OF INDIA