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Space-time cluster analysis of anemia in pregnant women in the province of Khyber Pakhtunkhwa, Pakistan (2014-2020)

Sami Ullah,[1] SM Aqil Burney,[2] Tariq Rasheed,[3] Shamaila Burney,[4] Mushtaq Ahmad Khan Barakzai[2]

[1]Department of Statistics and Data Science, Faculty of Science, Beijing University of Technology, Beijing, China; [2]Mathematics and Statistics Department, Institute of Business Management, Korangi Creek, Karachi, Pakistan; [3]Department of English, College of Science and Humanities, Prince Sattam Bin Abdulaziz University, Alkharj, Saudi Arabia; [4]Department of Business Administration, Salim Habib University, Karachi, Pakistan

Abstract

Anaemia is a common public-health problem affecting about two-thirds of pregnant women in developing countries. Space-time cluster analysis of anemia cases is important for public-health policymakers to design evidence-based intervention strategies. This study discovered the potential space-time clusters of anemia in pregnant women in Khyber Pakhtunkhwa Province, Pakistan, from 2014 to 2020 using space-time scan statistic (SatScan). The results show that the most likely cluster of anemia was seen in the rural areas in the eastern part of the province covering five districts from 2017 to 2019. However, three secondary clusters in the West and one in the North were still active, signifying important targets of interest for public-health interventions. The potential anemia clusters in the province's rural areas might be associated with the lack of nutritional education in women and lack of access to sufficient diet due to financial constraints.

Correspondence: Sami Ullah, Department of Statistics and Data Science, Faculty of Science, Beijing University of Technology, Beijing 100124, China. Tel.: +86.17813072535.
E-mail: sami.khan3891@gmail.com

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Introduction

Anemia is a nutritional deficiency disease and a major public-health problem, particularly in pregnant women in developing countries (WHO, 1992). Higher maternal age, high parity, lower education, poor socioeconomic status, and poor nutrition were found to be the main determinants of anemia in developing countries (Ali *et al.*, 2020). Anemia in pregnant women is highly associated with maternal mortality, preterm births, intrauterine deaths, fetal anemia, and low birth weight (Ali *et al.*, 2011; Allen, 2000; Figueiredo *et al.*, 2018).

In Pakistan, around 50% of women of reproductive age are anemic, with a higher proportion in pregnant women (Lone *et al.*, 2004; Kassa *et al.*, 2017). According to a recent National Nutritional Survey in 2018, around 41.7% of women of reproductive age are anemic in Pakistan, with a higher proportion in the rural areas (Government of Pakistan UNICEF, 2019).

A few studies on the prevalence of anemia in pregnant women have already been carried out in some parts of Pakistan (Baig-Ansari *et al.*, 2008; Shams *et al.*, 2017; Ullah *et al.*, 2019; Ullah *et al.*, 2013). These studies have focused on the prevalence in pregnant women and its associated risk factors in a single county. However, a space-time cluster analysis of anemia in pregnant women in Pakistan has not been carried out. This kind of analysis can identify significant spatiotemporal patterns of anemia occurrence in pregnant women. Its application in the study area would be valuable for health policymakers in designing evidence-based control strategies since space-time cluster analysis assists in finding the possible environmental and socio-economic determinants of anemia in pregnant women. This study aimed to discover the space-time clusters of anemia in pregnant women in the entire area of the province of Khyber Pakhtunkhwa (KP), Pakistan from 2014 to 2019 using space-time scan statistic (Kulldorff *et al.*, 1998).

Generally, statistical methods for automatic cluster detection are divided into two groups: global and local ones. The former can only assess the global tendency of clustering in the disease cases in an area without identifying the cluster locations (de Roza *et al.*, 2012; Kulldorff & Hjalmars, 1999; Liu *et al.*, 2012). On the other hand, local methods identify the specific geographic locations and time-frames of the potential clusters (Kulldorff, 2001; Kulldorff *et al.*, 1998, 2005). The local clustering methods are further categorized as clustering methods (Birant & Kut, 2007; Levine, 2006; Xie & Yan, 2008) and scan statistics (Kulldorff, 2001; Kulldorff *et al.*, 1998, 2005). Scan statistics techniques have been used extensively for detecting spatial and space-time clusters of public-health interest and in the environment in general (Ullah *et al.*,

2020; Ballesteros *et al*., 2021; Greene *et al*., 2021; Ullah, Daud, *et al*., 2021; Ullah, Nor, *et al*., 2021; Gleason & Ross, 2022). We applied the scan statistic using a freely available software, SaTScan (Kulldorff, 2018) under Poisson distribution to identify the significant spatiotemporal clusters of anaemia in pregnant women in KP Province, Pakistan.

Materials and Methods

Study-area and data collection

This study was conducted in the KP Province, which is located in the north-western part of Pakistan. The terrestrial area of this province is divided into 25 districts (Figure 1) that also includes the neighboring Federally Administered Tribal Areas, which have been combined with KP Province. The latest census population of this province is 30.52 million with a total area of 74,521 km^2.

The yearly data on anemia cases in pregnant women and the female population in each district were collected from the District Health Information System (DHIS), KP, Pakistan (DHIS, 2020). This system records the number of observed disease cases at the district level on a monthly basis. All of the hospitals in each district send the disease count data to the corresponding DHIS office at the district level every month. The DHIS offices in all districts send these data further to the provincial DHIS office, KP.

Space-time cluster detection

The scan statistic method applied was the SaTScan™ ver. 9.6 (Kulldorff, 2018). We used retrospective space-time analysis with a Poisson probability model to detect the spatiotemporal anaemia clusters of anaemia in pregnant women at the district-level in KP Province from 2014 to 2020. This approach assumes that the disease count follows a Poisson distribution with parameter λ as in Equation 1.

$$\lambda = \mu(z)\frac{nG}{\mu(G)} \qquad \text{(Eq. 1)}$$

where μ(z) represents the population of the sub-region z; μ(G) the overall population of the KP Province; and nG the total of the observed disease cases in KP Province. Under the null hypothesis (that no cluster occurs), the expected disease-counts in each sub-region is proportional to its population size. The space-time scan statistics is described by a cylindrical window with the circular base where the base corresponds to the terrestrial size and the height to the time frame of the cluster. The circular base of the cylinder was positioned on one of the county-centroids, whose radius varied from zero up to the maximum spatial window size and the height from zero to the maximum temporal size. The window was then moved in spatial and temporal dimensions to test for clusters of all probable sizes. Thus, a large number of overlying windows of different sizes were formed where each window (together with its cylinder) represented a candidate cluster. The log-likelihood ratio (LLR) was calculated over each window and the window with the maximum LLR named the most-likely cluster, *i.e.* the least likely to occur by chance. The other window/cylinders with significant LLRs were considered secondary space-time clusters. The significance of the potential clusters was tested by comparing the LLR value against the null distribution attained from the Monte-Carlo simulation (https://www.satscan.org/techdoc.html).

We executed the space-time scan statistic by setting the maximum size of the spatial window to a size covering 50% of the total population and the maximum temporal size to 50% of the study period (https://www.satscan.org/techdoc.html). The Monte-Carlo method with 9.999 replications was carried out to test a null hypothesis of no difference with respect to the relative-risk (RR) between the clusters. The level of significance was set at p<0.001.

Results

The space-time scan statistic detected a total of six spatiotemporal clusters of anemia cases in pregnant women in different parts of the study area during the period from 2014 to 2020. The results are summarized in Table 1 and the geographical locations of the space-time anemia clusters in the province are shown in Figure 2. The most likely cluster was detected in the eastern part of the province covering five districts (Abbottabad, Mansehra, Haripur, Toor Ghar, and Battagram) over three years 2017-2019. The secondary cluster covered a single district (Tank) for the period 2018-2020, while the third and fourth level clusters were observed in the northern part, each covering a single district: Malakand for the years 2016-2018 and Chitral for the years 2018-2020, respectively. The fifth cluster covered a single district, Hangu in the western part for the years 2019-2020, while the sixth cluster was perceived in the two central districts (Charsadda, Peshawar) for the last year of the study period. All of these clusters were significant at P< 0.001.

The results showed that the earliest clusters appeared in 2016

Table 1. The space-time clusters of anaemia in KP, Pakistan, 2014-2020.

Cluster type	Districts	No. of districts	Time-frame	Observed cases	Expected cases	LLR	P
Most Likely	Abbottabad, Mansehra, Haripur, Toor Ghar, Battagram	5	2017-2019	139845	46123.72	68342.67	<0.001
1st secondary	Tank	1	2018-2020	15384	1856.71	19132.51	<0.001
2nd secondary	Malakand	1	2016-2018	28220	7293.00	17572.53	<0.001
3rd secondary	Chitral	1	2019-2020	13836	4510.03	6245.64	<0.001
4th secondary	Hangu	1	2019-2020	9663	3656.10	3410.23	<0.001
5th secondary	Charsadda, Peshawar	2	2020-2020	24077	19467.32	522.57	<0.001

in Malakand District which persisted until 2018. In 2017, it appeared in the eastern part with the highest intensity and with the largest geographical size, which persisted until 2019. However, the rest of the four clusters persisted until the end of the study period. These active clusters are of high significance for public-health departments to identify their target of interest for possible interventions. In the active clusters, one occurred is in the northern district and three in the western districts. The last cluster covering two districts (Charsadda and Peshawar) occurred in the last year. These active clusters suggest these districts to be the emerging clusters that may become the most likely clusters with high intensity of anemia risk in the future if not effectively intervened by the health department.

Discussion and Conclusions

The period 2018-2020 shows the largest number of anemia clusters in the province (Figure 2). This result shows an increasing trend in the number of anemia clusters from 2014 to 2020 despite the huge increase in the number of health facilities in the province where the health facilities have increased from 786 in 2015 to 1445 in 2018 (BOS Khyber Pakhtunwa, 2019). The increased number of anemia clusters might be due to the high inflation in the country which limits the access of the poor population to sufficient healthy foods which was found to be one of the determinants of anemia (Ali *et al.*, 2020). The temporal graph in Figure 3 shows that the period 2017-2019 was perceived as a temporal cluster of anemia in pregnant women in the study-area with the highest volume in 2018.

This study identified the potential space-time clusters of anemia in pregnant women in different parts of KP province, Pakistan from 2014 to 2020. Most of the anemia clusters were found in the rural areas of KP Province, however, one cluster emerged in 2020 covering the urban district Peshawar, the capital city of KP province. The most likely cluster emerged in 2017 covering the largest number of districts in the eastern hilly areas which persisted until 2019. This shows that the anemia cases in pregnant women tend to cluster in the remote rural areas of the province and the period 2017-2020. In addition, most of the clus-

Figure 1. Map of Khyber Pakhtunkhwa province.

Figure 2. Geographical locations of space-time anaemia clusters.

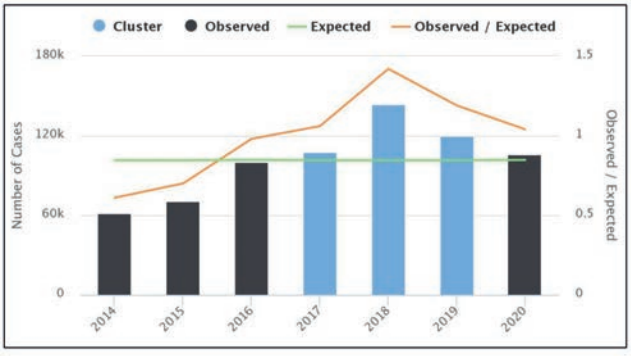

Figure 3. Temporal cluster of Anaemia in pregnant women in the study-area.

ters were found still active in the year 2020 suggesting these regions to be the important targets of interest for possible interventions. Moreover, the number of anemia clusters shows an increasing trend over time. These findings may help the policy-maker to design evidence-based intervention strategies. In addition, these findings may guide the epidemiologic research for investigate the environmental and socio-economic determinants of anemia in pregnant women in the study-area.

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