



Contents lists available at ScienceDirect

Journal of Infection and Public Health

journal homepage: <http://www.elsevier.com/locate/jiph>



Effect of meteorological variables on *Plasmodium vivax* and *Plasmodium falciparum* malaria in outbreak prone districts of Rajasthan, India

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ARTICLE INFO

Article history:

Received 6 October 2016
Received in revised form 2 January 2017
Accepted 11 February 2017

Keywords:

Malaria outbreak
Meteorological variables
P. vivax
P. falciparum
India

ABSTRACT

Background: Malaria is a public health problem caused by *Plasmodium* parasite and transmitted by anopheline mosquitoes. Arid and semi-arid regions of western India are prone to malaria outbreaks. Malaria outbreak prone districts viz. Bikaner, Barmer and Jodhpur were selected to study the effect of meteorological variables on *Plasmodium vivax* and *Plasmodium falciparum* malaria outbreaks for the period of 2009–2012.

Method: The data of monthly malaria cases and meteorological variables was analysed using SPSS 20v. Spearman correlation analysis was conducted to examine the strength of the relationship between meteorological variables, *P. vivax* and *P. falciparum* malaria cases. Pearson's correlation analysis was carried out among the meteorological variables to observe the independent effect of each independent variable on the outcome.

Results: Results indicate that malaria outbreaks have occurred in Bikaner and Barmer due to continuous rains for more than two months. Rainfall has shown to be an important predictor of malaria outbreaks in Rajasthan. *P. vivax* is more significantly correlated with rainfall, minimum temperature ($P < 0.01$) and less significantly with relative humidity ($P < 0.05$); whereas *P. falciparum* is significantly correlated with rainfall, relative humidity ($P < 0.01$) and less significantly with temperature ($P < 0.05$). The determination of the lag period for *P. vivax* is relative humidity and for *P. falciparum* is temperature. The lag period between malaria cases and rainfall is shorter for *P. vivax* than *P. falciparum*.

Conclusion: In conclusion, the knowledge generated is not only useful to take prompt malaria control interventions but also helpful to develop better forecasting model in outbreak prone regions.

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Introduction

Malaria is a public health problem caused by *Plasmodium* parasite and transmitted by anopheline mosquitoes. India is one of the highest malaria burdened countries in South East Asia, with more than one million confirmed malaria cases in 2014 [1]. *Plasmodium falciparum* (*P. falciparum*) and *Plasmodium vivax* (*P. vivax*) are the major parasites causing about 66% and 34% of malaria in India [2]. The intensity of this disease is different from place to place depending on epidemiological, geographical and meteorological factors. In India, malaria burden is higher in North-eastern states, Orissa, Chhattisgarh and Jharkhand, whereas the other states are less vulnerable but have local upsurge [1]. A previous record of most

devastating malaria epidemics has occurred in Punjab, a semi-arid region of India [3]. After malaria eradication efforts in the 1970s, the epidemic belt shifted to arid regions of Gujarat and Rajasthan [4,5]. The desert region of Rajasthan has experienced major epidemics in Barmer, Bikaner, Jaisalmer, Jodhpur, Pali, and Sri Ganganagar [5,6]. The semi-arid and arid regions of western India are treated as unstable malaria zone, where low and high incidences are being influenced by rainfall [7,8]. Therefore the situation is more complex by malaria outbreaks due to climatic factors.

It is well known that meteorological variables are drivers of malaria transmission apart from socioeconomic conditions and agricultural practices [9]. A positive association between meteorological variables and malaria transmission has been reported from India and across the world [10,11]. Apart from this, in 1990's Tyagi et al. reported that construction of major canal systems provided the breeding sites for malaria vectors, which led to malaria epidemics in Bikaner and Jodhpur [5]. In Barmer, after a prolonged

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<http://dx.doi.org/10.1016/j.jiph.2017.02.007>

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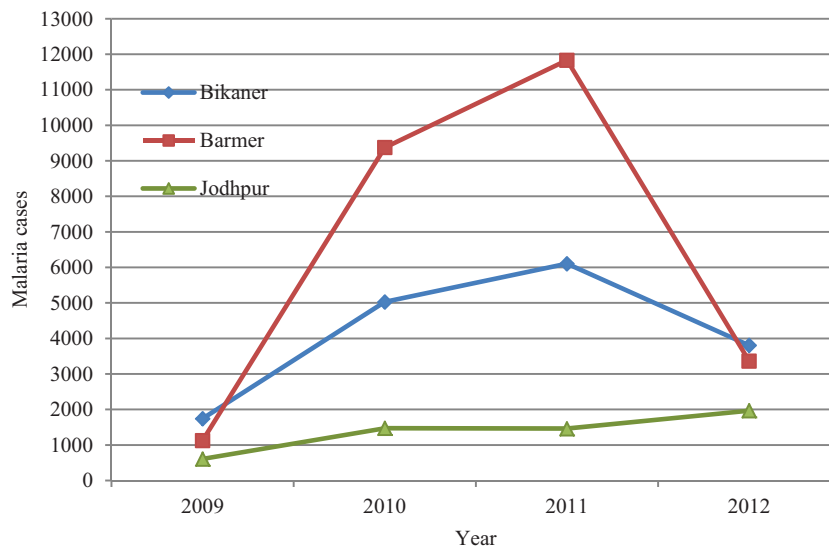


Fig. 1. Malaria incidence during 2009–2012 in Bikaner, Barmer and Jodhpur districts. The figure demonstrates that the annual trend of malaria cases in the above districts, malaria outbreaks were observed in Bikaner and Barmer in the years 2010 and 2011. Later, sharp drop of cases were observed in 2012. In Jodhpur, malaria cases increased gradually without causing any outbreak.

drought phase, normal rains during 1988 and 1989 led to floods that have resulted in malaria epidemics [7]. A study from the north-west India (Kutch, Gujarat) reported that rainfall is the influencing factor of malaria epidemics [12]. The above studies indicate that malaria outbreaks are multi-factorial and depend on the changing situation of that area and environmental factors.

However, previous investigations from Bikaner, Barmer and Jodhpur districts have provided information about the rainfall but did not provide the information regarding the effect of meteorological variables on *P. vivax* and *P. falciparum* malaria outbreaks. Apart from this, there is no current literature on meteorological factors in association with the malaria outbreaks in the present climate change scenario and still depends on the literature provided in 1990's. So, for the present study, a retrospective analysis is made to explore the effect of meteorological variables such as temperature, rainfall, and relative humidity on *P. vivax* and *P. falciparum* malaria in the outbreak prone districts of Bikaner, Barmer and Jodhpur in Rajasthan.

Materials and methods

Study area

Rajasthan is the largest state by area and is located in north-western India and the great Thar Desert is located in Rajasthan. Outbreak prone districts of Bikaner, Barmer, and Jodhpur were selected for the detailed analysis; where Bikaner and Barmer are situated in the centre and western part of the Thar Desert. Jodhpur is located in the western part of Rajasthan and shares a common border with five districts viz., Bikaner, Jaisalmer, Barmer, Pali, and Nagaur.

Data collection

Records of total monthly malaria cases of *P. vivax* and *P. falciparum* in respect of above referred three districts from January 2009–December 2012 were procured from National Vector Borne Disease Control Programme (NVBDCP), New Delhi. The monthly data of mean minimum and maximum temperature ($^{\circ}\text{C}$), relative humidity (at 8:30 IST and 5:30 IST) and monthly rainfall were procured from the Indian Meteorological Department, Pune for the same above period.

Data analysis

The data was analysed using Microsoft Excel version 2007 and SPSS 20v. The monthly cases of malaria was treated as the dependent variable and the meteorological variables such as monthly mean temperature (minimum, maximum and average), monthly total rainfall and monthly mean relative humidity (at 8:30 IST and 5:30 IST) as independent variables. Missing data values of independent variables were interpolated by linear interpolation. Spearman correlation analysis was conducted to examine the strength of the relationship between meteorological variables, *P. vivax* and *P. falciparum* malaria cases. Pearson's correlation analysis was carried out among the meteorological variables to observe the independent effect of each independent variable on the outcome.

Results

Trend of malaria cases in Bikaner, Barmer, and Jodhpur

Annual trend of malaria cases was analysed for the period of 2009–2012 in Bikaner, Barmer, and Jodhpur districts. Malaria cases in Bikaner showed a gradual increase in the total number of cases during 2009 (1743), with a peak in 2011 with 6103 cases and thereafter the cases were decreased to 3804 in 2012. A similar trend was observed in Barmer, where 1125 malaria cases were recorded during 2009 and a sudden increase of eight to ten-fold was observed in the successive years with a total number of 9373, 11,831 cases respectively. Later, a sharp drop in cases was observed in 2012 with 3361 cases. Trend of malaria cases in Jodhpur was different from Bikaner and Barmer, where only 608 malaria cases were recorded in 2009, which increased to 1473 in 2010 and stable in 2011; however, in 2012 slight increase in the number (1967) was recorded (Fig. 1). The trend of monthly malaria cases showed that malaria peak was observed in the month of September/October in all the study areas (Fig. 2). At the species level, the maximum number of malaria cases were due to *P. vivax* rather than *P. falciparum* in the above three districts.

Trend of meteorological variables

During the study period in Bikaner, the maximum temperature was 44°C , the minimum temperature is 6°C and maximum rain-

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