Association between rainfall and the prevalence of clinical cases of dengue in Thiruvananthapuram district, India

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Abstract
Dengue fever is a fast spreading mosquito borne viral disease transmitted by Aedes mosquitoes. The abundance and the transmission potential of Aedes mosquitoes are influenced by climatic factors. An investigation was carried out in Thiruvananthapuram district, Kerala to study the correlation between rainfall and prevalence of dengue infection during 2015–2019. Dengue data (2015–2019) were collected from Directorate of Health Services, Thiruvananthapuram and the rainfall data were derived from Indian Meteorological Department, Thiruvananthapuram. The correlation between the rainfall and the prevalence of dengue was assessed by regression analysis. Dengue cases usually follow a seasonal pattern, with most of the cases reported during the monsoon season. Rainfall were positively associated with the number of dengue cases and highly significant correlation was found between dengue cases and rainfall. The regression equation for prevalence of dengue (y) versus rainfall (x) is y = 1.28 x + 31.03 (r = 0.875, p < 0.001). The study indicated that the prevalence of dengue infection in Thiruvananthapuram district may depend on rainfall. Therefore, intensified surveillance and control of mosquito during the period with heavy rainfall is recommended.

Keywords: Dengue, rainfall, correlation, Thiruvananthapuram

Introduction
Dengue fever is a fast spreading mosquito borne viral disease transmitted by Aedes mosquitoes. Dengue viruses belong to family Flaviviridae and there are four serotypes of dengue viruses DENV-1, DENV-2, DENV-3, and DENV-4. Persons infected with dengue exhibit a wide spectrum of clinical symptoms ranging from asymptomatic to severe clinical manifestations, such as dengue shock syndrome [1]. The number of dengue cases has increased 30-fold globally over the past five decades [2] and about 40% of the world's population are now at risk of dengue [3]. Dengue is a major public health problem in India as dengue has expanded dramatically over the last few decades and at present in most of the states of India, dengue is almost endemic [4]. Some studies have reported that climate change might be responsible for the observed increase in dengue cases across India [5]. Climatic conditions mainly rainfall and temperature affects mosquito abundance and dengue transmission rate [6, 7]. Temperature influences the transmission of dengue fever via the survival and development of mosquito vectors, virus replication, biting rate and incubation period [8]. Rainfall provides breeding sites and stimulates eggs hatching for mosquitoes and therefore vector abundance [9, 10] as it breeds well in the open containers in and around houses.

India receives 75% of its rainfall during the southwest monsoon period from June to September [11] and Indian monsoon rainfall provides ample breeding habitats for dengue vectors Ae. aegypti and Ae. albopictus, thus leading to high vector densities [12]. Kerala gets rains in four spells: winter (January - February), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-December). Rainfall is scanty in the pre-monsoon period where as the southwest monsoon, from June to September, accounts for heavy rainfall. The northeast monsoon, starting in October and lasting up to December, is marked with moderate rainfall. Of the total annual rainfall (945 mm) in the state, 48% is received during the southwest monsoon, 32% during the northeast monsoon and the rest during other seasons.
A recent study has compiled all dengue outbreaks in India\(^{13}\), and it showed that most dengue outbreaks occurred in Punjab, Haryana, Rajasthan, Gujarat and Kerala states during the monsoon or post monsoon period. Kerala experiences the highest number of dengue cases, possibly because of higher percentage of infected mosquitoes, availability of breeding grounds, suitable temperature ranges (23.5–30 °C) and subsequent short incubation periods in all seasons (9–14 days) especially during the rainy seasons\(^{14, 15}\). However, the trend of dengue cases in Kerala doesn’t show any clear pattern. From 2010 to 2019 there were upswings and downswings in the number of cases\(^{16}\).

The district of Thiruvananthapuram reports two-third cases of dengue in the state of Kerala\(^{17}\) and has witnessed a substantial rise in the incidence of dengue cases since 2010\(^{18}\). In the year 2017 outbreaks of dengue with severe clinical manifestations were reported in the district\(^{19}\). The climate of Thiruvananthapuram is mostly hot tropical, with the monsoon season extending from June to October. The average annual rainfall in Thiruvananthapuram is 114.7 cm\(^{20}\) and the district is located at a relatively low altitude. The relationship between incidence of dengue and climate remains poorly understood and often differs across settings because of local climate heterogeneity\(^{21}\). Hence the influence of different climatic factors is certainly important to track the dengue fever transmission procedures. In this context an attempt has done to understand the influence of rainfall on dengue incidence of Thiruvananthapuram district, Kerala.

Materials and methods

In this study we have used five (2015–2019) years of monthly data on rainfall and reported cases of dengue in Thiruvananthapuram district, Kerala. The number of monthly reported dengue cases (from January 2015 to December 2019) were collected from Directorate of Health Services (DHS), Government of Kerala, Thiruvananthapuram. Since dengue is a notifiable disease, all the laboratory confirmed cases, including those from the private sector, were reported to the health services. Monthly rainfall data of the district were collected from the Indian Meteorological Department (IMD), Thiruvananthapuram. Since rainfall is different in different parts of the district an averaged data from four substations of the district is used for the study.

The data on monthly rainfall were correlated with the monthly dengue cases using Pearson’s correlation. A regression analysis was also attempted to understand the nature of association between the two variables (rainfall and dengue cases). Data on monthly rainfall was taken as independent variable and the reported dengue cases as dependent variable while attempting linear regression.

The model equation that was developed followed a regression relationship is:

\[
Y = B \times x + C
\]

where \(Y\) is the dengue incidence, \(B\) is the slope parameter, \(x\) is the monthly measurement of rainfall and \(C\) is the intercept parameter. The developed linear regression equation suggests that every increase in the rainfall, no matter how small, results in an incremental increase in dengue incidence. All statistical analyses were performed using SPSS software.

Result

Over the last 5 years (2015–2019), 13,515 dengue cases were reported from Thiruvananthapuram District by DHS and the number of reported cases varied from year to year. The highest dengue incidences were reported in 2017 (\(n = 8955\)) and lowest in 2018(\(n = 311\)). However, the deaths were negligible in contrast with the number of cases reported (Fig.1). The monthly dengue incidence data showed a distinct pattern of incidence (fig.2) with maximum number of cases reported during the monsoon season which starts in the month of June and peaks in months of July and August. The number of cases decline in November and December every year.

The mean monthly rainfall during the monsoon period in 2015, 2016, 2017, 2018 and 2019 was 227mm, 393mm, 409mm, 542mm, and 384mm respectively. The data showed that there is strong association between monthly dengue cases and monthly rainfall every year (fig.3–7). The peaks of dengue cases and rainfall matched perfectly which suggest that the dengue cases are related to rainfalls.
Pearson’s correlation analysis was performed to find relation between the numbers of monthly reported dengue fever cases with monthly average rainfall. High correlation was observed between average rain fall with average cases (76.5%; r= 0.875) (fig.8). When the data was analysed yearly, in 2017 there was highest correlation (73%; r=0.854) followed by year 2016(68%; r= 0.828) followed in 2018 correlation (56%; r= 0.747) whereas the years 2015 & 2019 shows low percentage of correlation with the rainfall (52%; r= 0.726) & (32%; r= 0.564) respectively. The details of correlation between rainfall and dengue cases are presented in Table 1.

The least square equation plot Dengue prevalence (y) versus rainfall (x) is y = 1.28 x + 31.03 (r = 0.875, p < 0.001).

Table 1: Correlation between dengue cases and rainfall from 2015 to 2019

|        | 2015    | 2016    | 2017    | 2018    | 2019    |
|--------|---------|---------|---------|---------|---------|
| Pearson’s r | 0.726** | 0.828*** | 0.854*** | 0.747** | 0.564   |
| pvalue  | < .001  | < .001  | < .001  | 0.005   | 0.056   |
| r²      | 0.527   | 0.68    | 0.729   | 0.558   | 0.318   |
| Percentage of correlation | 52% | 68% | 73% | 56% | 32% |

Note: * p < .05, ** p < .01, *** p < .001

Discussion
We have presented a simple analysis of the association of dengue epidemics with rainfall and from the results it was clear that the epidemic has a well-defined seasonality. Rainfall was significantly different among pre-monsoon, monsoon and post-monsoon periods. Average monthly premonsoon rain recorded was 148.9mm, during monsoon it increased to 264.12mm and during post monsoon the amount falls to 178.1mm only. There is increasing number of dengue cases from June onwards i.e. during the monsoon period and the number of cases decline in post monsoon season during all the five years of the study. Rainfall provides breeding habitats and opportunities for the proliferation of vectors in the environment. An increase in the amount of rainfall leads to more potential breeding sites, which, in turn, lead to an increase in the number of mosquitoes hatching [15]. Relatively high prevalence of Ae aegypti indices during the monsoon and post monsoon seasons were reported [25–27].

Many studies have reported the influence of rainfall on vector distribution and dengue cases. Dengue is endemic in Thailand
and Latin American countries, where a positive association between the prevalence of dengue and rainfall has been reported [22]. Aguiar et al. have shown that in Brazil, the risk of dengue infection is highly seasonal and increases primarily during the rainy season, when vector infestation reaches its peak [23]. Similarly, studies have also reported that compared with drier conditions, in wetter conditions, mosquitoes expand their spatial range thereby leading to increased risk of dengue infection [24]. Season specific pattern of dengue cases has been reported by others also [28, 29]. Hence seasonality could be a useful tool in the design of early warning systems for the prevention and control of dengue epidemics in our communities.

To understand the role of rainfall on dengue transmission, Pearson’s correlation analysis were carried out which showed a strong positive association between dengue cases and total rainfall (r=0.087) and highly significant correlation observed during the year 2017 (73%). In this study, the greatest number of dengue cases were also reported in 2017 (n= 8955). Regression analysis is able to explore the nature of association between variables by determining the amount of variance (r2) in the dependent variable (dengue incidence) that can be explained by independent variable (rainfall). The r2 value was 0.765 which indicates that rainfall approximately explains around 76.5 percent of variance (p < 0.001) in dengue and regression equation y = 1.28 x + 31.03 (r = 0.875, p < 0.001) which explains for every 1.28 ml of rainfall, there is an average increase of one dengue case. In a recent study, high dengue incidence, ranging between 21 and 50 per million, was reported for containers during monsoon period when compared to dry season and humidity which also determine the transmission of dengue, should be taken into account since these factors will become favorable with rainfall.

In the present study it was found that maximum rainfall was observed in August 2018 but highest number of dengue cases were reported in 2017 and least number were reported in 2018. Possible explanation for low incidence of dengue in 2018 may be because of herd immunity attained after the outbreak of dengue in 2017. The pattern of rainfall may also play a part as extremely heavy rainfall may flush mosquito larvae away from breeding sites or kill them outright [10]. In a study significantly lesser positivity was found for containers during monsoon period when compared to pre-monsoon period in Thiruvananthapuram district [17].

Conclusion
The present study showed that rainfall, as a single factor, likely plays a significant role in the incidence of dengue in Thiruvananthapuram district. Therefore, intensification of surveillance and control of mosquitoes especially during the monsoon period is recommended. However, other seasonal factors like ambient temperature and humidity which also determine the transmission of dengue, should be taken into account since these factors will become favorable with rainfall.

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