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Analysis of the Effects of Rainfall on Dengue Incidence in the City of Delhi, India

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ABSTRACT

Background and objectives: *Dengue fever is a vector-borne disease caused by the mosquito Aedes sp. The disease has spread to new geographical areas in the past few decades threatening previously unexposed populations to its risks. Environmental factors and unplanned urbanization are the two important variables affecting the increasing incidence of dengue. India has seen many outbreaks of the disease in the last decade. The capital city of India, Delhi has witnessed the increasing number of dengue cases in the last couple of years. Most of the cases occur during the monsoon period starting from July and lasting up to September. This study was carried out to assess the effects of seasonal rainfall on the incidence of dengue cases in Delhi.* ***Methods:*** *Retrospective data from 2005-2015 for annual rainfall and dengue incidence was collected and Pearson's correlation coefficient was calculated as a measure of association between the variables.* ***Results:*** *An overall positive but very weak correlation was found between annual rainfall and dengue incidence. An analysis of pre-monsoon, monsoon and post-monsoon rainfall patterns also indicated a very weak correlation between dengue incidence and rainfall patterns of the city.* ***Interpretation and Conclusion:*** *Our analysis indicates that weather variables may not be an absolute predictor of disease incidence and other factors must also be considered for the control of vector population.*

Keywords: Dengue, Rainfall, Climate, Delhi

INTRODUCTION

Dengue is an arboviral disease and it has become a major public health challenge worldwide. Recent studies have indicated that nearly 390 million people get infected with dengue virus every year and an estimated 3.9 billion people living in 128 countries are at risk of developing the disease [1]. A disease found earlier in the tropical regions of the world has expanded its geographical range in the last few decades [2]. The disease is transmitted by 2 different species of *Aedes* mosquito that could be found in tropical and subtropical regions of the world and manifests itself as dengue fever (DF) or in its more severe form, dengue hemorrhagic fever (DHF) [3]. The mosquito has adapted itself to cohabiting with humans and only the female of the species bite to acquire nutrients for nurturing the eggs [4]. Rapid urbanization, water storage practices, and climate play a huge role in the spread of these diseases [5,6]. India with its tropical, warm and humid climate provides an ideal environment for the breeding of dengue vectors [7]. Nearly 100,000 cases of dengue were reported from India by National vector-borne disease control programme (NVBDCP) in 2015 alone with the city of Delhi contributing substantially to the overall disease burden. Climate-associated variables like humidity, temperature, and rainfall indirectly affect dengue incidence by impacting mosquito survivability [8]. A seasonal pattern of disease occurrence, indicate climate as an important driving force for dengue incidence. Most part of India receives rainfall in the monsoon period from the months of July to September, and it has been observed that most of the dengue cases take place in this period, possibly by providing more breeding sites in standing water due to extensive rainfall. Recent studies on the correlation of weather variability and dengue incidence have produced interesting results with a strong positive correlation between temperature, humidity and dengue incidence [9-11]. Statistical analysis of such data has the power to predict future incidence and might help in designing better control strategies for prevention. This study uses publically available data of annual dengue incidence and climactic factor to ascertain the association between the incidence of dengue with annual temperature and annual rainfall patterns in the city of Delhi.

PATIENTS AND METHODS

The city of Delhi is located 28°36'36"N and 77°13'48"E in northern India. It covers an area of 1484.0 km^2. According to the 2011 census, the population of Delhi is estimated to be 16,787,941 and population density is 11,312,15/km^2. The climatic conditions can be divided into 3 distinct phases hot and arid extending from April to June, monsoon period extending from July to September and cold and dry weather from November to February with intermittent periods of transition in the months of March and October.

The data for dengue incidence for Delhi was obtained from NVBDCP. Retrospective data of the past 10 years from 2005 to 2015 was collected. Climate data for Delhi was obtained by the yearly weather reports published by the Indian Metrological Department (IMD). Total annual rainfall and maximum and minimum annual temperatures were considered for the final analysis. Pearson coefficient was calculated to identify a correlation between dengue cases and different climactic factor. Annual cumulative rainfall, annual maximum and minimum temperatures were considered as independent variables while an annual number of dengue cases were considered as a dependent variable.

RESULTS

Retrospective data collected for the last 11 years indicated a total of 39,321 cases of dengue in this period in the city of Delhi, with a maximum number of cases reported in the year 2015 (n=15867) and minimum number of cases reported in the year 2007 (n=548) (Table 1 and Figure 1).

Table 1 Annual dengue cases, deaths, rainfall, maximum temperature, minimum temperature and average temperature of Delhi

Year	Dengue Cases	Deaths	Annual Rainfall (mm)	Annual maximum temperature (°C)	Annual minimum temperature (°C)	Annual average temperature (°C)
2005	1023	9	587.2	45.0	3.0	24.00
2006	3366	65	377.1	45.0	0.0	22.50
2007	548	1	479.8	45.0	3.0	24.00
2008	1312	2	632.9	43.0	2.0	22.50
2009	1153	3	350.5	44.0	4.0	24.00
2010	6259	8	597.7	45.0	5.0	25.00
2011	1131	8	433.2	44.1	2.9	23.00
2012	2093	4	313.6	45.4	4.0	24.70
2013	5574	6	461.3	45.7	1.9	23.80
2014	995	3	305.6	45.5	2.6	24.05
2015	15867	60	436.0	45.5	4.0	24.75

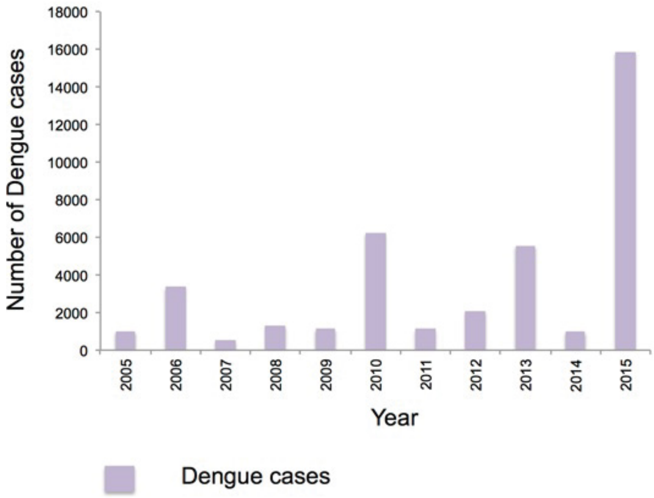

Figure 1 Number of dengue cases reported from the year 2005-2015

Maximum numbers of deaths were reported in the year 2006 (n=65) and 2015 (n=60). Delhi receives maximum rainfall in the monsoon season starting from July to September. Water logging due to poor civic infrastructure is a common problem during this period in Delhi. For the period of 11 years considered for this study an average of 80% rainfall was received during the monsoon season and maximum total rainfall was observed in the year 2008 (633 mm) and minimum total rainfall was observed in the year 2014 (306 mm) (Figure 2).

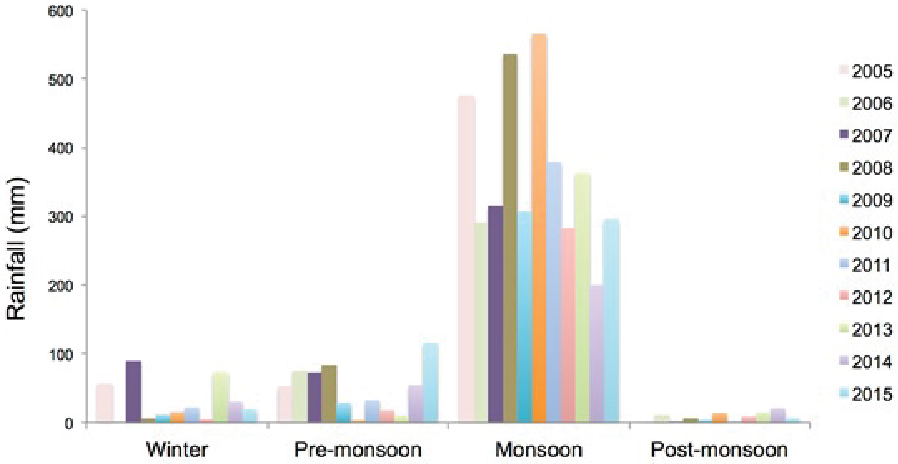

Figure 2 Season-wise distribution of annual cumulative rainfall

The annual maximum temperature was observed in the year 2013 at 45.7°C and annual minimum temperature was observed in the years 2006 and 2008 at 22.5°C. The monsoon season witness's maximum number of dengue cases. To study the overall effect of annual cumulative rainfall on dengue incidence, Pearson's correlation coefficient was calculated (Figure 3).

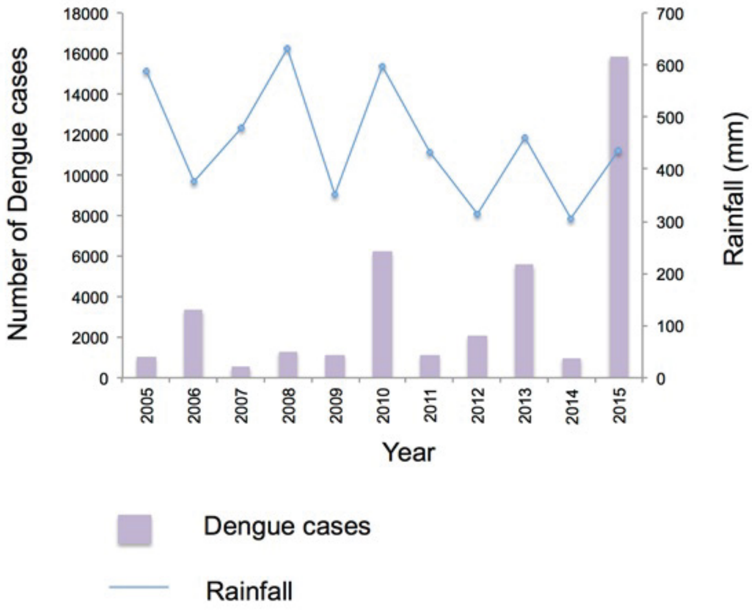

Figure 3 Comparison of dengue cases with annual cumulative rainfall

An estimation of Pearson's coefficient correlation analysis showed an overall positive albeit a very weak correlation between annual rainfall and dengue incidence (Table 2). We also analyzed the pattern of dengue incidence with annual maximum, minimum and average temperatures (Figures 4-6). Pearson coefficient was calculated with these 3 values and an overall positive correlation was found with dengue incidence with moderate correlation obtained with average temperature and dengue incidence (Table 2).

Table 2 Correlation coefficient between dengue incidence and various climactic factors

Variables		Dengue Cases
Rainfall	R	0.051
	R Standard Error	0.111
	t	0.154
	p-value	0.881
Max temp	R	0.402
	R Standard Error	0.093
	t	1.316
	p-value	0.221
Min temp	R	0.257
	R Standard Error	0.104
	t	0.798
	p-value	0.445
Mean temp	R	0.427
	R Standard Error	0.091
	t	1.415
	p-value	0.191

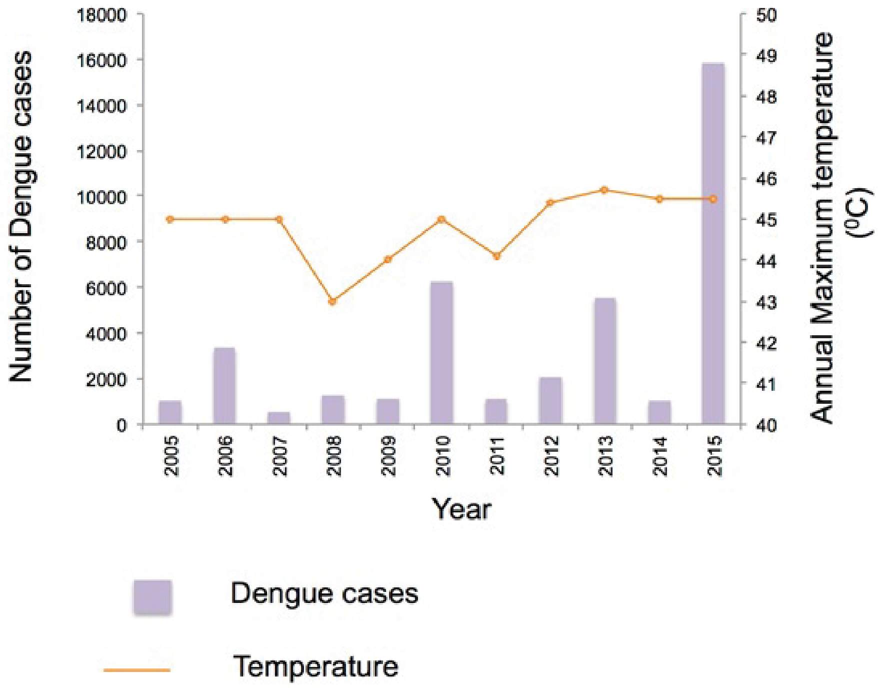

Figure 4 Comparison of dengue cases with annual maximum temperature

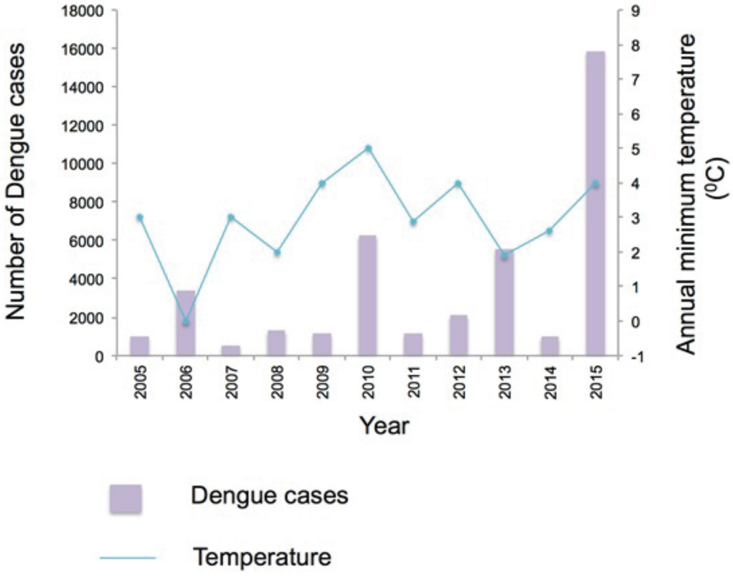

Figure 5 Comparison of dengue cases with an annual average temperature

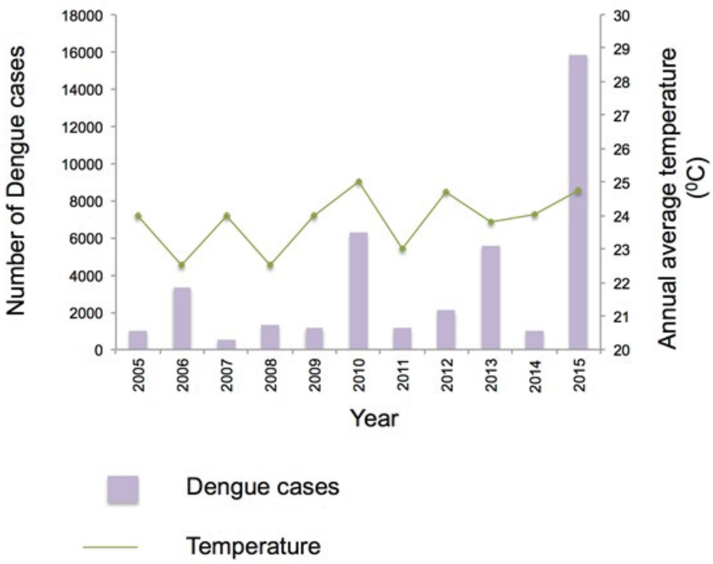

Figure 6 Comparison of dengue cases with annual minimum temperature

Since most of the rainfall takes place during the monsoon season we also analyzed dengue incidence with rainfall received during each season in different years. However, this analysis also didn't result in any significant correlation between dengue incidence and seasonal rainfall patterns (Table 3).

Table 3 Correlation coefficient between dengue incidence and winter, pre-monsoon, monsoon and post-monsoon rainfall

Variables		Dengue Cases
Winter rainfall	R	-0.128
	R Standard Error	0.109
	t	-0.387
	p-value	0.708

Pre-monsoon rainfall	R	0.36
	R Standard Error	0.097
	t	1.158
	p-value	0.277
Monsoon rainfall	R	-0.033
	R Standard Error	0.111
	t	-0.099
	p-value	0.923
Post-monsoon rainfall	R	0.146
	R Standard Error	0.109
	t	0.444
	p-value	0.667

DISCUSSION

The incidence of dengue has increased nearly 30 folds worldwide in the last couple of decades, with India contributing significantly to the overall disease burden. The disease, which spreads through and intermediate mosquito vector can only be controlled with supportive therapy as of now [12]. Without any vaccine or therapeutic interventions, control of the disease is heavily dependent upon controlling the vector population [13]. The city of Delhi has witnessed several outbreaks of dengue in the last few years with a maximum number of cases being reported in the year 2015. Delhi remains an epicenter for large-scale migration for people looking for education and livelihood. The civic amenities of the city are not well equipped to serve its nearly million population [14]. This has lead to an emergence of unorganized colonies and areas with poor urban planning and high population density. Frequent water logging during monsoon season is a result of a mediocre sewage disposal system. The city witnesses a seasonal dengue epidemic every year during monsoon season. An overburdened healthcare system is unable to cater to such high patient load during this season. Earlier studies published from different parts of the world have indicated that rainfall, humidity, and temperature are significant factors influencing dengue incidence by providing an ideal environment for the survivability of the mosquito vector. Estimation of their effects puts variations in weekly temperature patterns and humidity as the most significant factor affecting the vector population [15-18]. In this report, we have analyzed the correlation between annual rainfall, annual maximum and annual minimum temperature with dengue incidence for the last 11 years (2005-2015) for the city of Delhi. Calculation of Pearson's correlation coefficient indicates a very weak positive linear relationship between annual cumulative rainfalls with dengue cases. A moderate positive correlation was indicated between average annual temperature and dengue cases. Our analysis indicates that annual cumulative rainfall may not be the best indicator of dengue incidence, which in turn depends upon the vector population. Analysis of dengue incidence with rainfall received during winter, pre-monsoon, monsoon and post-monsoon period does not reveal any strong correlation either. Comparisons between annual maximum, minimum and average temperature do show a moderate ($p=0.4265$) correlation between average temperature and dengue incidence. Our results though preliminary in nature indicate that climatic factors may not be as effective in predicting dengue incidence at local levels. Several other factors like wind velocity, population density, and presence of susceptible population may also influence dengue incidence. We acknowledge the limitation of our study given that monthly or weekly rainfall pattern, relative humidity levels, temperature fluctuations, and dengue incidence are not publicly available from IMD or NVBDCP. The effects of climatic factors are widely considered to be of crucial importance for the incidence of vector-borne diseases and provide a useful tool in predicting and preparing for the ensuing epidemic, however, we must acknowledge the limitations of such analysis in predicting disease incidence and non-climactic factors should also be analyzed.

CONCLUSION

Our analysis indicates that weather variables may not be an absolute predictor of disease incidence and other factors must also be considered for the control of vector population.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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