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Climatic variability and dengue risk in urban environment of Delhi (India)

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ABSTRACT

The paper determines climate variability in Delhi represented by changes in weather pattern and makes an empirical assessment of their impact on dengue incidence by identifying the 'high risk' weeks of a year. Statistical technique of iterative chi-square which compares daily data of climatic elements for each weeks during the recent years (1999–2011) and previous years (1973–1998) selected for this study has been used for determining the weeks of a year during which there have been change in maximum and minimum temperatures, rainfall and relative humidity. Association of climate variability and dengue have been established by modelling longitudinal (panel) data for weekly dengue incidence, changes in climatic elements and the recorded climatic elements during January 2008 to May 2013 using the most suited Poisson regression applying generalized estimating equation approach. Findings reveal significant changes in weather across the year having significant and positive association with dengue cases at specified lags. Weeks in April and July to October with gaps have been identified as the high risk weeks based on the estimated relative risk. There has been intra-annual expansion in dengue risk period extending beyond monsoon and post-monsoon. The outcome of the study contributes to framing of future adaptation strategies.

1. Introduction

Dengue is the most important mosquito-borne viral disease caused by four closely related viruses and transmitted mainly by *Aedes aegypti* mosquito, the principal urban vector (Reiter, 2001; Hales et al., 2002; Hopp and Foley, 2003; Ebi and Nealon, 2016). It is the only vector-borne disease (VBD) having strong association with climatic elements, both at the local as well as global level (high confidence[1]) (Smith et al., 2014). In the last 50 years, dengue has spread most rapidly with 30 times increase in global incidence (WHO, 2012). Asia-Pacific region is the worst affected as three-fourth of the total global population exposed to dengue lives in this region (Smith et al., 2014). Asia alone contributed to 70% of the global burden of dengue with India contributing 34% of the total in 2010 (Ebi and Nealon, 2016). Dengue, a predominantly urban disease has been one of the most important VBDs in city of Delhi, India. There has been sharp increase in dengue incidence with four major outbreaks during 2000–2015, the worst being the outbreak in 2015 with staggering 15,867 dengue cases (Chakravarti and Kumaria, 2005; Nandi et al., 2009; Kumari et al., 2011; NVBDCP, 2015; WHO, 2016).

Ae. aegypti has been the most prevalent species, breeding throughout the year and the main vector of dengue in Delhi since 1965 (Krishnamurthy et al., 1965; Katyal et al., 1996; Kalra et al., 1997; Sharma et al., 1999, 2005). All the four serotypes (DENV 1–4) responsible for dengue fever have been detected circulating in Delhi (Nandi et al., 2008). Dengue occurs during monsoon (July to

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[1] An event is placed in the category of 'high confidence level' if there is a combination of high agreement and robust evidence that it will occur (IPCC, 2013)

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October). It starts in July, peaks in October and then starts declining in November (Katyal et al., 1996, 2003; Nandi et al., 2009). Breeding of *Ae. aegypti* takes place mostly in man- made habitats (Hopp and Foley, 2001). Life-cycle of *Ae. aegypti* is strongly influenced by climatic elements. Temperature influences mosquito survival rate, relative humidity influences adult mosquito mortality and water is essential for egg laying and hatching (Watts et al., 1987; Gubler, 1998; Patz et al., 1998; Hales et al., 2002; Hopp and Foley, 2001, 2003; Morin et al., 2013; Wu et al., 2016). High temperature results in smaller body size of the adult *Ae. aegypti,* compelling them for greater number of blood meals which increases the chance of disease transmission (Macdonald, 1956; Rueda et al., 1990; Tun-Lin et al., 2000).

Most of the research carried out so far at different locations in the tropical region has established relationship between climatic elements - temperature, precipitation and humidity, and dengue incidence (Morin et al., 2013). These includes studies carried out in Barbados (Depradine and Lovell, 2004), China (Lu et al., 2009), Indonesia (Arcari et al., 2007), Mexico (Chowell and Sanchez, 2006; Coloń-González et al., 2013), Peru (Chowell et al., 2011), Phillipines (Su, 2008), Puerto Rico (Schreiber, 2001; Johansson et al., 2009a; Barrera et al., 2011), Singapore (Hii et al., 2009; Pinto et al., 2011; Struchiner et al., 2015), Taiwan (Wu et al., 2007; Hsieh and Chen, 2009; Wu et al., 2009; Chen et al., 2010; Yu et al., 2011) and Trinidad (Chadee et al., 2007). Some studies have established relationship between El Nino Southern Oscillation (ENSO) and sea surface temperature which influences the weather pattern and dengue incidence. It has been determined in Mexico (Hurtado-Díaz et al., 2007; Brunkard et al., 2008; Colón-González et al., 2011), Thailand (Cazelles et al., 2005; Tipayamongkholgul et al., 2009), Costa Rica (Fuller et al., 2009), Puerto Rico (Johansson et al., 2009b), Vietnam (Thai et al., 2010), Caribbean (Amarakoon et al., 2008) and Colombia (Eastin et al., 2014). However there have been no efforts made till date to determine the effect of climate variability represented by changes in weather pattern on dengue incidence in urban area of Delhi in particular.

This paper aims at determining climate variability represented by changes in weather pattern and its impact on dengue incidence in Delhi. Unlike previous studies which establishes relationship between weather variability and dengue incidence using the weather data and dengue incidence recorded during the same time period, this study in addition to it, determines the impact of variability due to changes in the weather pattern attributable to climate change also. For the first time it uses the statistical technique of iterative chi-square (χ^2) to establish relationship between weather variability and health effect of climate change. The iterative chi-square (χ^2) technique, based on the methodology given by Caprio et al. (2009) has been used to identify the weeks of a year with statistically significant change in the weather pattern in the recent years (1999–2011) as compared to previous years (1973–1998) selected for this study. It uses the daily data of recorded climatic elements for the corresponding weeks in each year in the two time period to determine statistically significant deviation from the expected values or variability for each week separately during the recent year as compared to previous year. Unlike most of the studies determining climate variability using long weather time series, it uses daily weather data of the corresponding weeks of a year separately during the two time periods. Till date, use of this technique has remained restricted to establishing the relationship between daily weather occurrences and agricultural production only (Caprio and Williams, 1973; Caprio and Snyder, 1984; Kalma et al., 1992; Caprio and Quamme, 1999, 2002, 2006; Caprio et al., 2003). The weeks of a year with changes in weather pattern determined using this technique allows for incorporating the long term effect of variability in the model for establishing the impacts on dengue incidence. The successful use of this technique in this study provides a novel approach for studying the impact of weather variability on climate sensitive health effects.

Unlike most of the weather and dengue association studies which used time series data, this study uses longitudinal or panel data to model the relationship between changes in weather pattern and weekly dengue incidence for the period 2008–2013. The relationship has been modelled using Poisson regression applying the generalized estimating equation (GEE) approach which takes care of overdispersion, serial correlation, non-linearity and allows for hypothesis testing (McCullagh and Nelder, 1989; Ballinger, 2004; Agresti, 2007, 2013; Lu et al., 2009; Chen et al., 2010; Wooldridge, 2010). Based on this, weeks of the year with increased risk of dengue incidence are identified.

2. Methodology

2.1. Description of the study area – Delhi

The National Capital Territory (NCT) of Delhi with an area of 1483 km^2 and population density of 11,297 persons/km^2 in 2011 (Census of India, 2011) is situated in the subtropical belt of the Indian sub-continent between the latitudes of 28° 22′–28° 54′ N and 76° 48′–77° 23′ E, at an altitude of 216 m above mean sea level. Delhi has a typical tropical climate. Maximum temperature reaches up to 45 °C during the summer months of April, May and June. Minimum temperature falls to 2 °C during December and January. Delhi receives average annual rainfall of 614 mm, three-fourths of which falls in July, August and September. Land is divided into two zones, the extension of the Aravalli hills and the plains. The forest cover increased from 0.76% of the total area in 1980–81 to 12.22% in 2013 (State of Forest Report, 2013).

2.2. Data used

Daily data of maximum temperature (Tmax), minimum temperature (Tmin), rainfall and dew point recorded at Safdarjung, New Delhi (WMO station code – 421820, 28° 35′N–77° 12′ E, elevation 216 m) was extracted from the Global Surface Summary of the Day (GSOD) database, archived by National Climatic Data Centre (NCDC). Daily data from January 1973 to December 2011 has been used in the analysis, as noted by NCDC, “the data from 1973 onwards is most complete” (Barreca, 2012). Tmax, Tmin and dew point in a day are given in Fahrenheit and rainfall in inches. Daily average temperature and dew point was used to determine relative humidity