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Temperature dependent transmission potential model for chikungunya in India

Satya Ganesh Kakarla [a], Rajasekhar Mopuri [a], Srinivasa Rao Mutheneni [a,*], Kantha Rao Bhimala [b], Sriram Kumaraswamy [a], Madhusudhan Rao Kadiri [a], Krushna Chandra Gouda [b], Suryanaryana Murty Upadhyayula [c]

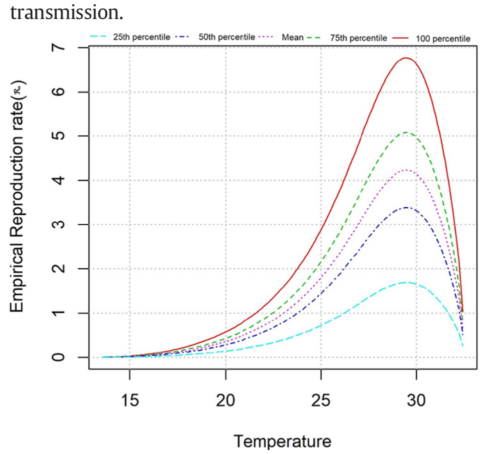
[a] Applied Biology Division, CSIR-Indian Institute of Chemical Technology, Tarnaka, Hyderabad 500007, Telangana, India
[b] CSIR-Fourth Paradigm Institute, NAL Belur Campus, Bangalore 560037, Karnataka, India
[c] National Institute of Pharmaceutical Education and Research, Guwahati 781032, Assam, India

HIGHLIGHTS

- Spatiotemporal distribution and transmission dynamics of chikungunya transmission in India.
- Assessed role of climatic factors on chikungunya virus outbreak in Delhi in 2016.
- Predicted potential transmission risk of chikungunya in India using R_0 model.
- Peak transmission of chikungunya is observed at 29°C and declined to zero below <17°C and above >34°C.

GRAPHICAL ABSTRACT

The risk of chikungunya transmission in recent years of climate is gradually increasing in India. The R_0 predicts the optimal temperature for peak chikungunya transmission is 29 °C and declined to zero below <17 °C and above >34 °C. Similarly the predicted temperatures are better suited for *Aedes* vectors development and diseases transmission.



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ABSTRACT

Chikungunya is a major public health problem in tropical and subtropical countries of the world. During 2016, the National Capital Territory of Delhi experienced an epidemic caused by chikungunya virus with >12,000 cases. Similarly, other parts of India also reported a large number of chikungunya cases, highest incidence rate was observed during 2016 in comparison with last 10 years of epidemiological data. In the present study we exploited R_0 mathematical model to understand the transmission risk of chikungunya virus which is transmitted by *Aedes* vectors. This mechanistic transmission model is climate driven and it predicts how the probability and transmission risk of chikungunya occurs in India. The gridded temperature data from 1948 to 2016 shows that the mean temperatures are gradually increasing in South India from 1982 to 2016 when compared with data of 1948–1981 time scale. During 1982–2016 period many states have reported gradual increase in risk of chikungunya transmission when compared with the 1948–1981 period. The highest transmission risk of chikungunya in India due to favourable ecoclimatic conditions, increasing temperature leads to low extrinsic incubation period,

* Corresponding author.
E-mail address: msrinivas@iict.res.in (S.R. Mutheneni).

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Rainfall
Temperature

mortality rates and high biting rate were predicted for the year 2016. The epidemics in 2010 and 2016 are also strongly connected to El Nino conditions which favours transmission of chikungunya in India. The study shows that transmission of chikungunya occurs between 20 and 34 °C but the peak transmission occurs at 29 °C. The infections of chikungunya in India are due to availability of vectors and optimum temperature conditions influence chikungunya transmission faster in India. This climate based empirical model helps the public health authorities to assess the risk of chikungunya and one can implement necessary control measures before onset of disease outbreak.

1. Introduction

Chikungunya is a major mosquito-borne viral disease and it is mainly transmitted by the primary vectors *Aedes aegypti* and *Ae. albopictus*. Chikungunya was first noticed in 1952 in Makonde, United Republic of Tanzania and it was first described by Robinson and Lumsden in 1953 (Robinson, 1955; Lumsden, 1955). Chikungunya is highly endemic in tropical and subtropical regions of the World (Deeba et al., 2016). It is reported that monkeys and other vertebrates act as reservoirs for chikungunya virus (Brooks et al., 2004). Similarly, Yergolkar et al. (2006) reported a series of epidemics of chikungunya in Africa, Southeast Asia and the Indian subcontinent.

Chikungunya is a major public health concern and infects millions of people across the globe. It is an alphavirus which belongs to the family Togaviridae. There are no different serotypes reported for chikungunya but three distinct genotypes were reported (Deeba et al., 2016). The three distinct genotypes are West African, East/Central/South African (ECSA) and Asian. The clinical symptoms of chikungunya generally start 4–7 days later, after the infected mosquito bites. The acute phase is characterized by painful polyarthralgia, high fever, asthenia, headache, body ache, backache, vomiting, rash, and myalgia. In the chronic phase, incapacitating arthralgia persists for months. Neurological syndromes (encephalitis, encephalopathy, and myelopathy or myeloneuropathy) and Non-neurological systemic syndromes (renal, hepatic, respiratory, cardiac and haematological manifestations including lymphadenopathy, oral ulcers and encephalitis petechiae) generally exist during chikungunya virus infection (Yergolkar et al., 2006; Suryawanshi et al., 2009; Kannan et al., 2009). The clinical symptoms confuse as they overlap each other and is always caused by both chikungunya and dengue virus. One of the symptoms specific for chikungunya is prolonged joint pain that occurs over a period of months to years but mortality due to chikungunya infection is rare (Chang et al., 2014). There is no specific treatment for the disease; treatment is generally focused on symptomatic care and mosquito vector control.

In recent years the outbreak of chikungunya has occurred in the Islands of the Indian ocean since 2005 (Lahariya and Pradhan, 2006). Later it spread to temperate zones of Europe that is Northern Italy in 2007 (Rezza et al., 2007), followed by France in 2010 (Grandadam et al., 2011) and 2014 (Roiz et al., 2015). Similarly, incidence of chikungunya was also reported in China (Wu et al., 2012), Papua New Guinea the Caribbean Islands (Van Bortel et al., 2014) and outbreak of chikungunya in the Americas (Leparc-Goffart et al., 2014). The East/Central/South African genotype chikungunya virus is responsible for the outbreak of chikungunya in Americas and the Asian genotype for the Caribbean Islands (Teixeira et al., 2015; Lanciotti and Valadere, 2014). The resurgence and global distribution of chikungunya in different geographical regions is due to various factors such as globalization, geographical expansion of vectors, loss of herd immunity, urbanization, international travel and climate change (Pialoux et al., 2007).

Chikungunya is a major public health problem and affecting billions of people in India. The outbreak of chikungunya was first reported in Calcutta, India in 1963 (Bhatia and Narain, 2009). Followed by subsequent outbreaks and sporadic cases were reported from Tamil Nadu, Andhra Pradesh and Maharashtra in 1964–65 and 1973 (Maharashtra only). Since 1973 the virus disappeared in India and no case was reported until the end of 2005. After 32 years the disease re-emerged and spurted as an epidemic in 2005 in many islands in the Indian Ocean including India (Yergolkar et al., 2006; Lahariya and Pradhan, 2006). During epidemic period, the confirmed cases were reported from Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu, Madhya Pradesh and Gujarat states of India. This epidemic affects nearly 1.3 million people in India with an attack rate of 4–45% (Lahariya and Pradhan, 2006). The epidemics is caused by the African genotype of chikungunya virus and is transmitted by the *Aedes* vectors (Yergolkar et al., 2006). By the year 2010, chikungunya has spread to >18 states/Union Territories in India and affects >3.7 million people (Ministry of Health and Family Welfare, 2010).

Chikungunya is a major public health problem in National Capital Territory (NCT) of Delhi due to its epidemics during 2010 and 2016 (Shrinet et al., 2012; Kaur et al., 2017). Researchers found that during epidemic periods was simultaneously masked by co-circulated dominant dengue virus over chikungunya virus (Chahar et al., 2009; Singh et al., 2012). This co-circulation has not been known due to lack of proper surveillance of both viruses which resulted to cause major outbreaks of chikungunya. Similarly, *Aedes* sp. mosquitoes are vectors for both the viruses and hence there is a chance that the epidemiology of chikungunya and dengue infections are temporally and spatially related (Furuya-Kanamori et al., 2016). Population movement and climatic factors also influence both vector and virus development and distribution of chikungunya (Telle et al., 2016).

The Indian climate is influenced heavily by the Indian monsoon system. The Indian summer monsoon rainfall (ISMR) is widespread all over India during the southwest monsoon period (June, July, August and September). The ISMR provides 80% of the total annual rainfall and controls the agricultural production and economy of India. Followed by Southwest monsoon, Northeast monsoon provides rainfall to coastal Andhra Pradesh and Tamilnadu. Various studies have reported that the ISMR has significantly decreasing trend since 1950 (Saha et al., 2014; Rao et al., 2012), similarly mean temperatures are gradually increasing during post monsoon (0.9 °C) and winter periods (1.1 °C) (Arora et al., 2005). A small variation in climatic factors has a huge impact on vector-borne diseases like malaria, Zika, dengue and chikungunya. The increasing temperature fastens the gonotrophic cycle of mosquitoes, enhanced feeding activity of vectors and low extrinsic incubation period (EIP) of parasite leads to higher transmission rate (Mutheneni et al., 2017).

In the present study temperature dependent traits of vector and virus were calculated to find out the transmission intensity of chikungunya through basic reproductive rate (R_0) model. The basic reproductive rate (R_0) is helpful in epidemiology to understand the risk of spread of infectious disease as it provides an index for transmission intensity and its threshold levels (Smith et al., 2007). The basic reproductive rate R_0 is defined as the average number of secondary infections which arises from a primary infection that has introduced into an otherwise susceptible population (Van den Driessche and Watmough, 2002). If R_0 is greater than one it indicates that the number of people infected is more and it could spread further transmission, which leads to an epidemic, however, if R_0 is less than one, viral transmission declines and most likely outbreak will not occur (Smith et al., 2007, Caminade et al., 2017).