Spatio-Temporal Patterns of Dengue Fever in Cali, Colombia

Eric Delmelle, The University of North Carolina at Charlotte, Charlotte, NC, USA
Irene Casas, Louisiana Tech University, Ruston, LA, USA
Jorge H. Rojas, Secretaría de Salud Pública Municipal, Santiago de Cali, Colombia
Alejandro Varela, Secretario de Salud Pública Municipal, Santiago de Cali, Colombia

ABSTRACT

Dengue fever is an arboviral disease typical of the tropics that can be life-threatening and if not controlled properly may result in an epidemic. The absence of an effective vaccine makes strategies to prevent the virus transmission the most effective means of control. The planning of such strategies, however, is difficult due to the constant movement of individuals and mosquito host (Aedes aegypti). In this paper, the spatial and temporal relations that might exist between infected individuals during a dengue-epidemic year are explored. This research is motivated in that a deep understanding of potential transmission patterns between individuals might lead to a better design and planning of control strategies. A GIS-based Health Exploratory AnaLysis Tool (HELP) is used to compute space-time relationships by means of spatial K-function, kernel density, space-time K-function and linking pairs of cases within significant time and space intervals. Significant clustering was observed at a scale of 50 meters and 750 meters, respectively while temporal significance was determined at two days and five to eight days. While an increase of cases occurs in the months following severe droughts due to an El Niño phenomenon, the location of clusters remains relatively stable. These are observed near areas where potential habitats for the mosquito exist such as storm drains, hard surfaces where water accumulates (e.g., vases, containers), but also in poorer neighborhoods. The results from the spatial analysis provide valuable information for health care managers to take preventive actions at the municipality level.

Keywords: Cali-Colombia, Clustering, Dengue Fever, Health Exploratory AnaLysis Tool (HELP), Spatio-Temporal Analysis

INTRODUCTION

Dengue fever is an arboviral disease of considerable importance due to its endemic nature. In recent decades it has grown dramatically, reaching a global presence in more than one hundred countries (Kittayapong et al., 2008), while it remains a threat to more than 2.5 billion people, particularly in tropical and subtropical areas, in rural as well as urban settings. Between fifty to one hundred million people are infected every year, creating a burden to communities and health entities that need to control and prevent the virus from becoming an epidemic (Méndez et al., 2006; WHO, 2009).

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The disease is transmitted to humans by mosquitoes of the genus *Aedes* (Monath, 1988). The mosquito, *Aedes aegypti*, inhabits and reproduces in warm temperature areas generally between 18° and 25° C (Wu et al., 2009). There is a temperature threshold below which the mosquito cannot survive and as temperature increases it is required to feed, which may eventually lead to an increasing rate of biting events. Higher temperatures, therefore, shorten the probability of mosquito survival (Kolivras, 2006). The *Aedes aegypti* mosquito tends to be more active during daytime, especially in the close proximity of houses (Halstead, 1997). The mosquito’s habitat is, most often, artificial water holding containers where they develop and lays eggs. This fact ties them to households, given that it is here where these containers are kept to store water for drinking and other household shores (a practice often observed in the developing world countries both in rural and urban areas). This means that transmission is generally focal, clustering in households and nearby neighbors over short periods of time (Kuno, 1995; Getis et al., 2003; Morrison et al., 1998). Only adult females transmit the virus to humans. The incubation period of the virus is around ten days, after which the virus replicates in the salivary glands of the *Aedes aegypti* mosquito. Symptoms of the disease include fever, joint and back pain (which has given the disease the name “break bone fever” (Suarez et al., 2005), severe headache, and nausea (Kolivras, 2006).

Dengue fever studies have focused in understanding patterns between mosquito infected areas and infected individuals (Chang et al., 2009); identifying causal relationships, in particular weather and vegetation (Tipayamongkholgul et al., 2009; Kolivras, 2006; Arboleda, Jaramillo-O and Peterson, 2009; Braga et al., 2010; Johansson, Dominici & Glass, 2009; Maciel-de-Freitas et al., 2010; Maria & Valencia, 2011; Wu et al. 2009); and spatio-temporal patterns of infected individuals (Eisen & Lozano-Fuentes, 2009; Getis et al., 2003; Mammen et al., 2008; Morrison et al., 1998; Rosa-Freitas et al., 2003; Tran et al., 2004; Kan et al., 2008). The disease is known to vary through time and space, due to a number of factors including the human host, the virus, the mosquito vector and the environment (Mammen et al., 2008). Determinant factors in the transmission include: mosquito density, circulating virus serotypes, and susceptibility of human populations (Kuno, 1997).

In the Americas, in spite of efforts to eradicate dengue fever during the 1950s and 1960s (OPS, 1960), a reinvasion occurred following a reduction in surveillance and control strategies (WHO, 1997). Between 2001 and 2007 more than thirty countries reported a total of 4,332,731 dengue cases (Cali, 2010) including the four different dengue serotypes (DENV-1, DENV-2, DENV-3, and DENV-4). In Colombia, in particular, the population living in areas at-risk of contracting the disease amounts to 26,000,000 people. These are areas with an elevation below 1,800 meters above sea level; a total of 900,000 square kilometers out of a total extension of 1,138,000 of the national territory (Colombianos, 2011). Dengue fever in Colombia was eradicated between 1952 and 1966, with a re-infestation occurring in the early 1970s (Romero-Vivas, Leake and Falconar, 1998). Since then the disease has become endemic in many areas presenting periodic outbreaks in 1991, 1994, 1998, 2001, 2006, and the most recent in 2010. This shows an epidemiological cycle every 2 to 3 years through the 1990s. Most of the outbreaks reported have been of serotype 1 (DENV-1) and 2 (DENV-2) (Mendez et al., 2010) but in the last decade 3 (DENV-3) and 4 (DENV-4) have also been present (Cali, 2010).

Cali, the focus of this study, is located 1,000 meters above sea level and is considered as an endemic dengue zone. During 2009 and the first quarter of 2010 more than 7,000 cases of dengue fever were reported with 2,500 being severe (Cali, 2010). By January of 2010 a total of 990 cases had been registered, with 106 cases being of hemorrhagic dengue fever. By week 10 of 2010 the cases had increased to 3,540 from which 296 were severe and 5 fatal (Cali, 2010). At this point the signs of an epidemic were evident and apparently intensified by
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