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Original article

São Paulo urban heat islands have a higher incidence of dengue than other urban areas

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ABSTRACT

Urban heat islands are characterized by high land surface temperature, low humidity, and poor vegetation, and considered to favor the transmission of the mosquito-borne dengue fever that is transmitted by the *Aedes aegypti* mosquito. We analyzed the recorded dengue incidence in Sao Paulo city, Brazil, in 2010–2011, in terms of multiple environmental and socioeconomic variables. Geographical information systems, thermal remote sensing images, and census data were used to classify city areas according to land surface temperature, vegetation cover, population density, socioeconomic status, and housing standards. Of the 7415 dengue cases, a majority (93.1%) mapped to areas with land surface temperature >28 °C. The dengue incidence rate (cases per 100,000 inhabitants) was low (3.2 cases) in high vegetation cover areas, but high (72.3 cases) in low vegetation cover areas where the land surface temperature was 29 ± 2 °C. Interestingly, a multiple cluster analysis phenogram showed more dengue cases clustered in areas of land surface temperature >32 °C, than in areas characterized as low socioeconomic zones, high population density areas, or slum-like areas. In laboratory experiments, *A. aegypti* mosquito larval development, blood feeding, and oviposition associated positively with temperatures of 28–32 °C, indicating these temperatures to be favorable for dengue transmission. Thus, among all the variables studied, dengue incidence was most affected by the temperature.

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Introduction

Urban heat islands (UHI) are areas with minimal vegetation cover and large man-made surfaces (e.g., dark roofs, asphalt lots, and roads) that absorb sunlight, re-radiate heat, and retain less water compared to natural land-cover. These attributes reduce humidity for evaporation and cooling.[1] Unfortunately, global warming tends to increase the adverse effects of UHI on human health. When heat waves occur, they lead to increased concentrations of air-borne pollutants in UHI, increasing morbidity and mortality caused by respiratory, heart, and circulatory diseases, typically among elderly persons.[2,3] In addition, young children and persons living with chronic illnesses are particularly vulnerable to the pollution and heat stress caused by UHI.[4]

UHI may also influence the transmission of infectious diseases, especially those transmitted by arthropod vectors whose metabolism is associated with temperature, such as dengue fever, a vector-borne disease of global importance.[5,6] Dengue virus infection causes a spectrum of symptoms, ranging from mild febrile illness to fatal hemorrhagic disease. Transmission to susceptible human hosts occur through the bite of an infected *Aedes aegypti* female, with symptoms appearing after an incubation period of 3–14 days (average, 4–7 days).[7] Dengue virus replication is amplified at temperatures >30 °C, resulting in the extrinsic incubation period (time required to mosquito become infective after consuming blood from an infected host) being reduced from 12–14 days to 7 days.[8] The extrinsic incubation period is also influenced by daily temperature fluctuations, as viral titers decrease when daily temperature fluctuations are ±10 °C.[9] Thus, UHI may amplify the incidence of dengue fever.

São Paulo is the largest city in Brazil, the capital of São Paulo state, and a major financial, corporate, and commercial center in South America. The city has a high vulnerability to the incidence of dengue fever, because of its socio-economic features, high population density, and the significant influx of persons from other cities and countries. *A. aegypti* Infestation was first detected in 1993, and the first autochthonous cases were reported in 1999. Autochthonous transmission has been continuous since 2001, and *A. aegypti* has been endemic in all urban areas since 2007. The incidence during 2010 and 2011 was 53 and 37.9 cases per 100,000 inhabitants, respectively.

In this study, we analyzed the association between the characteristics of UHI and the occurrence of dengue fever in São Paulo, over a two-year period (2010–2011), to identify the factors that may favor dengue transmission, and thereby facilitate effective surveillance and prevention of dengue fever.

Materials and methods

Study area

São Paulo is located in Southeastern Brazil (23°32′51″ S/46°38′10″ W), has an area of 1572 km^2, a population of over 11,000,000 inhabitants, and is divided into 96 Administrative Districts (ADs). The city has a subtropical climate, with rain in the summer and autumn months (December–May), and dry weather in the winter and spring months (June–November).

Ethics statement

We received approval from the Institutional Review Board of the São Paulo Secretary of Health (Comitê de Ética em Pesquisa da Secretaria Municipal de Saúde do Município de São Paulo) to use de-identified data from blood samples that were collected by public and private health facilities. All animal experiments were performed in accordance to the guidelines of the Institutional Ethics Review Committee (Brazilian Society of Science in Laboratory Animals-SBCAL/COBEA) and the Animal Care Committee of the Institute of Biomedical Sciences (Ethics Committee in Animal Experimentation – CEEA) – University of São Paulo (protocol #014/10).

Dengue data

Data regarding dengue cases in São Paulo between 2010 and 2011 were obtained from the Health Surveillance Coordination of São Paulo (COVISA). The majority of cases (99.5%) were classic dengue fever (no complications related to plasma leakage, fluid accumulation, respiratory distress, severe bleeding, or organ impairment). Only cases in which epidemiological investigation indicated the place of residence as the most likely place of infection were included in this study. During 2010–2011, viruses were isolated from 136 patients at the Adolfo Lutz Institute, São Paulo, Brazil, as described previously (serotype 1: 92%; serotype 2: 4%, serotype 3: 4%).[10,11]

Dengue cases geocoding

Dengue cases were geocoded according to the patient's home address, using the digital cartographic database of São Paulo (GEOLOG, LOC MSP) and Terraview 4.1.0 software (available at http://www.dpi.inpe.br/terraview/index.php).

Land surface temperature calculation and vegetation cover classification

Land surface temperature (LST) was calculated using thermal remote sensing images from the LANDSAT-5 thematic mapper (TM) to identify temperature zones and UHI in São Paulo. LANDSAT-5 TM multispectral images were selected for their lack of cloud cover. Three satellite images were obtained in 2010 (05/04/2010, 08/24/2010, and 11/28/2010), and three additional images in 2011 (05/23/2011, 07/26/2011, and 11/28/2011). Thermal band (Band 6) was used to calculate the LST in the selected images. Using the image obtained on 07/26/2011, bands 2 and 3 were used to establish the limits for soil and water, respectively, while band 4 was used to determine the vegetation cover. Spectral radiance was calculated, and temperature conversion was performed as described previously.[12] Ten different temperature zones (increments of 2 °C between 20 °C and 40 °C) were identified. The average LST for 2010–2011 was obtained using SPRING 5.1.7 software (http://www.dpi.inpe.br/spring/portugues/download.php).[13]