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Title: Potential Zika virus spread within and beyond India

Authors: Alexander G. Watts, PhD\textsuperscript{1,2,*}, Carmen Huber, MSA\textsuperscript{1,2}, Isaac I. Bogoch, MD\textsuperscript{3,4}, Oliver J. Brady, DPhil\textsuperscript{5}, Moritz U.G. Kraemer, DPhil\textsuperscript{6,7,8}, Kamran Khan, MD\textsuperscript{1,2,3}

Affiliations:

1 Li Ka Shing Knowledge Institute, St. Michael’s Hospital, Toronto, Canada
2 BlueDot, Toronto, Canada
3 Department of Medicine, Division of Infectious Diseases, University of Toronto, Toronto, Canada
4 Divisions of General Internal Medicine and Infectious Diseases, University Health Network, Toronto, Canada
5 Centre for the Mathematical Modeling of Infectious Diseases, London School of Hygiene and Tropical Medicine, University of London, United Kingdom
6 Department of Zoology, University of Oxford, Oxford, United Kingdom
7 Harvard Medical School, Boston, United States
8 Computational Epidemiology Lab, Boston Children’s Hospital, Boston, United States

*Address correspondence to Dr. Alexander G. Watts, Li Ka Shing Knowledge Institute, St. Michael’s Hospital, 30 Bond Street, Toronto, Ontario, M5B 1W8, Canada, Email: wattsa@smh.ca

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As of 28 October 2018, 147 cases of zika virus disease (ZVD) have been reported in Jaipur, the capital of Rajasthan state, India. Subsequently, as of 2 November 2018, a single case was reported in the neighbouring state of Gujarat and three additional cases were reported in the state of Madhya Pradesh, demonstrating national spread of ZVD and marking the largest reported outbreak of ZVD in Indian history. State health departments in India have mobilized hundreds of medical personnel to perform emergency screenings for ZVD. As a major tourist attraction for domestic and foreign visitors, the outbreak in Jaipur presents a high risk of Zika virus exportation. To anticipate the potential spread of ZVD in the face of an ongoing outbreak in Jaipur, we determined temporally-explicit air travel connectivity with Jaipur, and corresponding seasonal environmental suitability for Zika virus transmission in domestic and international destination cities.
We ranked destination cities based on their arriving volume of travellers on commercial flights from Rajasthan for November, December, and January using passenger-level, full-route, flight itinerary data from the International Air Transport Association (IATA) for the year 2017. We delineated suitability for transmission of Zika virus in India and Southeast Asia using distribution models of the virus’s primary mosquito vector *Aedes aegypti* and secondary vector *Aedes albopictus* limited by the well-characterized temperature thresholds for the genetically similar dengue virus for November, December, and January. Each month, top ranking domestic and international cities by connectivity were subsequently filtered to include only those cities located within 200 km of areas suitable for Zika virus transmission.

Over this 3-month period 326 cities that were within 200 km of areas suitable for Zika virus transmission received a total of 740,232 passengers from Rajasthan (summarized for December in Figure 1). Of these passengers, approximately 94% travelled to cities within India (n = 696,753). Mumbai received the most passengers (>24%), with Delhi, Bengaluru and Kolkata ranking second, third, and fourth respectively across all three months. Bangkok, Muscat, and Singapore were the only international cities ranked in the top twenty destinations.

Given the abundance of regions that are predicted to support Zika virus transmission and have large populations with limited previous exposure, and thus limited immunity, to Zika virus, Indian cities and countries with close international connections to Jaipur should prepare for potential importations of Zika virus. Our results suggest a greater risk of domestic spread from Jaipur within India in upcoming months but relatively lower potential for international exportation and spread. Notably, the city of Chennai may be especially vulnerable given relatively high connectivity to Rajasthan, a large urban population (> 7 million), and conditions conducive to year-round transmission of Zika virus via *Ae. aegypti*. If not controlled, the ZVD...
outbreak in Jaipur could have far-reaching consequences and public health and clinical personnel in domestic and global areas connected to the current epidemic should remain vigilant for possible importation of ZVD cases.

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References


Figure Captions

Figure 1. Number of passengers arriving from Rajasthan state (highlighted in red) by air for cities within 200 km of any Zika suitable area estimated for December. Proportion of total outbound passengers from Rajasthan provided in parentheses. Case counts for Jaipur are reported as of 2 November 2018.1
Total passenger volume (December)

- ≤5,000
- 5,001 - 28,000
- >28,001

Suitable range for Zika virus transmission (December)

- *Ae. aegypti*
- *Ae. albopictus*