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Low Risk of International Zika Virus Spread due to the 2016 Olympics in Brazil

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Brazil is the most severely affected country in Latin America's ongoing Zika virus (ZIKV) epidemic, which was declared a Public Health Emergency of International Concern by the World Health Organization (WHO) amid recognition of ZIKV as a cause of microcephaly and other congenital disorders, as well as Guillain–Barré syndrome. The Brazilian city of Rio de Janeiro is scheduled to host the Olympic and Paralympic Games from August to September 2016, with a projected attendance of 350 000 to 500 000 visitors.

Considerable attention is being focused on potential ZIKV exposure among travelers attending the Olympics and the possibility that they will contribute to the international spread of ZIKV upon return to their home countries (1, 2). The presence of the *Aedes aegypti* mosquito vector throughout many countries of Africa, Asia, and the Americas is central to these concerns. In addition, ZIKV transmission may occur through sex, unless condoms are used. Some members of the international academic community, most of whom are based outside Brazil, have advocated such measures as postponing the Olympics or relocating events to another country to prevent travel-associated ZIKV infections and exportation (1). In contrast, WHO has advised that travelers who are not pregnant may attend the Olympics safely while taking precautions to avoid ZIKV exposure, and that canceling or relocating the event will not alter international ZIKV spread significantly (3).

This controversy underscores the need for quantitative determinations of the risk that infected travelers returning from the Olympics will introduce ZIKV to their home countries by mosquito-borne or sexual modes of transmission. To provide an evidence basis for

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policymakers, we therefore estimated returning travelers' total person-days at risk for transmitting ZIKV after becoming infected during travel, based on a model for ZIKV transmission in Brazil (4, 5). We define the time at risk for transmission as the period beginning when an infected symptomatic or asymptomatic traveler returns to his or her home country and ending when detectable levels of ZIKV are cleared from his or her blood.

Our calculation provides worst-case estimates of travel-associated ZIKV risk by assuming that visitors encounter the same infectious exposures as local residents. Under these pessimistic conditions, we estimate that an individual traveler's probability of acquiring infection in Rio de Janeiro ranges from 1 in 56 300 to 1 in 6200 (Appendix Figure, available at www.annals.org). This range translates to a lower bound of 6 (95% CI, 2 to 12) and an upper bound of 80 (CI, 63 to 98) total ZIKV infections among travelers attending the Olympics, with between 1 (0 to 4) and 16 (9 to 24) expected to have symptoms. Because few pregnant women likely will attend the events owing to WHO travel advisories, these estimates reiterate previous statements of the low personal effect of ZIKV on travelers (2, 6).

Accounting for the natural clearance of virus after 9.9 days (7), we expect the total number of infected travelers returning to all countries to be between 3 (0 to 7) and 37 (25 to 49). Based on the distribution of foreign visitors to the 2014 FIFA (Fédération Internationale de Football Association) World Cup in Brazil (8), most travelers (53.3%) are expected to come from the United States, Canada, Europe, Oceania, Japan, South Korea, and Israel, where the overall risk of local mosquito-borne transmission is expected to be low (Appendix Figure). Sexual transmission by men thus is the primary concern during the expected 14.9 (0 to 39.6) to 192.2 (108.9 to 277.2) person-days of viremia among travelers returning to those regions.

Most of the remaining travelers (30.2% of the total) are expected to return to Latin American countries already experiencing autochthonous ZIKV transmission, contributing 9.0 (0.0 to 29.7) to 116.0 (59.4 to 188.1) additional person-days of viremia. This effect is negligible relative to prevalent infections caused by ongoing transmission in these countries.

Although the potential introduction of ZIKV to African countries has been of central concern in arguments for postponing or relocating the games (1), we expect a total of only 1.1 (0.0 to 9.9) to 14.5 (0.0 to 39.6) person-days of viremia among travelers returning to all African countries, who made up only 4.0% of World Cup visitors.

Our outcomes highlight the low ZIKV infection, disease, and transmission risk among travelers to the 2016 Olympics in Rio de Janeiro. Attendees of the Olympics likely will encounter a lower risk for ZIKV exposure than the Brazilian population by staying in screened and airconditioned accommodations, in addition to taking precautionary measures individually; for instance, foreign travelers to the 2014 FIFA World Cup in Brazil were less likely than other visitors to report mosquito bites during their stay (9). Only 3 dengue infections were reported among World Cup attendees, despite considerably more pessimistic forecasts (2).

The magnitude of ZIKV risks attributable to the Olympics should be interpreted in the context of all opportunities for the virus to spread internationally. Aside from the Olympics, Brazil receives more than 6 million international arrivals annually, whereas the Caribbean

region hosts nearly 30 million visitors annually and may encounter seasonal increases in ZIKV transmission risk during the summer (2, 3, 8). As of 6 July, the United States has reported 1132 cases of travel-associated ZIKV disease, orders of magnitude higher than the number of imported infections we expect from the Olympics (10). No cases are known to have led to locally acquired mosquito-borne cases in the United States, and only 14 are known to have involved sexual transmission (10). In this context, our findings support the current WHO position that canceling or relocating the Olympics will not significantly alter the international spread of ZIKV.

Policymakers and the public require credible information about travel-associated ZIKV risks during the Olympics to make evidence-based decisions. Whereas several assessments also have suggested that individual travelers face minimal risk (2, 6), the decisions of many athletes to withdraw from the games over ZIKV fears have reinforced public perceptions of risk. Communicating evidence-based assessments to policymakers, as well as through the media, is a top priority to inform the public of ZIKV risk and effective prevention measures.

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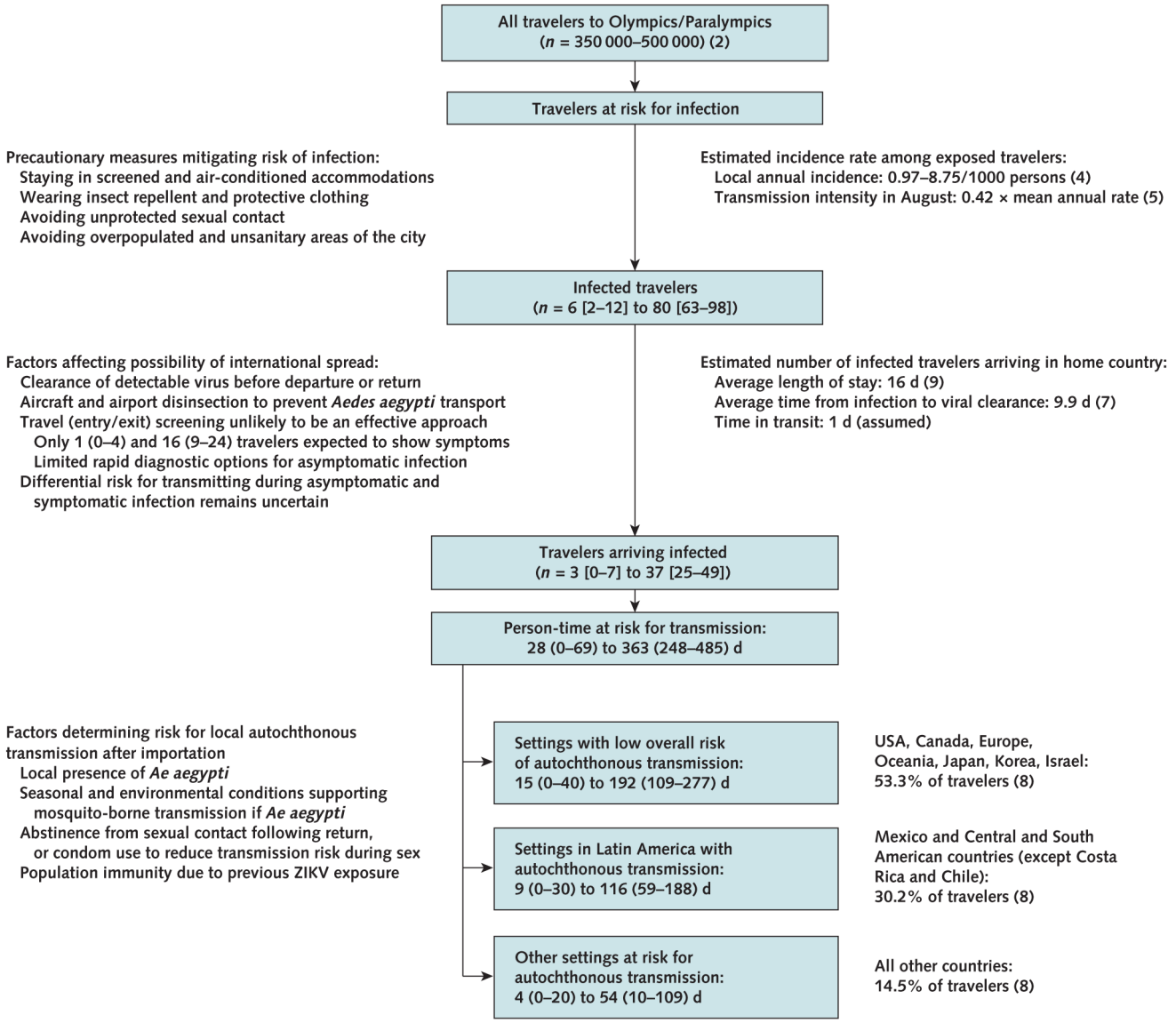

Appendix Figure. Factors affecting travel-associated risk for ZIKV infection and spread

Probability for infection based on the incidence rate (λ) in Rio de Janeiro state, calculated by dividing the total ZIKV infections (15 918 to 143 985 for lower and upper bounds, respectively, accounting for suspected underreporting and a 4:1 ratio of asymptomatic and symptomatic cases) in 2015 by the at-risk population (16.47 million [4]) and adjusting for the relative transmission intensity in August based on the seasonal dynamics of dengue (13.3 per 100 000 per month, compared with an annual average of 31.7 per 100 000 per month) (5). The formula $1 - e^{-\lambda(16/365)}$ provides the estimated probability of an individual becoming infected over 16 days (median duration of international trips to Brazil for 2014 FIFA World Cup travelers) (9). Lower and upper bounds for total infections are each taken to follow Binom (n = Total travelers, p). The probability of an individual becoming infected and departing before clearing the infection is calculated by integrating the function $f(t|\lambda)[1 - F(16 - t|\lambda)]$ for t in 0 to 16 days, assuming exponentially distributed interevent times with

mass distribution *f*. Assuming 1-day transit time, the number remaining infected upon arrival is scaled by $1 - F(1|\lambda)$. The numbers departing and arriving before viral clearance are each binomially distributed. Excess visitors from each country during the 2014 FIFA World Cup were calculated via the difference in entries to Brazil during the months of June and July 2014 relative to the same months in 2013 (8). Numbered references in the figure apply to citations in the main text. FIFA = Fédération Internationale de Football Association; ZIKV = Zika virus infection.