Mosquito-borne infectious disease, risk-perceptions, and personal protective behavior among U.S. international travelers

Oghenekaro Omodiora*, Maya C. Luetke, Erik J. Nelson

*Department of Recreation, Park, and Tourism Studies, Indiana University School of Public Health–Bloomington, United States of America

Abstract

Vector-borne diseases account for a significant amount of the global infectious disease burden, including morbidity and mortality. In particular, mosquito-borne infectious diseases (MBIDs) have the greatest burden in number of cases, mortality, and disability-adjusted life years and their prevention and control is critical. However, prevention efforts are hindered by the absence of vaccines and failure of long-term mosquito vector control for these MBIDs. Thus, personal protective behaviors (PPBs) may offer the most promising and effective mode of prevention. This study examines the impact of awareness, perceived susceptibility, and perceived severity for five MBIDs (e.g., Malaria, Dengue, Zika, Chikungunya and West Nile) on the adoption of PPBs. Study participants (n = 1043) were recruited from a probability-based internet panel of adult United States residents with a history of traveling outside of the country in the past year. Data were collected in the U.S. between June 7, 2017 and June 12, 2017. Our findings show that awareness of Zika disease among respondents was consistently associated with adoption of all three PPBs. Respondents that reported high-perceived severity for all five MBIDs were also more likely to report adopting the PPBs of wearing covering clothing and use of mosquito repellent spray. Our findings indicate that U.S. travelers are largely more concerned about Zika, Chikungunya, and Dengue than Malaria and West Nile and that these concerns drive their adoption of the three recommended PPBs. This information should inform the development and design of future public health campaigns for behavior modification to prevent MBIDs.

1. Introduction

Vector-borne diseases (VBDs) cause significant morbidity and mortality worldwide, accounting for as much as 17% of the global infectious disease burden (Organization, W.H., 2017a). Over one billion people are infected with VBDs annually and more than one million die from those infections each year (Organization, W.H., 2014). Of all the known VBDs, mosquito-borne infectious diseases (MBIDs) account for the highest number of reported cases, mortality, and disability-adjusted life years (World Health Organization, 2018a). Malaria, for example, has an enormous burden globally. In 2016, there were an estimated 216 million cases of malaria worldwide—a slight increase from the previous year—and an estimated 445,000 deaths (Organization, W.H., 2017b). Dengue also has a large global burden with researchers estimating that there are 96 million disease cases per year with > 390 million infections annually (Organization, W.H., 2017a; Bhatt et al., 2013). Although the global burden resulting from Zika, Chikungunya, and West Nile respectively are not as high as those for Malaria, and Dengue, their impact are nevertheless important, particularly, as there have been several large-scale outbreaks of these diseases and transmission has expanded to regions previously unaffected (Kraemer et al., 2015; Campos et al., 2015; Van Bortel et al., 2014; Nash et al., 2001). For example, in the U.S., the CDC reported a statistically significant increase in birth defects associated with Zika virus infection in the second half of 2016 (Delaney et al., 2018). Human risks of Zika virus infection include pregnancy loss, microcephaly, Guillain-Barré syndrome, and other central nervous system malformations (Prevention, U.S.C.f.D.C.a, 2018; World Health Organization, 2018b). In the same year, WNV as the leading cause of domestically acquired arthropod-borne viruses in the continental U.S. was reported in 47 states and the District of Columbia, with 61% of cases being classified as neuroinvasive (Burakoff et al., 2018). The economic costs to national health systems resulting from long-term sequelae for survivors of these MBIDs, the negative impact on travel, tourism, and trade (Focosi et al., 2016) of these
Due to the transmission dynamics and nature of MBIDs, it is critical that targeted and effective prevention messages be disseminated to at-risk populations in order to encourage adoption of the recommended PPBs (Zielinski-Gutierrez and Hayden, 2006). Awareness, perceived susceptibility and perceived severity are constructs drawn from the Health Belief Model (Hochbaum et al., 1952). The former refers to an individual’s subjective assessment of the risk of developing a health problem, while the latter relates to her/his beliefs regarding the severity of the disease. Risk perceptions can be categorized into three levels: high, low, or neither high nor low. The perceived severity and perceived susceptibility of each MBID during international travel are presented in Table 1.

Table 1
Predicting wearing covering clothes to keep mosquitoes away among U.S. International Travelers.

| Have you heard about Zika disease? | Row % | p-Value | UOR\(^a\) | 95% CI | AOR\(^b\) | 95% CI |
|-----------------------------------|-------|---------|-----------|-------|-----------|-------|
| - No                              | 14% (13) | 0.002 | 1.00 | 1.00 | 1.00 | 1.00 |
| - Yes                             | 30% (284) | 2.51 | 1.42-4.81 | 1.91 | 0.96-4.07 |
| Have you heard about Dengue disease? | - No | 28% (157) | 0.7644 | 1.00 | 1.00 | 1.00 |
| - Yes                             | 29% (140) | 1.04 | 0.80-1.36 | 0.75 | 0.52-1.06 |
| Have you heard about West Nile Virus disease? | - No | 21% (31) | 0.0413 | 1.00 | 1.00 | 1.00 |
| - Yes                             | 30% (266) | 1.55 | 1.03-2.40 | 1.35 | 0.80-2.30 |
| Have you heard about Chikungunya disease? | - No | 25% (193) | < 0.0001 | 1.00 | 1.00 | 1.00 |
| - Yes                             | 39% (104) | 1.94 | 1.44-2.61 | 2.03 | 1.39-2.99 |
| Have you heard about Malaria disease? | - No | 19% (12) | 0.0647 | 1.00 | 1.00 | 1.00 |
| - Yes                             | 29% (285) | 1.82 | 0.99-3.61 | 1.60 | 0.71-3.80 |

Perceived Susceptibility to Zika disease during international travel

| - High                             | 40% (60) | 1.00 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 28% (133) | 0.59 | 0.40-0.87 | 0.4 | 0.21-0.74 |
| - Low                              | 25% (104) | 0.50 | 0.34-0.75 | 0.35 | 0.18-0.69 |

Perceived Susceptibility to Dengue disease during international travel

| - High                             | 31% (33) | 0.6263 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 29% (138) | 0.91 | 0.58-1.46 | 4.87 | 1.75-14.36 |
| - Low                              | 27% (126) | 0.82 | 0.52-1.31 | 4.46 | 1.45-14.46 |

Perceived Susceptibility to West Nile disease during international travel

| - High                             | 32% (43) | 0.4919 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 29% (133) | 0.84 | 0.56-1.29 | 1.08 | 0.51-2.33 |
| - Low                              | 27% (121) | 0.78 | 0.51-1.19 | 1.12 | 0.49-2.61 |

Perceived Susceptibility to Chikungunya disease during international travel

| - High                             | 34% (38) | 0.3821 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 27% (132) | 0.73 | 0.48-1.15 | 0.48 | 0.18-1.27 |
| - Low                              | 28% (127) | 0.77 | 0.50-1.20 | 0.69 | 0.22-2.11 |

Perceived Susceptibility to Malaria disease during international travel

| - High                             | 34% (45) | 0.1513 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 30% (125) | 0.84 | 0.56-1.28 | 1.05 | 0.51-2.19 |
| - Low                              | 26% (127) | 0.69 | 0.46-1.05 | 0.82 | 0.37-1.84 |

Perceived Severity of Zika disease

| - High                             | 33% (255) | < 0.0001 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 15% (20) | 0.37 | 0.22-0.59 | 0.41 | 0.21-0.75 |
| - Low                              | 16% (22) | 0.39 | 0.24-0.62 | 0.62 | 0.31-1.24 |

Perceived Severity of Dengue disease

| - High                             | 34% (220) | < 0.0001 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 23% (58) | 0.57 | 0.41-0.80 | 0.64 | 0.37-1.07 |
| - Low                              | 13% (19) | 0.29 | 0.17-0.47 | 0.34 | 0.14-0.79 |

Perceived Severity of West Nile disease

| - High                             | 31% (234) | 0.0027 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 23% (36) | 0.67 | 0.44-0.99 | 1.34 | 0.74-2.41 |
| - Low                              | 19% (27) | 0.50 | 0.32-0.78 | 1.93 | 0.93-4.02 |

Perceived Severity of Chikungunya disease

| - High                             | 34% (201) | < 0.0001 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 24% (73) | 0.62 | 0.45-0.85 | 1.02 | 0.36-1.70 |
| - Low                              | 16% (23) | 0.36 | 0.22-0.57 | 0.79 | 0.36-1.70 |

Perceived Severity of Malaria disease

| - High                             | 31% (244) | 0.0013 | 1.00 | 1.00 | 1.00 |
| - Neither high nor low             | 24% (31) | 0.69 | 0.44-1.05 | 1.23 | 0.67-2.23 |
| - Low                              | 17% (22) | 0.44 | 0.27-0.70 | 0.96 | 0.44-2.02 |

\(^{a}\) UOR = Unadjusted Odds Ratio.  
\(^{b}\) AOR = Adjusted Odds Ratio.

diseases further highlights the urgent need for their prevention and control. More so, because more than half of the world’s human population live in areas infested with mosquito vectors of these diseases (Tam et al., 2016). For these MBIDs there are no vaccinations, asymptomatic infections are common, and control of the mosquito vectors has proven difficult to maintain over the long term. Accordingly, the most promising prevention mechanisms may lie in the adoption of personal protective behaviors (PPBs), which have been shown to be effective in MBID risk reduction (Loeb et al., 2005; Gujral et al., 2007). Recommended PPBs include, but are not limited to, 1) wearing covering clothes to prevent mosquito bites, 2) using mosquito repellent spray on self, and 3) use of mosquito coils or lighting fires to deter mosquitoes from lingering near occupied areas.
about the seriousness of a disease (Janz and Becker, 1984). Within the framework of the Health Belief Model (HBM), a positive linear relationship is said to exist between high perceived susceptibility for a negative health outcome and adoption of a health behavior. Similarly, the HBM posits that the stronger an individual’s perceived severity of a negative health outcome, the more likely they will be motivated to avoid it by adopting the recommended preventive behavior (Rosenstock, 1974). This evaluation results from awareness, which is based on health information and knowledge. While mixed results have been reported on the relationship between perceived susceptibility and infectious disease preventive behavior (Donohoe et al., 2018; Chen et al., 2007), the evidence consistently supports a strong positive relationship between perceived severity and adoption of infectious disease preventive behavior (Omodior et al., 2017b; Ibuka et al., 2010; van der Snoek et al., 2006). However, because the impact of risk perceptions on preventative health behavior is not the same, it is necessary to determine the extent to which MBIDs risk perceptions predict PPBs with a view to designing targeted interventions. Specifically, for different MBIDs for which the same set of PPBs are prescribed, it is essential for effective health promotion messaging to determine which risk perceptions drive the adoption of the recommended behavior. Very few studies have investigated how risk perceptions for different MBIDs affect adoption of specific PPBs among U.S. international travelers, who are a particularly at-risk group. The aim of this study is to determine if awareness, perceived susceptibility, and perceived severity respectively for Malaria, Dengue, Zika, Chikungunya and West Nile, are associated

Table 2
Predicting use of Mosquito repellent spray on self among U.S. International Travelers.

|                          | Row % | p-Value | UOR a | 95% CI      | AOR b | 95% CI      |
|--------------------------|-------|---------|-------|-------------|-------|-------------|
| Have you heard about Zika disease? |       |         |       |             |       |             |
| - No                     | 19% (17) | 0.0003  | 1.00  | 1.00        |       |             |
| - Yes                    | 39% (371) | 2.74     | 1.63-4.86 | 2.44 | 1.26-4.98  |       |             |
| Have you heard about Dengue disease? |       |         |       |             |       |             |
| - No                     | 36% (200) | 0.3386 | 1.00  | 1.00        |       |             |
| - Yes                    | 39% (188) | 1.14     | 0.89-1.47 | 0.85 | 0.62-1.18  |       |             |
| Have you heard about West Nile Virus disease? |       |         |       |             |       |             |
| - No                     | 31% (45) | 0.1181 | 1.00  | 1.00        |       |             |
| - Yes                    | 38% (343) | 1.37     | 0.95-2.02 | 1.07 | 0.66-1.74  |       |             |
| Have you heard about Chikungunya disease? |       |         |       |             |       |             |
| - No                     | 34% (263) | 0.0002 | 1.00  | 1.00        |       |             |
| - Yes                    | 47% (125) | 1.73     | 1.31-2.30 | 1.77 | 1.23-2.55  |       |             |
| Have you heard about Malaria disease? |       |         |       |             |       |             |
| - No                     | 25% (16) | 0.0418 | 1.00  | 1.00        |       |             |
| - Yes                    | 38% (372) | 1.88     | 1.08-3.46 | 1.47 | 0.68-3.26  |       |             |
| Perceived Susceptibility to Zika disease during international travel |       |         |       |             |       |             |
| - High                   | 51% (77) | 0.0006 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 36% (170) | 0.54     | 0.37-0.78 | 0.38 | 0.20-0.71  |       |             |
| - Low                    | 34% (141) | 0.49     | 0.34-0.72 | 0.33 | 0.17-0.64  |       |             |
| Perceived Susceptibility to Dengue disease during international travel |       |         |       |             |       |             |
| - High                   | 42% (44) | 0.4361 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 35% (167) | 0.77     | 0.50-1.19 | 6.41 | 3.94-18.73 |       |             |
| - Low                    | 38% (177) | 0.87     | 0.57-1.34 | 10.42 | 3.46-33.53 |       |             |
| Perceived Susceptibility to West Nile disease during international travel |       |         |       |             |       |             |
| - High                   | 45% (60) | 0.1184 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 37% (170) | 0.71     | 0.48-1.04 | 0.92 | 0.46-1.86  |       |             |
| - Low                    | 35% (158) | 0.67     | 0.45-0.99 | 0.75 | 0.35-1.63  |       |             |
| Perceived Susceptibility to Chikungunya disease during international travel |       |         |       |             |       |             |
| - High                   | 46% (52) | 0.0567 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 34% (166) | 0.61     | 0.40-0.92 | 0.39 | 0.15-1.01  |       |             |
| - Low                    | 38% (170) | 0.70     | 0.46-1.07 | 0.44 | 0.14-0.32  |       |             |
| Perceived Susceptibility to Malaria disease during international travel |       |         |       |             |       |             |
| - High                   | 46% (62) | 0.061   | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 37% (153) | 0.67     | 0.45-1.00 | 0.84 | 0.42-1.69  |       |             |
| - Low                    | 35% (173) | 0.63     | 0.43-0.93 | 0.74 | 0.35-1.57  |       |             |
| Perceived Severity of Zika disease |       |         |       |             |       |             |
| - High                   | 43% (335) | < 0.0001 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 21% (28) | 0.36     | 0.23-0.55 | 0.40 | 0.22-0.69  |       |             |
| - Low                    | 18% (25) | 0.29     | 0.18-0.46 | 0.46 | 0.24-0.87  |       |             |
| Perceived Severity of Dengue disease |       |         |       |             |       |             |
| - High                   | 44% (284) | < 0.0001 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 31% (28) | 0.56     | 0.41-0.77 | 0.76 | 0.46-1.23  |       |             |
| - Low                    | 18% (26) | 0.27     | 0.17-0.42 | 0.53 | 0.24-1.13  |       |             |
| Perceived Severity of West Nile disease |       |         |       |             |       |             |
| - High                   | 41% (306) | < 0.0001 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 33% (50) | 0.69     | 0.47-0.99 | 1.59 | 0.91-2.77  |       |             |
| - Low                    | 22% (32) | 0.41     | 0.27-0.62 | 1.36 | 0.68-2.70  |       |             |
| Perceived Severity of Chikungunya disease |       |         |       |             |       |             |
| - High                   | 44% (263) | < 0.0001 | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 33% (98) | 0.60     | 0.45-0.81 | 0.91 | 0.58-1.42  |       |             |
| - Low                    | 18% (27) | 0.28     | 0.18-0.44 | 0.54 | 0.26-1.11  |       |             |
| Perceived Severity of Malaria disease |       |         |       |             |       |             |
| - High                   | 41% (310) | 0.0001  | 1.00  | 1.00        |       |             |
| - Neither high nor low   | 29% (37) | 0.58     | 0.38-0.86 | 0.90 | 0.50-1.60  |       |             |
| - Low                    | 24% (32) | 0.46     | 0.30-0.70 | 1.54 | 0.78-3.06  |       |             |

*a* UOR = Unadjusted Odds Ratio.

*b* AOR = Adjusted Odds Ratio.
with the adoption of PPBs. We hypothesize that the association between risk perceptions for each of these 5 MBIDs and adoption of the following PPBs, 1) wearing covering clothes for mosquito bite prevention, 2) use of mosquito repellent spray, and 3) use of mosquito coil or lighting fires, among U.S. international travelers, is not the same. These study outcomes have important implications for designing health messaging aimed at increasing the adoption of recommended PPBs in at risk populations. Additionally, the findings of this study may be used to monitor the effectiveness of existing interventions aimed at increasing adoption of PPBs.

### 2. Methods

#### 2.1. Data collection

Study participants were recruited from a probability-based internet panel by Qualtrics (Qualtrics, Provo, Utah, USA) (Qualtrics, 2017) between June 7, 2017 and June 12, 2017. The eligibility criteria for study participation were: (1) adult men and women age ≥ 18 years of age, (2) residence in the United States, (3) spoke English, and (4) had a history of traveling outside of the United States. An Internet survey panel was selected because it is cost-effective and permits the collection of a large and diverse sample over a short timeline (Hays et al., 2015). In total,

### Table 3

Predicting use of mosquito coil/lighting fires to keep mosquitos away among U.S. International Travelers.

|                                      | Row % | p-Value | UOR   | 95% CI       | AOR   | 95% CI       |
|--------------------------------------|-------|---------|-------|--------------|-------|--------------|
| Have you heard about Zika disease?   |       |         |       |              |       |              |
| - No                                 | 8% (07) | 0.0051 | 1.00  | 1.00         |       |              |
| - Yes                                | 20% (189) | 2.93  | 1.43-7.08 | 3.98 | 1.66-11.07 |
| Have you heard about Dengue disease? |       |         |       |              |       |              |
| - No                                 | 17% (96) | 0.1505 | 1.00  | 1.00         |       |              |
| - Yes                                | 21% (100) | 1.26  | 0.92-1.72 | 0.91 | 0.61-1.35 |
| Have you heard about West Nile Virus disease? |       |         |       |              |       |              |
| - No                                 | 19% (27) | 0.9546 | 1.00  | 1.00         |       |              |
| - Yes                                | 19% (169) | 1.01  | 0.65-1.62 | 1.14 | 0.66-2.02 |
| Have you heard about Chikungunya disease? |       |         |       |              |       |              |
| - No                                 | 16% (121) | < 0.0001 | 1.00  | 1.00        |       |              |
| - Yes                                | 28% (75) | 2.13  | 1.53-2.96 | 2.07 | 1.36-3.17 |
| Have you heard about Malaria disease? |       |         |       |              |       |              |
| - No                                 | 19% (12) | 0.9439 | 1.00  | 1.00         |       |              |
| - Yes                                | 19% (184) | 1.02  | 0.55-2.04 | 0.57 | 0.25-1.39 |
| Perceived Susceptibility to Zika disease during international travel |       |         |       |              |       |              |
| - High                               | 33% (49) | < 0.0001 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 17% (81) | 0.43  | 0.28-0.65 | 0.52 | 0.27-1.04 |
| - Low                                | 16% (66) | 0.39  | 0.25-0.60 | 0.59 | 0.29-1.23 |
| Perceived Susceptibility to Dengue disease during international travel |       |         |       |              |       |              |
| - High                               | 32% (34) | 0.0011 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 18% (83) | 0.45  | 0.28-0.73 | 1.53 | 0.54-4.42 |
| - Low                                | 17% (79) | 0.43  | 0.27-0.70 | 2.79 | 0.90-8.98 |
| Perceived Susceptibility to West Nile disease during international travel |       |         |       |              |       |              |
| - High                               | 30% (40) | 0.0013 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 18% (84) | 0.52  | 0.33-0.80 | 1.03 | 0.47-2.28 |
| - Low                                | 16% (72) | 0.45  | 0.29-0.70 | 0.84 | 0.35-2.05 |
| Perceived Susceptibility to Chikungunya disease during international travel |       |         |       |              |       |              |
| - High                               | 31% (35) | 0.0011 | 1.00  | 1.00        |       |              |
| - Low                                | 16% (72) | 0.42  | 0.26-0.68 | 0.54 | 0.17-1.79 |
| - Neither high nor low                | 19% (89) | 0.50  | 0.32-0.80 | 0.91 | 0.34-2.58 |
| Perceived Susceptibility to Malaria disease during international travel |       |         |       |              |       |              |
| - High                               | 31% (41) | 0.0006 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 18% (77) | 0.51  | 0.33-0.80 | 0.85 | 0.40-1.84 |
| - Low                                | 16% (78) | 0.43  | 0.28-0.67 | 0.65 | 0.28-1.54 |
| Perceived Severity of Zika disease    |       |         |       |              |       |              |
| - High                               | 21% (161) | 0.0194 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 12% (16) | 0.53  | 0.30-0.90 | 0.51 | 0.24-1.00 |
| - Low                                | 14% (19) | 0.61  | 0.36-1.00 | 0.67 | 0.31-1.38 |
| Perceived Severity of Dengue disease  |       |         |       |              |       |              |
| - High                               | 21% (135) | 0.0503 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 17% (42) | 0.75  | 0.51-1.09 | 0.87 | 0.48-1.56 |
| - Low                                | 13% (19) | 0.56  | 0.33-0.93 | 0.70 | 0.28-1.70 |
| Perceived Severity of West Nile disease |       |         |       |              |       |              |
| - High                               | 20% (146) | 0.557  | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 16% (25) | 0.80  | 0.49-1.25 | 1.11 | 0.56-2.12 |
| - Low                                | 17% (25) | 0.86  | 0.53-1.36 | 2.01 | 0.93-4.29 |
| Perceived Severity of Chikungunya disease |       |         |       |              |       |              |
| - High                               | 21% (123) | 0.1442 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 17% (52) | 0.80  | 0.55-1.13 | 1.19 | 0.69-2.02 |
| - Low                                | 14% (21) | 0.64  | 0.38-1.04 | 0.97 | 0.41-2.22 |
| Perceived Severity of Malaria disease |       |         |       |              |       |              |
| - High                               | 20% (153) | 0.4549 | 1.00  | 1.00        |       |              |
| - Neither high nor low                | 18% (23) | 0.88  | 0.53-1.41 | 1.23 | 0.63-2.38 |
| - Low                                | 15% (20) | 0.73  | 0.43-1.19 | 0.92 | 0.41-2.03 |

* UOR = Unadjusted Odds Ratio.
* AOR = Adjusted Odds Ratio.
2.2. Statistical analysis

All analyses were conducted using R version 3.4.2 (Team, R.C, 2017). Responses for study participants’ level of education were recoded thus: “GED or less” (< 9th grade, 9–12th grade, High School graduate), “College” (Some college, Associates, Bachelors), and “Graduate school degree” (Graduate school). Based on Chi square cross-tabulation, we derived row percentages and the corresponding p-values to represent the proportion of subjects in each attribute category who adopted the recommended PPB under consideration. Next, we ran logistic regression models to determine which variables had significant predictive power for each of the three PPBs. We fit separate models to examine the relationship between PPBs and awareness, perceived susceptibility, and perceived severity for each of the five MBIDs. The first model used the PPB of ‘wearing covering clothes to keep mosquitoes away’ as the dependent variable. The second and third models were similar to the first, except that the dependent variables utilized were the ‘use of mosquito repellent spray on self’ and ‘use of mosquito coil or lighting fires to keep mosquitoes away’ respectively. An a priori significance of p < 0.05 was used to determine statistical significance.

3. Results

Study participants’ mean age was 36.1 years (SD = 13.77). The gender distribution was, female 68% (n = 710) and male 32% (n = 333). Seventy-two percent (n = 754) reported their race as white, 13% (n = 133) as Black/African American, 7% (n = 77) as Asian, < 1% as Native American (n = 08) and Native Hawaiian (n = 04), while 4% (n = 42) reported more than one race. Twenty-eight percent (n = 297) of study participants reportedly wore covering clothes to keep mosquitoes away. Thirty-seven percent (n = 388) used mosquito repellent or spray on self, and 19% (n = 196) said they used mosquito coils or lit fires to keep mosquitoes away.

We found statistically significant differences in row percentages for awareness of Zika (p < 0.002) and Chikungunya (p < 0.0001), and wearing covering clothing to keep mosquitoes away. We also found significant differences in row percentages for the three categories of perceived severity (‘High’, ‘Neither high nor low’, ‘Low’) for all five MBIDs, among participants who wore covering cloth to keep mosquitoes away (Table 1). Bivariate logistic regression revealed significant differences in the odds of wearing covering clothing to keep mosquitoes away for the following variables, 1) awareness of Zika, West Nile and Chikungunya, 2) perceived susceptibility to Zika and, 3) perceived severity of Zika, Dengue, West Nile, and Chikungunya. After adjusting for demographic variables (age, gender, race, education, and income) in multivariate logistic regression, the odds of wearing covering clothing to keep mosquitoes away was significantly associated with, 1) awareness of Chikungunya disease, 2) perceived susceptibility to Zika and Dengue diseases respectively, and 3) perceived severity of Zika and Dengue diseases respectively.

We found statistically significant differences in row percentages for

---

### Table 4

Summary table of adjusted multivariate logistic regressions: significant predictors of Mosquito Borne Infectious Diseases Personal Protective Behaviors.

| MBID           | Wearing covering clothing | Using mosquito repellent spray on self | Using mosquito coil/lighting fires |
|----------------|---------------------------|---------------------------------------|-----------------------------------|
| Zika awareness | No                        | Yes                                   | Yes                               |
| Dengue awareness | No                       | No                                    | No                                |
| West Nile awareness | No                     | No                                    | No                                |
| Chikungunya awareness | Yes                   | Yes                                   | No                                |
| Malaria awareness | No                       | No                                    | No                                |
| Perceived susceptibility to Zika | Yes               | Yes                                   | No                                |
| Perceived susceptibility to Dengue | Yes          | Yes                                   | No                                |
| Perceived susceptibility to West Nile | No          | No                                    | No                                |
| Perceived susceptibility to Chikungunya | No | No                                    | No                                |
| Perceived susceptibility to Malaria | No | No                                    | No                                |
| Perceived severity of Zika | No                | Yes                                   | No                                |
| Perceived severity of Dengue | No               | Yes                                   | No                                |
| Perceived severity of West Nile | No             | No                                    | No                                |
| Perceived severity of Chikungunya | No            | Yes                                   | No                                |
| Perceived severity of Malaria | No            | No                                    | No                                |

Note: Yes indicates a significant association, not the directionality of the association. No indicates that no significant association was found in the adjusted multivariate logistic regression.
awareness of Zika (p < 0.0003), Chikungunya (p < 0.0002), and Malaria (p < 0.0418) respectively, and use of mosquito repellent spray on self, among U.S international travelers. Row percentages for the 3 categories of perceived susceptibility (‘High’, ‘Neither high nor low’, ‘Low’) to Zika during international travel were significantly different in association with use of mosquito repellent spray on self. We also found significant differences (p < 0.05) in row percentages for the 3 categories of perceived severity (‘High’, ‘Neither high nor low’, ‘Low’) for all 5 MBIDs, among participants who use mosquito repellent spray on self (Table 2). Bivariate logistic regression revealed significant differences in the odds of use of mosquito repellent spray on self, and 1) awareness of Zika, Chikungunya and, Malaria, 2) perceived susceptibility to Zika and, 3) perceived severity of all 5 MBIDs (i.e. Zika, dengue, West Nile, Chikungunya and Malaria). After adjusting for demographic variables (age, gender, race, education, and income) in multivariate logistic regression, the odds of use of mosquito repellent spray on self among U.S. international travelers was significantly associated with, 1) awareness for Zika and Chikungunya diseases respectively, 2) perceived susceptibility to Zika disease and Dengue respectively and, 3) perceived severity of Zika disease.

We found evidence of statistical significance in the proportion of study participants who reported use of mosquito coil/lighting fires to keep mosquitoes away, and 1) awareness of Zika disease (p < 0.0051) and Chikungunya (p < 0.0001) respectively, 2) perceived susceptibility to all 5 MBIDs (i.e. Zika (p < 0.0001), Dengue (p < 0.0011), West Nile (p < 0.0013), Chikungunya (p < 0.0011), and Malaria (p < 0.0006), and 3) perceived severity of Zika (p < 0.0194) and Dengue (p < 0.0503) respectively (Table 3). Bivariate logistic regression revealed significant differences in the odds of use of mosquito coil/lighting fires to keep mosquitoes away and, i) awareness of Zika and Chikungunya respectively, ii) perceived susceptibility to all 5 MBIDs (i.e. Zika, Dengue, West Nile, Chikungunya, and Malaria), iii) perceived severity of all 5 MBIDs (i.e. Zika, Dengue, West Nile, Chikungunya and Malaria). After adjusting for demographic variables (age, gender, race, education, and income) in multivariate logistic regression, the odds of using mosquito coil/lighting fires to keep mosquitoes away was significant in association with, awareness for Zika and Chikungunya diseases respectively. No other significant differences were observed.

4. Discussion

A major challenge for instructional content designers when creating messages for behavior modification in disease risk prevention, is ascertaining what motivates the target population to engage in the recommended behavior. For U.S. travelers to regions of the world where various MBIDs are endemic, understanding the strength of risk perceptions for different MBIDs and how these work either in isolation or together, to ultimately drive the adoption of PPBs, is important public health implications for MBID control and prevention. Our findings show that awareness of Zika disease among U.S. international travelers was consistently associated with adoption of all three personal protective behaviors as indicated by row percentages and significant Chi-square p-values. Additionally, U.S. international travelers with high-perceived severity for all five MBIDs were also more likely to report adopting wearing covering clothing and use of mosquito repellent spray to keep mosquitoes away. The only PPB for which perceived severity for all five MBIDs did not show significant association across board was using mosquito coil/lighting fires to keep mosquitoes away. Although effective in preventing mosquito exposure, use of mosquito coil/lighting fires is less universally available as a PPB, compared to wearing covering clothing and use of mosquito repellent sprays. Diminished availability may lead to reduced self-efficacy for adoption of the behavior, which may partly explain why perceived severity was not associated with this particular recommended PPB.

As seen in Table 4, after adjusting for the presence of other variables in separate logistic regression models, awareness of Chikungunya disease was significantly associated with the odds of engaging in all three recommended PPBs. Further, awareness of Zika and Chikungunya diseases were significantly associated with odds of engaging in both use of mosquito repellent and use of mosquito coils or lighting fires. Previous studies have demonstrated the association between exposure to health messages, awareness and behavior modification (Carleton et al., 1996; Kaskutas and Graves, 1994). A possible explanation for the effect of Chikungunya and Zika awareness on PPB is that awareness increases overall intention to adopt the recommended behavior which, studies have shown is a significant predictor of actual behavior (Omodior et al., 2015; Ajzen, 1985). Additionally, the odds of wearing covering clothing and using mosquito repellent were associated with perceived susceptibility to Zika disease and Dengue. Although perceived susceptibility to Chikungunya was not significantly associated with the odds of adoption of any of the three personal protective behaviors in the current study, previous studies have reported association (Omodior et al., 2017b).

Although this study did not investigate the proportion of U.S. international travelers who specifically adopted all three protective behaviors, identifying predictors of multiple behaviors is significant. This is because it has been recommended that individuals at risk of MBIDs should adopt multiple components of an insect repellent system (which includes use of repellents on skin/clothing, wearing covering clothing, etc.) for maximum protection (US Army Public Health Center, 2016). It is also interesting to note that a previous study of U.S. international travelers reported low Chikungunya awareness (Omodior et al., 2017a). It would therefore seem that raising awareness for Chikungunya disease together with Zika, with a focus on encouraging increased adoption of personal protective behavior among U.S. international travelers is an effective health promotion strategy. Our study findings seem to indicate that U.S. international travelers are largely more concerned about Zika, Chikungunya, and Dengue compared to Malaria and West Nile and these concerns drive their adoption of the three recommended MBID personal protective behaviors. This could indicate that information campaigns surrounding these three diseases have been more effective than others, especially because outbreaks and epidemics of these diseases have been featured in the news media more recently in relation to travel (U.S. Centers for Disease Control and Prevention, 2017; US Centers for Disease Control and Prevention, 2015; U.S. Centers for Disease Control and Prevention, 2016). Our findings further support previous studies which indicate that perceived severity is consistently predictive of MBID preventive behavior (Omodior et al., 2017b; Ibuka et al., 2016; van der Snoek et al., 2006).

A major limitation of this study is that the associations modeled between the explanatory and outcome variables are based on self-reporting. Whether these associations reflect actual behavior cannot be determined from this study. Secondly, study participants were drawn from an internet-based panel. This leaves out non-internet users, who may be significantly different from the former. Additionally, because study participants were volunteer U.S. international travelers, the risk-perceptions of non-volunteer subjects may not have been captured in our study. In spite of these limitations, the findings from this study provide useful insights into the risk perceptions of U.S. international travelers and how these predict adoption of three recommended personal protective behaviors. Individuals and groups charged with instructional design of health promotion messages for control and prevention of mosquito-borne infectious diseases would find the information valuable, as they plan and develop content for mosquito-borne disease prevention and control interventions.

Conflict of interest disclosures

The authors whose names are listed on this article certify that they have NO affiliations or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.
References

Ajzen, I., 1985. From intentions to actions: a theory of planned behavior. In: Action Control. Springer, pp. 11–39.
Bhatt, S., et al., 2013. The global distribution and burden of dengue. Nature 496 (7446), 504–507.
Buraloff, A., et al., 2018. West Nile virus and other nationally notifiable arboviral diseases—United States, 2016. Morb. Mortal. Wkly Rep. 67 (1), 13.
Bureau, U.S.C, 2017. American Community Survey (ACS) (cited 2018 Jan 10); Available from: https://www.census.gov/programs-surveys/acs/.
Campos, G.S., Randeau, A.C., Sardi, K.I., 2015. Zika virus outbreak, bahia, brazil. Emerg. Infect. Dis. 21 (10), 1885.
Carleton, R.A., et al., 1996. Report of the expert panel on awareness and behavior change to the board of directors, American Heart Association. Circulation 93 (9), 1768–1772.
Chen, J.Y., et al., 2007. Health disparities and prevention: racial/ethnic barriers to flu vaccinations. J. Community Health 32 (1), 5–20.
Delaney, A., et al., 2018. Population-based surveillance of birth defects potentially related to Zika virus infection—15 states and US territories, 2016. Morb. Mortal. Wkly Rep. 67 (3), 91.
van der Snoek, E.M., et al., 2006. Incidence of sexually transmitted diseases and HIV infection in men who have sex with men related to knowledge, perceived susceptibility, and perceived severity of sexually transmitted diseases and HIV infection: Dutch MSM-cohort study. Sex. Transm. Dis. 33 (3), 193–198.
Donohoe, H., Omotorid, O., Roe, J., 2018. Tick-borne disease occupational risks and behaviors of Florida Fish, Wildlife, and Parks Service employees—a health belief model perspective. J. Outdoor Recreat. Tour. 22, 9–17.
Focosi, D., Maggi, F., Pistello, M., 2016. Zika virus: implications for public health. Clin. Infect. Dis. 63 (2), 227–233.
Gujral, I.B., et al., 2007. Behavioral risks for West Nile virus disease, northern Colorado, 2003. Emerg. Infect. Dis. 13 (3), 415.
Hays, R.D., Liu, H., Kapteny, A., 2015. Use of Internet panels to conduct surveys. Behav. Res. Methods 47 (3), 685–690.
Hochbaum, G., Rosenstock, I., Kegels, S., 1952. Health Belief Model. United States Public Health Service.
Ibuka, Y., et al., 2010. The dynamics of risk perceptions and precautionary behavior in response to 2009 (H1N1) pandemic influenza. BMC Infect. Dis. 10 (1), 296.
Janz, N.K., Becker, M.H., 1984. The health belief model: a decade later. Health Educ. Q. 11 (3), 1–47.
Kaskutas, L.A., Graves, K., 1994. Relationship between cumulative exposure to health messages and awareness and behavior-related drinking during pregnancy. Am. J. Health Promot. 9 (2), 115–124.
Kraemer, M.U., et al., 2015. The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus. elife 4.
Loeb, M., et al., 2005. Protective behavior and West Nile virus risk. Emerg. Infect. Dis. 11 (9), 1433.
Nash, D., et al., 2001. The outbreak of West Nile virus infection in the New York City area in 1999. N. Engl. J. Med. 344 (24), 1807–1814.
Omodior, O., Pennington-Gray, L., Donohoe, H., 2015. Efficacy of the theory of planned behavior in predicting the intention to engage in tick-borne disease personal protective behavior amongst visitors to an outdoor recreation center. J. Park. Recreat.
Adm. 33 (2).
Omodior, O., et al., 2017a. Chikungunya disease awareness among U.S. travelers to Caribbean destinations. Int. J. Travel Med. Glob. Health 5 (1), 20–27.
Omodior, O., Pennington-Gray, L., Thapa, B., 2017b. Modeling insect-repellent use for chikungunya disease prevention among US-Caribbean travelers. Int. J. Travel Med. Glob. Health 5 (4), 125–134.
Organization, W.H, 2014. A Global Brief on Vector-Borne Diseases. World Health Organization, Geneva.
Organization, W.H, 2017a. Vector-Borne Diseases Factsheet. World Health Organization, Geneva.
Organization, W.H, 2017b. World Malaria Report 2017. World Health Organization, Geneva.
Prevention, U.S.C.D.C.a, 2018. Zika and pregnancy: infection during pregnancy (cited 2018 September, 27); Available from: https://www.cdc.gov/pregnancy/zika/testing-follow-up/effects-during-pregnancy.html.
Prevention, U.S.C.D.C.a, 2018. West Nile virus and other nationally notifiable arboviral diseases—United States, 2016. Morb. Mortal. Wkly Rep. 67 (1), 13.
Sheeran, P., Harris, P.R., Epton, T., 2014. Does heightening risk appraisals change people’s intentions and behavior? A meta-analysis of experimental studies. Psychol. Bull. 140 (2), 511.
Tam, C.C., Khan, M.S., Legido-Quigley, H., 2016. Where economics and epidemics collide: migrant workers and emerging infections. Lancet 388 (10052), 1374–1376.
Team, R.C., 2017. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
U.S. Centers for Disease Control and Prevention, 2016. Dengue (cited 2018 June, 08); Available from: https://wwwnc.cdc.gov/travel/diseases/dengue.
U.S. Centers for Disease Control and Prevention, 2017. Prevent Zika on Your trip (cited 2018 June, 08); Available from: https://www.cdc.gov/viajosinzika/.
U.S Army Public Health Center, 2016. DoD Insect Repellent System (cited 2016 4 October); Available from: https://phc.amedd.army.mil/topics/envirohealth/epm/Pages/DoDInsectRepellentSystem.aspx.
US Centers for Disease Control & Prevention, 2015. Chikungunya in the Caribbean (cited 2016 06 October); Available from: http://wwwnc.cdc.gov/travel/notices/watch/chikungunya-caribbean (March).
Van Bortel, W., et al., 2014. Chikungunya outbreak in the Caribbean region, December 2013 to March 2014, and the significance for Europe. Eur. Secur. 19 (13), 2079.
World Health Organization, 2016. Knowledge, attitudes and practice surveys: Zika virus disease and potential complications: resource pack. Available from: http://apps.who.int/iris/bitstream/handle/10665/204689/?sequence=1.
World Health Organization, 2018a. Annex 1. Global Burden of Major Vector-Borne Diseases, as of March 20 (cited 2018 June, 04); Available from: http://www.who.int/ vector-control/burden/vector-borne_diseases.pdf.
World Health Organization, 2018b. Zika virus (cited 2018 September, 27); Available from: http://www.who.int/news-room/fact-sheets/detail/zika-virus.
Zielinski-Gutierrez, E.C., Hayden, M.H., 2006. A model for defining West Nile virus risk perception based on ecology and proximity. EcoHealth 3 (1), 28–34.