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Mosquito Avoidance Practices and Knowledge of Arboviral Diseases in Cities with Differing Recent History of Disease

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Abstract. As the range of dengue virus (DENV) transmission expands, an understanding of community uptake of prevention and control strategies is needed both in geographic areas where the virus has recently been circulating and in areas with the potential for DENV introduction. Personal protective behaviors such as the use of mosquito repellent to limit human–vector contact and the reduction of vector density through elimination of oviposition sites are the primary control methods for *Aedes aegypti*, the main vector of DENV. Here, we examined personal mosquito control measures taken by individuals in Key West, FL, in 2012, which had experienced a recent outbreak of DENV, and Tucson, AZ, which has a high potential for introduction but has not yet experienced autochthonous transmission. In both cities, there was a positive association between the numbers of mosquitoes noticed outdoors and the overall number of avoidance behaviors, use of repellent, and removal of standing water. Increased awareness and perceived risk of DENV were associated with increases in one of the most effective household prevention behaviors, removal of standing water, but only in Key West.

INTRODUCTION

Dengue virus (DENV), chikungunya virus (CHIKV), and Zika virus (ZIKAV) are emerging as significant threats in communities where the primary vector, *Aedes aegypti*, is established.[1–3] DENV currently affects populations in 125 countries with 100 million annual symptomatic infections and nearly 4 billion people at risk.[4,5] Models project expansion of *Ae. aegypti* into new locations as climatic conditions become more supportive of mosquito development and survival.[4,6–8] Although the suitable habitat range expands because of climate, geographic spread of *Ae. aegypti* is aided by increased globalization and transportation.[9,10]

The presence of competent vectors does not always lead to subsequent viral transmission.[2] Although climatic shifts may make an area suitable for vector presence, human behavior modifies the incidence of disease. Socioeconomic factors influence vector–human contact through higher use of air conditioning with closed windows, screened windows and doors, and better overall housing infrastructure.[3,11–15] Furthermore, studies of arboviral diseases demonstrate that disease knowledge and perceived risk may drive human preventive behavior to reduce vector–human contact and mosquito density.[16–22]

To ascertain the factors that influence mosquito avoidance strategies, we conducted a knowledge, attitudes, and practices (KAP) survey to evaluate the role that mosquito and disease knowledge, perceived risk of disease, experience with public health campaigns, and perception of mosquito control responsibility play in influencing residents' preventive behaviors. Our study areas include two cities with differing histories of arbovirus transmission: Key West, FL, and Tucson, AZ. Key West has a tropical wet and dry savanna climate with an average annual rainfall of 1,012 mm and an average annual minimum temperature of 22.8°C and maximum of 28.1°C. Tucson has a subtropical steppe climate with averages of 294 mm rainfall, 13.2°C minimum temperature, and 28.4°C maximum temperature.[23] Although environmentally distinct, both have established populations of *Ae. aegypti*.[24,25] Residents of Key West experienced an outbreak of DENV in 2009–2010. In 2015, there were 60 imported DENV cases in Arizona, but no locally acquired transmission was detected.[26] Although no local DENV transmission has been reported in Tucson, residents have been exposed to mosquito control campaigns related to West Nile virus (WNV) transmission, a disease that is endemic to the city. The purpose of this study was to use household surveys to examine differences in prevention strategies undertaken within the two cities with established *Ae. aegypti* populations, one with a history of DENV and one without.

MATERIALS AND METHODS

Site description. Before 2009, the last known locally acquired cases of DENV in Florida occurred in 1934.[27] An outbreak of DENV was detected in Key West and neighboring Stock Island, FL, in 2009–2010, with a total of 93 autochthonous cases of DENV confirmed by the Florida State Health Department.[27,28] Outreach and educational activities were conducted by the Florida Mosquito Controls District and the Monroe County Health Department during the outbreak.

Aedes aegypti populations were noted in Tucson between 1931 and 1946,[29,30] after which they remained undetected until 1994.[24,31] Although there have been no reported autochthonous DENV cases in Tucson, DENV cases are reported annually in Hermosillo, Sonora, Mexico, just 250 miles south of Tucson.[32] In 2014, over 60 cases of DENV were reported in Yuma, AZ. All cases had a history of cross-border travel, with most traveling across the border to San Luis Rio Colorado, Sonora (Arizona Department of Health Services, personal communication). Thus, although no autochthonous DENV cases have been confirmed yet in Arizona, cross-border travel from endemic areas is indicative of the risk of viral introduction.

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Study design and sample selection. *Key West and Stock Island (hereafter referred to as Key West).* We conducted household surveys from mid-June to mid-July 2012 to assess KAP with respect to DENV and residential mosquito control. A total of 400 residential parcels were randomly selected for inclusion in the survey using data obtained from the Monroe County Appraisers Office. Parcel data reflect distinct property boundaries and can be assigned as residential, governmental, commercial, or multiple uses. Residential parcels and multiple-use parcels that included residential use were included for selection. If a parcel had multiple residential units listed, that parcel was repeated in the database for an equivalent number of times to ensure all residential units had an equal probability of selection. Household surveys were conducted from mid-June to mid-July 2012 reflecting the period with highest mosquito activity. The sampling period was restricted to 1 month to reduce any seasonal variability in responses.

Tucson. Residential surveys were conducted in late July and August 2012. Timing coincided with the peak of mosquito activity after the onset of the monsoon rains and was restricted to a 1-month period. Parcel data were obtained from Pima County. Because of the greater geographic size of Tucson, a random set of 20 points at least 1 km apart were generated using ArcGIS (Redlands, CA) within the city limits of Tucson. The closest residential neighborhoods, defined as two by two city blocks, were selected for participation. Within each neighborhood, 20 residential parcels were randomly selected for a total of 400 randomly selected parcels.

Surveys were conducted following the same standardized procedure in each city. To account for variability in activities and work schedules, two home visits were made at different times of day and on both weekdays and weekends. If residents were unreachable on the first attempt, informational material was left inviting them to participate and asking them to call to set up a time that would work best. If, after the second visit, the randomly selected household remained unreachable or refused to participate, a systematic approach was used to find a replacement for the home. Most of the respondents were from the replacement sampling (82% of Key West respondents and 75% of Tucson respondents). Reasons for nonparticipation included 1) direct refusal, 2) no one at home after two attempts, and 3) vacant or abandoned homes. In Tucson, replacements were not obtained for all randomly selected parcels because of time constraints (1-month sampling period), resulting in a final sample size of 375 households in this city. Environmental data were also collected, and the property was examined for the presence of potential mosquito oviposition sites and immature mosquitoes. Only the results of the KAP survey are presented in this analysis. To minimize bias, training was provided to all interviewers on ethics, maintaining a neutral attitude toward responses, and minimizing leading bias. This was of particular concern in Key West, an area that has experienced public health campaigns to educate community members about DENV and reduction of mosquito populations.

KAP survey content. Survey topics included residential history, awareness of mosquito-borne diseases, perceived risk of mosquito-borne diseases, health-care-seeking behavior, knowledge of mosquito habitat, perceptions of mosquito control responsibility (personal and governmental), perceptions toward alternative control methods (biologic versus chemical), willingness to pay for public control of mosquitoes, and demographic information. Given the recent outbreak of DENV in Key West, questions were added to target knowledge of specific symptoms, local public health concerns, and local educational campaigns. Because of the lack of DENV transmission in Tucson, eight questions were added in Tucson to assess knowledge awareness and perceptions of local public health measures to combat WNV, which is endemic in Tucson.

Ethics statement. A disclosure statement that was read to participating households indicated that they were under no obligation to participate and they could stop participation at any time. Written consent was not obtained as it would be an added link between study data and participants, and the survey was designed to pose minimal risks to participants. Participants were provided a copy of the disclosure statement with contact information for the principal investigator if questions arose. The study protocol, including a disclosure statement, was approved by the University of Arizona Human Subjects Research Committee and deemed exempt.

Data analysis. Absolute and relative frequencies of responses were calculated for all survey respondents, for a total of 400 in Key West and 375 in Tucson. Three separate dichotomous outcomes were defined to examine respondents' participation in mosquito avoidance strategies: 1) the reported use of five or more mosquito avoidance practices, regardless of the established efficacy of each method (see Table 2 for full list); 2) reported frequency of emptying standing water at least once per week or after each rainfall,

TABLE 1
Characteristics of survey respondents

	Key West (N = 400*)	Tucson (N = 375*)
	n (%)	n (%)
Age group (year)		
18–35	98 (25.3)	108 (29.6)
36–50	77 (19.9)	88 (24.1)
51–65	121 (31.3)	97 (26.6)
≥ 66	91 (23.5)	72 (19.7)
Gender (female)	183 (46.1)	198 (53.4)
Race		
White non-Hispanic	247 (63.8)	203 (55.2)
Hispanic	77 (19.9)	133 (36.1)
Black	36 (9.3)	11 (3.0)
American Indian/Alaska Native	5 (1.3)	6 (1.6)
Asian/Pacific Islander	14 (3.6)	5 (1.4)
Multiracial	0 (0)	4 (1.1)
Other	8 (2.1)	6 (1.6)
Own home	228 (61.1)	273 (74.2)
Household income ($)		
< 35,000	54 (13.5)	114 (30.4)
35,000–49,999	31 (7.8)	50 (13.3)
50,000–74,999	52 (13.0)	62 (16.5)
75,000–99,999	37 (9.3)	25 (6.7)
≥ 100,000	72 (18.0)	55 (14.7)
Declined	154 (38.5)	69 (18.4)
Highest level of education completed		
Less than high school	30 (7.7)	37 (10.0)
High school graduate	93 (23.9)	59 (16.0)
Some college	77 (19.8)	83 (22.5)
Associate's	19 (4.9)	31 (8.4)
Bachelor's	107 (27.5)	88 (23.9)
Graduate or professional	63 (16.2)	71 (19.2)

*Not all categories sum to the total number of individuals because of missing data.

TABLE 2
Respondents reporting use of mosquito avoidance strategies in Key West, FL, and Tucson, AZ

	Key West	Tucson	
	N (%)	*N* (%)	*P* value
Wear protective clothing	122 (30.5)	112 (29.9)	0.85*
Burn citronella candles	140 (35.0)	78 (20.8)	< 0.001*
Drain stagnant water	285 (71.3)	176 (46.9)	< 0.001*
Call mosquito control	107 (26.8)	12 (3.2)	< 0.001*
Burn coils	59 (14.8)	25 (6.7)	< 0.001*
Burn tiki torches	72 (18.0)	18 (4.8)	< 0.001*
Spray insecticide	163 (40.8)	113 (30.1)	0.002*
Stay indoors	217 (54.3)	113 (30.1)	< 0.001*
Fix and install screens	N/A‡	80 (21.3)	N/A‡
Clear yard of brush and long weeds	N/A‡	116 (30.9)	N/A‡
Other	5 (1.3)	2 (0.5)	0.45†
Nothing	27 (6.8)	89 (23.7)	< 0.001*
Reported frequency of checking for standing water			0.01*
Never	78 (21.1)	102 (29.1)	
Once or twice a month	47 (12.7)	41 (11.7)	
Once a week	59 (15.9)	52 (14.9)	
More than once a week	53 (14.3)	45 (12.9)	
Daily	75 (20.3)	41 (11.7)	
After every rainfall	58 (15.7)	69 (19.7)	
Water checking frequency§			0.0497*
Ineffective frequency	125 (33.8)	143 (40.9)	
Effective frequency	245 (66.2)	207 (59.1)	

*Calculated by χ^2 test.
†Calculated by Fisher's exact test.
‡Some avoidance questions were not asked of residents in both cities and are therefore excluded.
§An effective frequency of checking for standing water was considered to be once a week, more than once a week, daily, or after every rainfall.

a frequency considered sufficient to prevent complete development of immature *Ae. aegypti* mosquitoes; and 3) reported use of mosquito repellent to be "often" or greater (in contrast to "sometimes" or less).

To examine correlates with these mosquito avoidance strategies, we used univariate logistic regression models to compare those who undertook prevention strategies and those who did not. Factors assessed in these models were demographic characteristics and KAP regarding mosquitoes and arboviral diseases. Multivariable models were explored for potential confounding and effect modification but are not presented, as there was no significant influence on parameter estimates or overall model goodness of fit.

Multiple imputation was performed to examine the impact of missing data in the household income question (38.5% for Key West and 18.4% for Tucson). Sensitivity analyses were performed to examine suitability of model parameters. Several cut points for the threshold of total avoidance strategies were explored. Questions that pertained only to Tucson were excluded from the calculations of total strategies used. None of these adjustments substantively changed the results from those presented here.

RESULTS

Respondent characteristics differed between the two study sites (Table 1). In Tucson, respondents were younger, more likely to be Hispanic, and reported lower income overall (30.4%, < $35,000 annually, compared with 13.5% in Key West < $35,000 annually).

Respondents in Key West were significantly more likely to report using each of the mosquito avoidance strategies than respondents in Tucson (Table 2). Not only did Key West respondents report greater use of specific strategies, but they also reported use of a greater number of the total avoidance strategies (Figure 1). Respondents in Key West also reported checking for and removing standing water from their property more frequently than those in Tucson ($P = 0.01$) (Table 2).

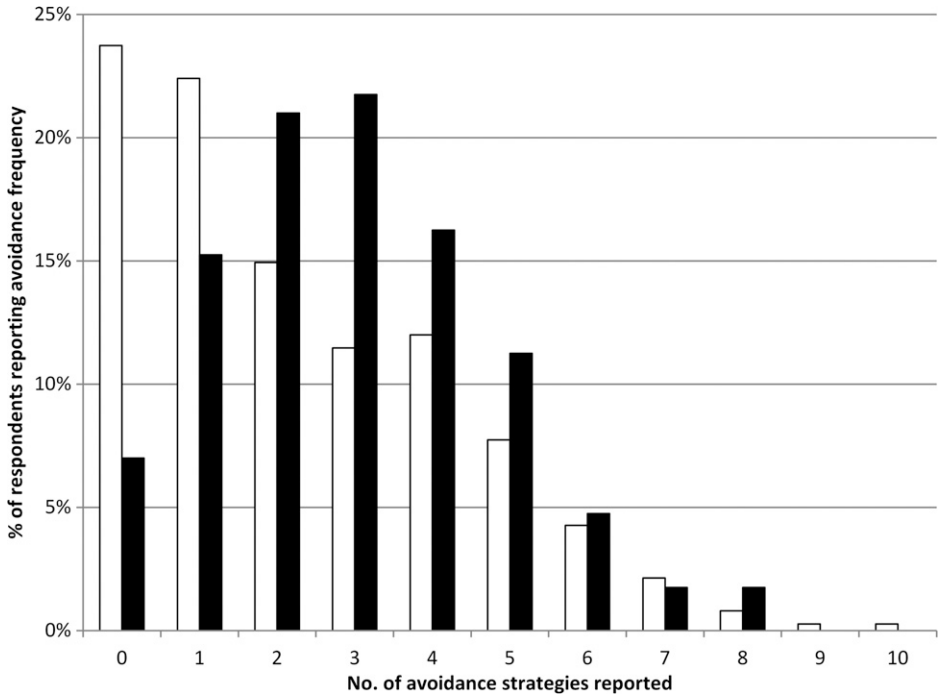

FIGURE 1. Total number of mosquito avoidance strategies listed by survey respondents in Key West, FL, and Tucson, AZ. Black bars = Key West, FL; white bars = Tucson, AZ.

TABLE 3
The association between respondent demographic characteristics and reported avoidance strategies used in Key West, FL

	OR (95% CI)		
	Reports practicing five or more avoidance strategies 87 (21.8%)	Uses repellent often or always 61 (15.3%)	Checks for standing water at least once a week or after each rainfall 245 (66.2%)
Age group (year)			
18–35	Ref.	Ref.	Ref.
36–50	1.46 (0.74, 2.89)	1.25 (0.60, 2.61)	1.99 (1.05, 3.79)*
51–65	1.01 (0.53, 1.91)	0.76 (0.37, 1.55)	3.78 (2.07, 6.91)*
≥ 66	0.56 (0.26, 1.20)	0.32 (0.12, 0.86)*	2.48 (1.33, 4.61)*
Own home			
Yes	0.91 (0.55, 1.51)	1.78 (1.01, 3.14)*	0.54 (0.34, 0.84)*
No	Ref.	Ref.	Ref.
Children live in the home			
Yes	1.76 (1.06, 2.93)*	1.31 (0.72, 2.37)	0.79 (0.49, 1.28)
No	Ref.	Ref.	Ref.
Residency duration			
< 1 year	0.61 (0.20, 1.88)	1.00 (0.27, 3.66)	0.26 (0.10, 0.67)*
1–5 years	0.81 (0.40, 1.64)	1.59 (0.71, 3.55)	0.31 (0.16, 0.61)*
≥ 5 years	0.61 (0.35, 1.08)	1.02 (0.52, 2.01)	0.90 (0.52, 1.57)
Lifelong	Ref.	Ref.	Ref.

CI = confidence interval; OR = odds ratio.
*$P < 0.05$ by Wald χ^2 test for this level of the variable.

Logistic regression was used to explore factors associated with utilization of mosquito avoidance practices (Key West, Table 3; Tucson, Table 4). In both cities, all older age groups (> 35 years) had higher odds of reporting that they cleared standing water from their yard on an effective schedule (those older than 65 years relative to 18–35 years old, Key West odds ratio [OR] = 2.48, 95% confidence interval [CI] = 1.33–4.61; Tucson OR = 2.09, 95% CI = 1.12–3.91). In Key West, age was also positively associated with use of insect repellent: those older than 65 years had 68% decreased odds of using repellent (OR = 0.32, 95% CI = 0.12–0.86) as compared with the 18- to 35-year-old group. Key West respondents that owned their home had lower odds of reporting effective water removing practices than non-homeowners (OR = 0.54, 95% CI = 0.34–0.84). Key West residents with children living in the home had higher odds of practicing multiple mosquito avoidance strategies as compared with those without children in the household (OR = 1.76, 95% CI = 1.06–2.93).

Associations were also explored between the avoidance strategies and knowledge and perceptions about mosquitoes and arboviruses (Tables 5 and 6). In general, respondents who noticed fewer mosquitoes had lower odds of participating in avoidance strategies than those noticing many mosquitoes. This relationship is noted in both the Key West (OR = 0.53, 95% CI = 0.28–1.00) and Tucson (OR = 0.39, 95% CI = 0.22–0.68) analyses. Participants in Key West were asked about their knowledge of mosquito breeding sites. Compared with those who did not know where mosquitoes lay eggs or did not report a standing water source, those who reported either standing water or a specific oviposition container had higher odds of reporting using multiple avoidance strategies (OR = 2.37, 95% CI = 1.02–5.52 and OR = 3.33, 95% CI = 1.36–8.15, respectively). Furthermore, respondents

TABLE 4
The association between respondent demographic characteristics and reported avoidance strategies used in Tucson, AZ

	OR (95% CI)		
	Reports practicing five or more avoidance strategies 58 (15.5%)	Uses repellent often or always 61 (16.4%)	Checks for standing water at least once a week or after each rainfall 207 (59.1%)
Age group (year)			
18–35	Ref.	Ref.	Ref.
36–50	1.85 (0.89, 3.87)	1.52 (0.71, 3.28)	2.95 (1.61, 5.39)*
51–65	1.73 (0.83, 3.58)	1.68 (0.80, 3.52)	3.16 (1.74, 5.75)*
≥ 66	0.85 (0.35, 2.06)	0.77 (0.31, 1.93)	2.09 (1.12, 3.91)*
Own home			
Yes	0.69 (0.36, 1.33)	0.79 (0.40, 1.53)	0.64 (0.39, 1.04)
No	Ref.	Ref.	Ref.
Children live in the home			
Yes	1.44 (0.85, 2.45)	1.34 (0.77, 2.33)	0.93 (0.60, 1.44)
No	Ref.	Ref.	Ref.
Residency duration			
< 1 year	1.08 (0.13, 9.11)	1.02 (0.12, 8.63)	†
1–5 years	1.88 (0.72, 4.88)	0.91 (0.29, 2.84)	0.60 (0.26, 1.38)
≥ 5 years	1.31 (0.74, 2.30)	1.04 (0.58, 1.85)	0.84 (0.53, 1.32)
Lifelong	Ref.	Ref.	Ref.

CI = confidence interval; OR = odds ratio.
*$P < 0.05$ by Wald χ^2 test for this level of the variable.
†No individuals met these criteria.

TABLE 5
The association between respondent mosquito and arbovirus perceptions with reported avoidance strategies used in Key West, FL

	OR (95% CI)		
	Reports practicing five or more avoidance strategies 87 (21.8%)	Uses repellent often or always 61 (15.3%)	Checks for standing water at least once a week or after each rainfall 245 (66.2%)
Mosquitoes noticed outside			
None	0.30 (0.10, 0.87)*	0.26 (0.06, 1.13)	0.53 (0.28, 1.00)*
Very few to moderate	Ref.	Ref.	Ref.
Quite a few to many	1.59 (0.90, 2.78)	2.38 (1.29, 4.37)*	1.52 (0.82, 2.81)
Stated mosquito breeding sites			
Do not know or not standing water	Ref.	Ref.	Ref.
Salt marshes and puddles	0.63 (0.07, 5.54)	0.63 (0.07, 5.54)	2.50 (0.70, 8.92)
Just standing water	2.37 (1.02, 5.52)*	1.74 (0.74, 4.09)	2.36 (1.29, 4.32)*
At least one container stated	3.33 (1.36, 8.15)*	1.33 (0.50, 3.49)	1.97 (1.00, 3.87)*
Believes control of mosquitoes is their own responsibility			
Strongly disagree	0.85 (0.08, 9.30)	1.92 (0.27, 13.6)	0.50 (0.10, 2.48)
Disagree	1.28 (0.23, 7.10)	1.28 (0.23, 7.10)	0.55 (0.15, 1.96)
Neither agree nor disagree	Ref.	Ref.	Ref.
Agree	1.96 (0.54, 7.04)	1.76 (0.49, 6.37)	1.63 (0.67, 3.95)
Strongly agree	2.65 (0.77, 9.18)	1.25 (0.35, 4.42)	2.81 (1.19, 6.64)*
Would take preventative action if they had a mosquito problem			
Yes	0.98 (0.60, 1.61)	1.49 (0.82, 2.72)	2.01 (1.29, 3.14)*
No	Ref.	Ref.	Ref.
Heard of dengue			
Yes	1.91 (1.00, 3.63)	0.89 (0.47, 1.69)	2.18 (1.31, 3.65)*
No	Ref.	Ref.	Ref.
Dengue seriousness			
Not heard of	0.55 (0.28, 1.08)	1.08 (0.55, 2.11)	0.49 (0.28, 0.84)*
Not at all	0.73 (0.34, 1.58)	0.71 (0.28, 1.77)	1.04 (0.53, 2.03)
Slight to very	Ref.	Ref.	Ref.
Extremely	1.77 (0.89, 3.54)	1.13 (0.48, 2.65)	1.49 (0.69, 3.22)
Perceived likelihood of dengue infection			
Not heard of	0.76 (0.37, 1.58)	1.32 (0.63, 2.78)	0.50 (0.28, 0.90)*
Very unlikely	Ref.	Ref.	Ref.
Unlikely to equally likely/unlikely	1.81 (1.01, 3.24)*	1.63 (0.84, 3.17)	1.24 (0.72, 2.13)
Likely to very likely	2.60 (1.12, 6.05)*	0.84 (0.24, 2.91)	1.38 (0.54, 3.50)
Level of dengue awareness			
Never heard of	Ref.	Ref.	Ref.
Heard of	1.70 (0.41, 7.17)	0.76 (0.20, 2.84)	1.09 (0.39, 3.02)
Heard of outbreak	1.68 (0.41, 6.78)	0.76 (0.22, 2.58)	1.90 (0.71, 5.11)
Knows someone who had dengue	2.60 (0.67, 10.13)	1.53 (0.48, 4.91)	3.64 (1.33, 9.93)*
Knows of the Key West mosquito control website			
Yes	2.69 (1.20, 6.03)*	2.07 (0.83, 5.13)	1.86 (0.73, 4.73)
No	Ref.	Ref.	Ref.
Heard of any mosquito control and prevention information in preceding 2 months			
Yes	1.94 (1.13, 3.34)*	1.18 (0.61, 2.30)	1.55 (0.88, 2.71)
No	Ref.	Ref.	Ref.

CI = confidence interval; OR = odds ratio.
* $P < 0.05$ by Wald χ^2 test for this level of the variable.

knowledgeable about mosquito oviposition sites had higher odds of checking their yards for standing water (stated standing water: OR = 2.36, 95% CI = 1.29–4.32; stated a specific container: OR = 1.97, 95% CI = 1.00–3.87). Dengue awareness was associated with increased participation in avoidance strategies to a greater extent in Key West than in Tucson. Key West respondents who had heard of DENV had higher odds of checking their yard for standing water (OR = 2.18, 95% CI = 1.31–3.65). Key West residents had higher odds of using several avoidance practices when they thought it was more likely that they or a family member would become infected with DENV (unlikely to equally likely/unlikely versus very unlikely: OR = 1.81, 95% CI = 1.01–3.24; likely to very likely versus very unlikely: OR = 2.60, 95% CI = 1.12–6.05). Among Key West respondents, recent exposure to educational messages was associated with utilization of five strategies or more (OR = 1.94, 95% CI = 1.13–3.34) but not with the specific strategies of repellent use or standing water removal. Though 85.9% of Tucson residents had heard of WNV (Table 7), overall respondents' knowledge and perceptions of the disease was not significantly associated with any mosquito avoidance behavior.

DISCUSSION

With recent DENV activity in Key West and the potential for introduction of DENV into Tucson, it is important to assess the use of mosquito avoidance strategies among community members to limit the spread of mosquito-borne viruses. Greater use of mosquito avoidance strategies was

TABLE 6
The association between respondent mosquito and arbovirus perceptions with reported avoidance strategies used in Tucson, AZ

	OR (95% CI)		
	Reports practicing five or more avoidance strategies 58 (15.5%)	Uses repellent often or always 61 (16.4%)	Checks for standing water at least once a week or after each rainfall 207 (59.1%)
Mosquitoes noticed outside			
None	0.20 (0.06, 0.66)*	0.66 (0.27, 1.64)	0.39 (0.22, 0.68)*
Very few to moderate	Ref.	Ref.	Ref.
Quite a few to many	1.48 (0.80, 2.74)	3.37 (1.81, 6.30)*	1.02 (0.58, 1.80)
Believes control of mosquitoes is their own responsibility			
Strongly disagree	1.83 (0.49, 6.86)	4.81 (1.07, 21.75)*	1.16 (0.52, 2.56)
Disagree	4.84 (1.37, 17.05)*	2.52 (0.53, 11.92)	0.52 (0.24, 1.11)
Neither agree nor disagree	Ref.	Ref.	Ref.
Agree	2.83 (0.77, 10.42)	3.97 (0.86, 18.41)	0.80 (0.36, 1.77)
Strongly agree	3.23 (0.85, 12.29)	5.91 (1.26, 27.66)*	0.70 (0.30, 1.61)
Would take preventative action if they had a mosquito problem			
Yes	1.17 (0.63, 2.16)	0.81 (0.44, 1.49)	2.11 (1.29, 3.44)*
No	Ref.	Ref.	Ref.
Heard of dengue			
Yes	1.61 (0.95, 2.74)	1.10 (0.63, 1.91)	1.33 (0.86, 2.05)
No	Ref.	Ref.	Ref.
Dengue seriousness			
Not heard of	0.61 (0.32, 1.19)	1.02 (0.49, 2.10)	1.17 (0.68, 2.02)
Not at all	0.96 (0.44, 2.10)	0.96 (0.39, 2.36)	2.95 (1.42, 6.15)*
Slight to very	Ref.	Ref.	Ref.
Extremely	1.23 (0.22, 7.06)	5.72 (1.10, 29.70)*	0.71 (0.15, 3.46)
Perceived likelihood of dengue infection			
Not heard of	0.66 (0.36, 1.19)	1.08 (0.56, 2.05)	0.65 (0.40, 1.07)
Very unlikely	Ref.	Ref.	Ref.
Unlikely to equally likely/unlikely	1.07 (0.45, 2.57)	1.32 (0.50, 3.44)	0.58 (0.27, 1.24)
Likely to very likely	2.10 (0.43, 10.35)	3.46 (0.71, 16.93)	1.23 (0.24, 6.46)
Level of dengue awareness			
Never heard of	Ref.	Ref.	Ref.
Heard of	1.43 (0.82, 2.51)	1.16 (0.66, 2.04)	1.43 (0.91, 2.26)
Knows someone who had dengue	3.29 (1.20, 8.98)*	0.66 (0.15, 3.02)	0.78 (0.30, 2.05)
Heard of WNV			
Yes	2.34 (0.89, 6.11)	0.93 (0.43, 2.02)	1.54 (0.85, 2.81)
No	Ref.	Ref.	Ref.
WNV seriousness			
Not heard of	0.39 (0.15, 1.03)	1.16 (0.52, 2.60)	0.68 (0.37, 1.26)
Not at all	0.57 (0.25, 1.27)	1.10 (0.52, 2.34)	0.99 (0.55, 1.79)
Slight to very	Ref.	Ref.	Ref.
Extremely	0.99 (0.40, 2.43)	1.55 (0.62, 3.88)	1.63 (0.71, 3.72)
Perceived likelihood of WNV infection			
Not heard of	0.50 (0.18, 1.39)	1.14 (0.48, 2.72)	0.60 (0.31, 1.17)
Very unlikely	Ref.	Ref.	Ref.
Unlikely to 50/50	1.19 (0.65, 2.18)	1.01 (0.53, 1.93)	0.76 (0.46, 1.25)
Likely to very likely	1.70 (0.66, 4.36)	1.59 (0.59, 4.27)	1.80 (0.69, 4.67)
Level of WNV awareness			
Never heard of	Ref.	Ref.	Ref.
Heard of	2.20 (0.84, 5.79)	0.94 (0.43, 2.05)	1.51 (0.82, 2.75)
Know someone with WNV	4.48 (1.24, 16.2)	0.75 (0.18, 3.10)	2.14 (0.75, 6.15)
Heard of Fight the Bite			
Yes	0.93 (0.38, 2.25)	1.04 (0.41, 2.60)	1.02 (0.49, 2.12)
No	Ref.	Ref.	Ref.
Heard of any mosquito control and prevention information in preceding 2 months			
Yes	1.44 (0.80, 2.61)	1.67 (0.91, 3.10)	1.16 (0.69, 1.94)
No	Ref.	Ref.	Ref.

CI = confidence interval; OR = odds ratio; WNV = West Nile virus.
* $P < 0.05$ by Wald χ^2 test for this level of the variable.

evident in Key West compared with Tucson (Table 2). Similar to previous literature, factors associated with use of avoidance strategies varied by strategy.[16–22]

Several patterns of behavior were consistent between the two cities. In both cities, older individuals had higher odds of checking their yard and empty standing water. This finding may be more reflective of available time, leisure activity, or home maintenance practices between age groups. Mosquito avoidance behaviors in both cities were associated with the number of mosquitoes noticed when outdoors. Interestingly, in both cities > 60% of participants indicated that they noticed no mosquitoes outdoors (Table 7). There were

TABLE 7
Mosquito and disease knowledge among respondents in Key West, FL, and Tucson, AZ

	Key West (N = 400*)	Tucson (N = 375*)
	n (%)	n (%)
Mosquitoes noticed outside		
None	271 (67.8)	230 (61.3)
Very few to moderate	52 (13.0)	73 (19.5)
Quite a few to many	77 (19.3)	72 (19.2)
Stated mosquito breeding sites		
Do not know or no standing water	64 (16.0)	†
Salt marshes and puddles	14 (3.5)	†
Just standing water	222 (55.5)	†
At least one container stated	100 (25.0)	†
Mosquitoes come from nearby sources		
Strongly disagree	84 (21.6)	34 (10.6)
Disagree	108 (27.8)	72 (22.5)
Neither agree nor disagree	64 (16.5)	54 (16.9)
Agree	95 (24.5)	89 (27.8)
Strongly agree	37 (9.5)	71 (22.2)
Believes control of mosquitoes is their own responsibility		
Strongly disagree	10 (2.5)	95 (25.6)
Disagree	21 (5.3)	94 (25.3)
Neither agree nor disagree	26 (6.6)	41 (11.1)
Agree	123 (31.2)	82 (22.1)
Strongly agree	214 (54.3)	59 (15.9)
Would take preventative action if they had a mosquito problem		
Yes	259 (64.8)	278 (74.1)
Heard of dengue		
Yes	308 (77.0)	158 (42.5)
Dengue seriousness		
Not heard of	91 (23.5)	214 (60.4)
Not at all	52 (13.4)	73 (20.6)
Slight to very	199 (51.4)	60 (16.9)
Extremely	45 (11.6)	7 (2.0)
Perceived likelihood of DENV infection		
Not heard of	91 (23.6)	214 (58.8)
Very unlikely	140 (36.4)	108 (29.7)
Unlikely to equally likely/unlikely	124 (32.2)	35 (9.6)
Likely to very likely	30 (7.8)	7 (1.9)
Level of dengue awareness		
Never heard of	15 (3.8)‡	214 (57.5)
Heard of	60 (15.0)	139 (37.4)
Heard of outbreak	231 (57.8)	†
Knows someone who had dengue	94 (23.4)	19 (5.1)
Knows of the Key West mosquito control website		
Yes	27 (6.8)	†
Heard of any mosquito control and prevention information in preceding 2 months		
Yes	98 (32.3)	91 (27.7)
Heard of WNV		
Yes	†	322 (85.9)
WNV seriousness		
Not heard of	†	53 (14.6)
Not at all	†	62 (17.0)
Slight to very	†	216 (59.3)
Extremely	†	33 (9.1)
Perceived likelihood of WNV infection		
Not heard of	†	53 (14.9)
Very unlikely	†	160 (45.1)
Unlikely to 50/50	†	113 (31.8)
Likely to very likely	†	29 (8.2)
Level of WNV awareness		
Never heard of	†	53 (14.1)
Heard of	†	300 (80.0)
Know someone with WNV	†	22 (5.9)
Heard of Fight the Bite		
Yes	†	27 (8.4)

DENV = dengue virus; WNV = West Nile virus.
*Not all categories sum to the total number of individuals because of missing data.
†Some avoidance questions were not asked of residents in both cities and are therefore excluded.
‡The number of individuals classified as "Never heard of dengue" is smaller than previous questions because of individuals that responded they had never heard of dengue but subsequently stated they had heard of the outbreak or knew someone with dengue.

consistently lower odds of avoidance behaviors among those who never noticed mosquitoes outdoors and higher odds of avoidance behavior if participants noticed "quite a few" or "very many" mosquitoes. Rather than for disease prevention, these behavioral differences may be a reaction to the nuisance aspect of mosquito biting as has been demonstrated in previous literature.[19,21]

The residential status of individuals in Key West is associated with mosquito avoidance practices. Homeowners in Key West had higher odds of clearing standing water from their yard than renters. This could be a result of the highly visible presence of public mosquito control in the area. Homeowners in Key West may depend upon mosquito control to perform these tasks. Renters may be unaware of existing mosquito control efforts and, therefore, perform breeding site reduction activities on their own. Indeed, an independent association existed in which individuals who felt mosquito control was their responsibility being more likely to remove standing water. However, Key West homeowners were more likely to report that they agreed or strongly agreed that mosquito control was their own responsibility (93.7% among owners, 71.5% among renters, $P < 0.001$, χ^2). Key West residents were also more likely to participate in more than five avoidance strategies if they have children living in the home; evidence suggests that having children in the home may actually minimize the practice of negative health behaviors.[33]

Although there are significant differences in overall use of avoidance strategies between the two cities, it is important to note that all the strategies listed are not of equal effectiveness. A summary score placing equal weight to each activity is intended to measure the respondent's total perceived mosquito avoidance efforts, and is not intended to indicate their level of risk reduction. Of the commonly recommended avoidance strategies, Key West residents more frequently reported staying indoors and removing standing water than Tucson residents, but there was no difference in the reported frequency of wearing protective clothing, which was quite low for both cities. It is also important to note that although there is a statistically significant difference in what is considered to be an effective rate of checking for standing water between the cities, the magnitude of the difference (66.2% in Key West versus 59.1% in Tucson) may be a reflection of more annual rainfall in Key West compared with Tucson.[23]

Disease awareness and perception of risk appear to play a bigger role in Key West than in Tucson. In Key West, there was a positive association between both knowledge of and

personal experience with DENV, which was associated with higher frequency of removing of standing water. Further, there was a positive association between heightened perception of disease risk and using at least five avoidance strategies. These relationships are similar to those seen in other studies of mosquito avoidance and arbovirus prevention.[16,17,19,21,22] However, there are notably very few significant associations between DENV knowledge and mosquito avoidance in Tucson. There are two possible explanations for this discrepancy: 1) in the absence of community experience with the disease, these associations may be attenuated; or 2) there were so few people with knowledge of DENV that the CIs were too large to detect a difference. However, there was also no association between perceptions of WNV and mosquito avoidance in Tucson, which contrasts with previous studies during the emergence period of WNV.[34] The first case of WNV in Arizona occurred in 2003, and residents may have become complacent and less likely to exhibit concern and carry out the associated avoidance behaviors. Despite similar levels of participants having heard mosquito control and prevention messages (32.3% and 27.7%, Key West and Tucson, respectively; Table 7), reported exposure to such educational messages was only associated with increased mosquito avoidance behaviors in Key West. However, only reporting using five or more strategies was associated with having heard these messages. The most frequently recommended prevention strategies of removing standing water and using mosquito repellant were not associated despite a survey of Key West stakeholders rating the communication of educational messages to the public as being one of the most effective methods of reducing dengue risk.[35]

To our knowledge, this study is the first to examine mosquito-related behavioral differences between residents in cities, both with *Ae. aegypti* populations, but one with and one without DENV transmission. We explored both the total number of reported mosquito avoidance behaviors and those behaviors previously identified as effective in reducing disease transmission. Although surveys were standardized and interviewers were trained to minimize leading bias, participants were aware that the survey was asking about viruses transmitted by mosquitoes and may have self-reported responses they felt were expected by the interviewers. This could have resulted in an overestimation of the frequency of these practices taking place. However, the lower reporting of several of the strategies, such as repellent use, outdoor clothing, and so forth, indicates that individuals were not just answering yes to every strategy they had heard. We attempted to minimize selection bias by randomly selecting our participants and making multiple recruitment attempts on different days and at different times of day. Sampling with replacement in a systematic manner increased the sample size and was associated with randomly selected geographic locations (the households initially selected). However, response bias is still possible. It is unclear in what direction this would drive the overall estimates of reported practices, but we anticipate that it would have less impact on the results of the regression analysis where associations are examined between these practices and other characteristics of responders. Prevalence rates of practices are likely to be the most biased. Finally, the generalizability of these results may be limited to other communities with *Ae. aegypti* populations, with no transmission or recent DENV introduction.

Understanding the avoidance behaviors undertaken is critical given recent arboviral outbreaks of CHIKV and ZIKAV in the western hemisphere. Just as both of our study sites have the potential for DENV transmission, they are also at risk of local transmission of CHIKV and ZIKAV. The results herein should inform stakeholders that although communication of effective control strategies to the community is an important part of controlling mosquito populations, education alone may not be enough to ensure sustained effective mosquito avoidance behaviors.

This research suggests that additional work is needed to expand and evaluate the effects of public health campaigns on mosquito avoidance behaviors. The results suggest that increased awareness of the disease and knowledge about the mosquito vector are associated with participation in effective prevention practices. However, results exploring WNV in Tucson suggest that public health educators should be alerted that this relationship may decline if the disease becomes endemic. Future research efforts will be needed to see if the associations noted in Key West diminish over time, or if additional/sustained public health campaigns may be effective in maintaining and expanding the use of effective avoidance strategies.

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