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A comparison of compliance rates with anti-vectorial protective measures during travel to regions with dengue or chikungunya activity, and regions endemic for *Plasmodium falciparum* malaria

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Abstract

Background. There is limited information on compliance rates with anti-vectorial protective measures (AVPMs) during travel to countries with risk of dengue and chikungunya. We evaluated differences in mosquito exposures, and factors associated with AVPM compliance in travellers going to countries where the principal mosquito-borne infectious disease threat is falciparum malaria and those where risk of dengue or chikungunya predominates.
Methods. Department of Defence beneficiaries with planned travel to regions where the predominant mosquito-borne infection is falciparum malaria, and those with predominantly dengue or chikungunya risk, were included. Regions were divided into three groups: 'high-risk falciparum malaria', 'low-risk falciparum malaria' and 'chikungunya/dengue risk'. Demographics, trip characteristics, arthropod exposure and AVPM compliance were captured using pre- and post-travel surveys. Skin repellent compliance was defined as self-reported use, categorized as 'often/every day'. A logistic regression model was used to estimate factors associated with AVPM compliance.
Results. 183 (9%), 185 (9%) and 149 (7%) travelled to high and low falciparum malaria risk regions, and chikungunya/dengue risk regions, respectively. Overall, 53% (95% CI: 48–57%) and 16% (95% CI: 12–19%) were compliant with repellent use on skin and clothing, respectively. Daytime bites were reported more frequently in chikungunya/dengue risk regions than high malaria risk regions (37% vs. 10%), while night time bites were frequently in high malaria risk regions (53% vs 20%; $P < 0.001$). Compliance with skin repellents was associated with female gender [RR: 1.54 (95% CI: 1.05–2.28)], observing mosquitoes during travel [RR: 2.77 (95% CI: 1.76–4.36)] and travel during the rainy season [RR: 2.45 (95% CI: 1.66–3.71)]).

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Conclusions. Poor AVPM compliance was observed in the overall cohort. Compliance with skin repellent use was associated with female gender, observing mosquitoes and travelling during the rainy season, and was not associated with the risk of malaria or chikungunya/dengue at the travel destination.

Key words: Anti-vectorial protective measures, malaria, dengue, chikungunya, compliance

Background

Anti-vectorial protective measures (AVPM), such as the application of insect repellents on skin and clothing, wearing long sleeved clothing, and sleeping under bed nets, are key preventive strategies against vector borne febrile illnesses during deployment and travel.[1] AVPM are especially important in locations where environmental pest control (e.g. eliminating mosquito breeding sites) is not possible, or in the absence of effective vaccines and chemoprophylaxis, as in the case of arboviral infections. The recent outbreaks of chikungunya and Zika virus in South America, Central America and the Caribbean highlight the need to evaluate compliance and the effectiveness of AVPM.[2,3] Prior studies on AVPM compliance have largely focused on travel to malaria endemic regions.[4–6] AVPM compliance in this travel population is low, and varies widely depending on the type of AVPM being evaluated, traveller demographics and trip characteristics.[6,7] There is limited information on AVPM compliance during travel to countries where risk of dengue and chikungunya predominates, and the existing literature consists of retrospective case reports of imported dengue associated with AVPM non-compliance.[8–10]

There are important differences in the biting patterns of mosquito vectors associated with malaria versus dengue or chikungunya transmission, that may affect AVPM use.[1] Anopheline mosquitoes, associated with malaria transmission, are relatively quiet night-time feeders with minimal inflammation following bites, unlike the diurnal *Aedes* mosquitoes that have a noisy flight and inflammatory bites. As a result, anopheline mosquitoes may be overlooked, possibly leading to lower rates of AVPM compliance. In addition, air-conditioning may not be as effective AVPM in areas where *Aedes* mosquitoes transmit dengue or chikungunya, especially during trips involving outdoor activities. A better understanding of mosquito exposure and AVPM compliance is important to inform a pragmatic strategy for vector avoidance during travel.

The TravMil study [Deployment and Travel Related Infectious Disease Risk Assessment, Outcomes, and Prevention Strategies Among Department of Defense (DoD) Beneficiaries] prospectively evaluates infectious disease risks, and the effectiveness of prevention and treatment strategies, in DoD beneficiaries travelling outside the continental USA.[11] We utilized data from the TravMil cohort to assess differences in mosquito exposures and AVPM compliance in travellers going to countries where falciparum malaria is the predominant mosquito borne infectious disease threat, compared with regions where the risk of dengue or chikungunya transmission predominates, and to evaluate factors associated with AVPM compliance.

Methods

Study Design

TravMil is a prospective, observational cohort of DoD beneficiaries travelling outside the continental United States for $\leq$6.5 months. Consenting adult and paediatric travellers are enrolled pre-travel at six military travel clinics (Naval Medical Centre Portsmouth, VA; Naval Medical Centre San Diego, CA; Walter Reed National Military Medical Centre, Bethesda, MD; San Antonio Military Medical Centre, San Antonio, TX; Madigan Army Medical Centre, Tacoma, WA and Landstuhl Regional Medical Centre, Landstuhl, Germany) and in the pre-deployment setting. Travel medicine physicians and independent duty corpsmen counsel travellers and deployers, respectively on the use of AVPM, but no standardization of counselling is performed as part of the study. Participant demographics, travel itineraries and accommodations are abstracted during the pre-travel visit. A post-travel survey, completed up to 8 weeks after return, collects information on AVPM use during travel, mosquitoes observed and the frequency and timing of bites during travel. AVPM evaluated include the use of insect repellents on skin and clothes, and the use of bed nets. The study has been approved by the Uniformed Services University Infectious Disease Institutional Review Board.

The present analysis was limited to study participants who travelled to destinations that fell under 1 of 3 categories based on the high or low risk of falciparum malaria, and areas with extremely limited or absent malaria risk but ongoing chikungunya/dengue activity (listed below).[12–14] Malaria transmission risk was based on the *Plasmodium falciparum* parasite rate ($Pf\mathrm{PR}_{2\text{-}10}$), defined as the proportion of children aged 2–10 years in the population found to carry asexual blood-stage parasites. We used a global malaria map of $Pf\mathrm{PR}_{2\text{-}10}$, to select countries with a uniform *P. falciparum* parasite rate ($Pf\mathrm{PR}_{2\text{–}10}$) across locales, since subject itineraries had limited information regarding specific areas visited within countries.[14]

Countries with high risk of falciparum malaria transmission ($Pf\mathrm{PR}_{2\text{–}10} > 35\%$): Burkina Faso, Sierra Leone, Liberia, Cote d' Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, Uganda, Democratic Republic of Congo

Countries with low risk of falciparum malaria transmission ($Pf\mathrm{PR}_{2\text{–}10} < 5\%$): Somalia, Ethiopia, Kenya, Botswana, Zimbabwe, Djibouti, Eritrea

Countries with risk of chikungunya/dengue transmission and very limited or absent falciparum malaria risk: Cuba, Puerto Rico, Jamaica, British Virgin Islands, US Virgin Islands, Anguilla, St Kitts and Nevis, Montserrat, Antigua/Barbuda, Guadeloupe, Dominica, Martinique, St Lucia, Barbados, St Vincent and Grenadines, Grenada, Trinidad and Tobago, Aruba, Curacao, Bonaire, El Salvador, Costa Rica

Participants could be included in the analysis multiple times if they took multiple trips, but participants who travelled to more than one risk category in a single trip were excluded. Trip purpose was categorized as follows: military travel, vacation (including visiting friends and relatives), business, medical support/teaching or humanitarian work and other (i.e. adventure travel/

ecotour, adoption and other). Visiting friends and relatives was combined with vacation, since it comprised a small proportion of the cohort, with similar AVPM compliance rates to vacation travellers. Accommodations such as non-air-conditioned hotels, camping or dormitories were categorized as being high risk for mosquito bites; low-risk accommodations included air-conditioned hotels, private residences, cruise ships, military accommodations or safari lodges. Travel for any duration during the rainy season (i.e. even if part of the trip occurred outside the rainy season) was considered to be high risk for bites. The rainy season for destinations was defined as follows[15]: (i) countries with risk of chikungunya/dengue transmission: travel to Cuba, Puerto Rico, Jamaica, Montserrat, Dominica, Martinique, Trinidad and Tobago, Curacao, El Salvador, Costa Rica between May and December, and travel to British and US Virgin Islands, Anguilla, St Kitts and Nevis, Antigua/Barbuda, Guadeloupe, St Lucia, Barbados, St Vincent and Grenadines, Grenada, Aruba, and Bonaire between October and April; (ii) countries with high risk of malaria transmission: travel between April and July or September and October; (iii) countries with low risk of malaria transmission: travel to Eritrea or Djibouti between December and February, Somalia or Kenya between April and June or October and November, Ethiopia between June and September, or Zimbabwe and Botswana between November and March.

Statistical Analysis

A Kruskal-Wallis test for continuous variables and Fishers exact test or chi-square for categorical variables were used to compare demographic and trip characteristics of travellers in the three risk categories. Correlation coefficients for timing of mosquito bites and skin insect repellent use were calculated using the Pearson's correlation coefficient. A log-binomial logistic regression model was used to estimate the relative risk of AVPM compliance. Two models were constructed. The first used compliance with skin repellents alone as the outcome measure. Compliance with skin repellents was defined as self-reported use categorized as 'often/every day', while 'never' or 'rarely' constituted non-compliance. For the second model, self-reported use of permethrin on clothes in addition to regular use of skin repellents constituted AVPM compliance. Both models were adjusted for age, gender, military trip purpose, trip duration, mosquitoes observed during travel, accommodation risk level and travel during rainy season. Data analysis was performed using SAS statistical software, version 9.3 (SAS Institute, Cary, NC).

Results

Cohort Characteristics

From January 2010 to October 2015, 2630 individuals were enrolled pre-travel, of whom 2030 (77%) completed the post-travel survey. Five hundred and seventeen subjects (25%) travelled to destinations with risk of malaria or chikungunya/dengue transmission and were included in the present analysis: 183 (9%), 185 (9%) and 149 (7%) travelled to destinations with high and low risk for malaria transmission, and risk for chikungunya/dengue, respectively. The median duration between trip return and completion of the post-travel survey was 23 days. The descriptive characteristics of the groups are summarized in Table 1. A greater proportion of travellers going to high malaria risk destinations were African American, active duty personnel, and were travelling during the rainy season ($P < 0.05$ for all comparisons). AVPM compliance was low in the overall cohort (Figure 1). Approximately 53% (95% CI: 48–57%) of travellers used skin repellents 'often' or on a daily basis, 16% (95% CI: 12–19%) used permethrin on clothing and 39% (95% CI: 35–43%) used a bed net.

Several differences were noted in AVPM use among the three groups (Figure 1). Higher compliance rates with skin repellent use was noted among travellers to chikungunya/dengue risk regions (59%) and high risk malaria regions (56%) compared with low malaria risk regions (44%; $P = 0.01$). Among travellers to chikungunya/dengue risk regions, no significant change in compliance was observed during the chikungunya epidemic that started in December 2013 [62% prior to the epidemic; 50% during the epidemic; RR: 0.80 (95% CI: 0.56–1.12)]. We also evaluated the type of skin repellent used by participants. Among travellers who used a skin repellent, a higher proportion travelling to chikungunya/dengue risk regions used effective repellents [i.e. N,N-Diethyl-meta-toluamide (DEET), picaridin or Avon Skin So Soft Bug Guard, (Avon Products Inc., New York, NY) (containing picardin or IR3535)] compared with malaria risk regions [98% (79/81) chikungunya/dengue risk, 95% (88/93) low malaria risk, 88% (88/100) high malaria risk; $P = 0.04$].

Next we evaluated the frequency and timing of bites in the three regions. No significant difference was observed in the proportion of travellers that experienced > 10 mosquito bites in the three risk regions [14% ($n = 25$) high malaria risk, 8% (n = 15) low malaria risk and 13% (n = 19) chikungunya/dengue risk ($P = 0.19$)]. However, the timing of bites among the regions differed among subjects who reported receiving bites in the post travel survey. A greater proportion of travellers to chikungunya/dengue risk regions experienced mosquito bites during the day [37% ($n = 28$)] as compared with the night [20% (n = 15)] or both [26% (n = 20)]. In contrast, travellers to high-risk malaria regions reported isolated night-time bites more frequently [53% (n = 60) compared with 10% in the day alone ($n = 11$) and 18% ($n = 21$) reported both; $P < 0.001$]. A weak positive correlation was observed between timing of bites and timing of skin repellent use ($r = 0.293$; $P < 0.001$ for bites and repellent use during the day, and $r = 0.222$; $P = 0.0003$ for bites and repellent use during the night). Travellers to chikungunya/dengue risk regions more frequently used skin repellents during the daytime [37% ($n = 111$) chikungunya/dengue risk, 34% ($n = 100$) low malaria risk, 29% ($n = 86$) high malaria risk; $P < 0.001$] while evening/night-time repellent use was more common in malarious regions [18% ($n = 45$) chikungunya/dengue risk, 33% ($n = 81$) low malaria risk, 49% ($n = 123$) high malaria risk; $P < 0.05$].

Compliance rates for bed net use were higher in malaria risk regions compared with chikungunya/dengue risk regions (Figure 1). A greater proportion of participants in high malaria risk regions used bed nets >75% of the time [38% ($n = 63$), vs low malaria risk 32% ($n = 54$), and chikungunya/dengue risk 5% ($n = 4$); $P < 0.001$]. Fifty six percent ($n = 43$) of participants travelling to chikungunya/dengue risk regions stated that a bed net was not recommended at the pre-travel visit, vs 15%

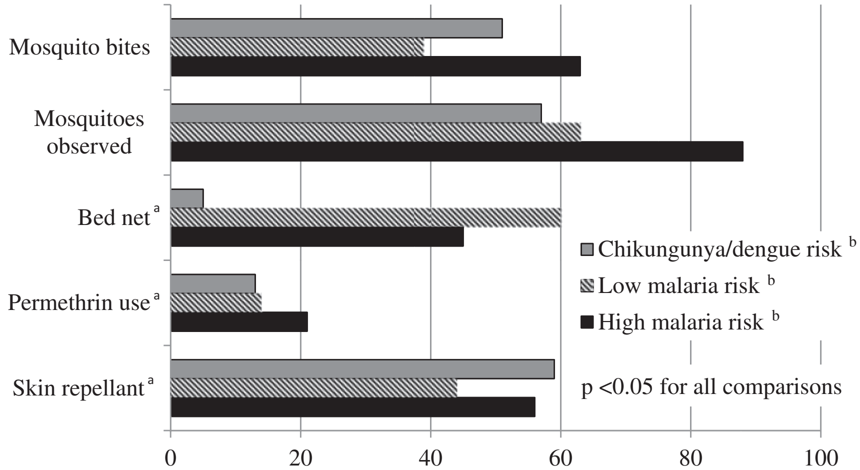

Figure 1. Use of anti-vectorial protective measures (AVPMs) and mosquito exposures during travel for travellers going to countries with risk for falciparum malaria or chikungunya/dengue.

Table 1. Demographic and trip characteristics for travelers going to countries with risk for falciparum malaria or chikungunya/dengue[a]

Characteristic	High malaria risk (n = 183)	Low malaria risk (n = 185)	Chikungunya/ dengue risk (n = 149)	*P*-value
Age				
≤24 years	15(32)	10(21)	22(47)	0.001
25-50 years	111(52)	47(22)	57(27)	
≥ 50 years	56(22)	128(50)	70(28)	
> 1 trip to risk area	17 (9)	12 (6)	2 (1)	0.0095
Male Gender	111(61)	95(51)	75(50)	0.100
Race				
White	92(50)	151(80)	93(62)	<0.001
African American	73(40)	16(8)	17(11)	<0.001
Duty Status				
Active Duty	94(52)	35(19)	62(42)	<0.001
Retired Military	38(21)	77(42)	42(28)	<0.001
Family of AD/ Retired	50(27)	73(39)	45(30)	0.085
Duration of travel				
≤ 2 weeks	61(33)	52(28)	58(38)	0.11
> 2 weeks	122(67)	133(72)	91 (61)	
Purpose of travel				
Military travel	49(26)	28(15)	48(32)	0.002
Vacation and visiting friends and relatives	82(45)	123(66)	90(60)	<0.001
Teaching/ humanitarian	33(18)	27(15)	10(6)	0.002
Accommodations[b]				
High risk	34 (19)	34 (18)	9 (6)	<0.001
Low risk	149 (81)	151 (82)	140 (94)	
Travel during the rainy season				
Yes	103 (56)	75 (40)	125 (84)	<0.001
No	80 (44)	113 (60)	24 (16)	

[a]Malaria risk in country of travel was defined by the prevalence of falciparum malaria in children between 2 and 10 years ($Pf\text{PR}_{2\text{-}10}$). High-risk countries = $Pf\text{PR}_{2\text{–}10}$ > 35%: Burkina Faso, Sierra Leone, Liberia, Cote d' Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, Uganda, Democratic Republic of Congo; Low risk countries = $Pf\text{PR}_{2\text{–}10}$ < 5%: Somalia, Ethiopia, Kenya, Botswana, Zimbabwe, Djibouti, Eritrea. Chikungunya/dengue risk countries: Cuba, Puerto Rico, Jamaica, British Virgin Islands, US Virgin Islands, Anguilla, St Kitts and Nevis, Montserrat, Antigua/Barbuda, Guadeloupe, Dominica, Martinique, St Lucia, Barbados, St Vincent and Grenadines, Grenada, Trinidad and Tobago, Aruba, Curacao, Bonaire, El Salvador.

[b]High-risk accommodations defined as hotel without air-conditioning, camping or dormitory; low risk accommodations include hotel with air-conditioning, private residence, cruise ship, military accommodations or safari lodge

($n = 24$) of high-risk malaria regions and 10% ($n = 17$) of low risk malaria region. Of those travelling to malarious regions that were not recommended a bed net, ∼50% stayed in air-conditioned accommodations (12/24 for high-risk risk regions and 9/17 for low-risk malaria regions).

Factors associated with compliant use of skin insect repellents were examined in a multivariate model (Table 2). The variables 'mosquitoes observed' and 'mosquito bites' were closely related and therefore only 'mosquitoes observed' was included in the multivariate model. Compliance was associated with female gender [RR: 1.54 (95%CI: 1.05–2.28)] observing mosquitoes during travel [RR: 2.77 (95% CI: 1.76–4.36)], travel during the rainy season [RR: 2.45 (95%CI: 1.66–3.71)]. A similar model was used to evaluate compliance with repellent use on skin and clothing (Table 3). Military trip purpose [RR: 2.93 (95% CI: 1.48–5.78)] and travel during the rainy season [RR: 2.20 (95%CI: 1.14–4.20] were associated with compliance in the multivariable model.

Discussion

We evaluated differences in AVPM use in a prospective cohort of DoD beneficiaries travelling to regions with varying levels of malaria transmission risk and risk of chikungunya/dengue transmission. AVPM compliance in the overall cohort was poor, despite receiving pre-travel counselling: 53% (95% CI: 48–57%) were compliant with skin repellent use, 16% (95% CI: 12–19%) used permethrin on clothing, and 39% (95% CI: 35–43%) used a bed net. Low rates of AVPM compliance rates have been previously documented in civilian travellers and deployed military personnel. In a cohort of French civilians travelling to malaria endemic locations, 42% reported skin repellent use, and 3.1% used a bed net.[5] Similarly, 54% of backpackers trekking through forests in Southeast Asia reported regular skin repellent use.[16] Rates of skin repellent use are even lower among deployed military personnel. In a cohort of French troops travelling to tropical Africa in 2007, 19% reported frequently using a skin repellent, and 51% reported sleeping under a bed net.[4] Only 19 (45%) of US Marines deployed to Liberia in 2003

Table 2. Factors associated with regular use of insect repellents on skin during travel[a]

	Compliance with skin repellent use (%)	Univariate OR (95% CI)	Multivariate OR (95% CI)
Regions[b]			
Low malaria risk	79 (44)	ref.	ref.
High malaria risk	100 (56)	**1.27 (1.03–1.57)**	1.01 (0.62–1.64)
Chikungunya/dengue risk	88 (59)	**1.34 (1.09–1.66)**	1.30 (0.77–2.20)
Age			
≤24 years	29 (61.70)	ref.	ref.
25–50 years	122 (58.65)	0.95 (0.74–1.22)	0.93 (0.45–1.90)
≥50 years	116 (46.59)	**0.75 (0.58–0.98)**	0.83 (0.40–1.68)
Gender			
Male	131 (48.34)	ref.	ref.
Female	136 (58.37)	**1.20 (1.02–1.42)**	**1.54 (1.05–2.28)**
Active duty			
No	161 (50.31)	ref.	
Yes	106 (57.61)	1.14 (0.97–1.35)	
Trip duration > 2 week			
No	94 (56.63)	ref.	ref.
Yes	173 (51.03)	0.90 (0.76–1.06)	0.66 (0.44–0.99)
Military trip purpose			
No	195 (50.52)	ref.	ref.
Yes	72 (60.50)	1.19 (1.00–1.42)	1.15 (0.70–1.88)
Mosquito bitten			
No	113 (45.75)	ref.	
Yes	154 (59.69)	**1.30 (1.10–1.54)**	
Mosquitoes observed			
No	54 (36.00)	ref.	ref.
Yes	213 (60.00)	**1.66 (1.32–2.09)**	**2.77 (1.76–4.36)**
Accommodations[c]			
Low risk for bites	230 (53.49)	ref.	ref.
High risk for bites	37 (49.33)	0.92 (0.72–1.18)	1.00 (0.58–1.72)
Rainy season travel			
Not during rainy season	83 (39.2)	ref.	ref.
During rainy season	185 (62.0)	**2.54 (1.78–3.65)**	**2.45 (1.66–3.71)**

[a]Compliance with skin repellent use defined as self-reported use categorized as 'frequent/often'. Non-compliance defined as self-reported use categorized as 'rarely' or 'never'

[b]Malaria risk in country of travel was defined by the prevalence of falciparum malaria in children between 2 and 10 years ($PfPR_{2-10}$). High-risk countries = $PfPR_{2-10} > 35\%$: Burkina Faso, Sierra Leone, Liberia, Cote d' Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, Uganda, Democratic Republic of Congo; Low risk countries = $PfPR_{2-10} < 5\%$: Somalia, Ethiopia, Kenya, Botswana, Zimbabwe, Djibouti, Eritrea. Chikungunya/dengue risk countries: Cuba, Puerto Rico, Jamaica, British Virgin Islands, US Virgin Islands, Anguilla, St Kitts and Nevis, Montserrat, Antigua/Barbuda, Guadeloupe, Dominica, Martinique, St Lucia, Barbados, St Vincent and Grenadines, Grenada, Trinidad and Tobago, Aruba, Curacao, Bonaire, El Salvador

[c]High-risk accommodations defined as hotel without air-conditioning, camping or dormitory; low-risk accommodations include hotel with air-conditioning, private residence, cruise ship, military accommodations or safari lodge

Table 3. Factors associated with regular use of skin repellents and permethrin on clothing during travel[a]

	Compliance with use of repellent on skin and clothing (%)	Univariate OR (95% CI)	Multivariate OR (95% CI)
Regions[b]			
Low malaria risk	12 (8.11)	Ref	Ref
High malaria risk	25 (14.04)	1.32 (0.76–2.31)	1.28 (0.64–2.56)
Chikungunya/dengue risk	12 (8.11)	0.76 (0.38–1.52)	0.46 (0.19–1.08)
Age			
≤24 years	2 (4.26)	Ref	Ref
25–50 years	29 (13.94)	3.27 (0.80–13.25)	2.80 (0.62–12.63)
≥50 years	25 (10.04)	2.35 (0.57–9.62)	3.91 (0.86–17.8)
Gender:			
Male	31 (11.44)	ref.	Ref
Female	25 (10.73)	0.94 (0.57–1.54)	1.28 (0.70–2.33)
Active duty			
No	26 (8.13)	ref.	
Yes	30 (16.30)	**2.00 (1.22–3.28)**	
Trip duration > 2 weeks			
No	16 (9.64)	ref.	Ref
Yes	40 (11.80)	1.22 (0.70–2.12)	0.76 (0.41–1.41)
Military trip purpose			
No	32 (8.29)	Ref.	Ref.
Yes	24 (20.17)	**2.43 (1.49–3.96)**	**2.93 (1.48–5.78)**
Mosquito bites			
No	24 (9.72)	Ref.	
Yes	32 (12.40)	1.28 (0.77–2.10)	
Mosquito observed			
No	10 (6.67)	Ref.	Ref.
Yes	46 (12.96)	**1.94 (1.01–3.74)**	1.68 (0.78–3.65)
Accommodations[c]			
Low risk for bites	49 (11.40)	ref.	Ref
High risk for bites	7 (9.33)	0.80 (0.34–1.84)	0.85 (0.35–2.04)
Rainy season travel:			
Not during rainy season	83 (39.2)	Ref	Ref
During rainy season	185 (62.0)	1.67 (0.92–3.00)	**2.20 (1.14–4.20)**

aCompliance defined as self-reported use of skin repellent categorized as 'frequent/often' and use of permethrin on clothing. Non-compliance defined as no or rare self-reported use of skin repellents or no permethrin use on clothing.

bMalaria risk in country of travel was defined by the prevalence of falciparum malaria in children between 2 and 10 years ($PfPR_{2-10}$). High-risk countries = $PfPR_{2-10} >35\%$: Burkina Faso, Sierra Leone, Liberia, Cote d' Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, Uganda, Democratic Republic of Congo; Low-risk countries = $PfPR_{2-10} < 5\%$: Somalia, Ethiopia, Kenya, Botswana, Zimbabwe, Djibouti, Eritrea. Chikungunya/dengue risk countries: Cuba, Puerto Rico, Jamaica, British Virgin Islands, US Virgin Islands, Anguilla, St Kitts and Nevis, Montserrat, Antigua/Barbuda, Guadeloupe, Dominica, Martinique, St Lucia, Barbados, St Vincent and Grenadines, Grenada, Trinidad and Tobago, Aruba, Curacao, Bonaire, El Salvador

cHigh-risk accommodations defined as hotel without air-conditioning, camping or dormitory; low-risk accommodations include hotel with air-conditioning, private residence, cruise ship, military accommodations or safari lodge.

reported DEET use, 5 (12%) used permethrin-treated clothing, and none used bed netting.[17] The reasons for poor compliance could not be evaluated in our study, but plausible explanations may include the perception of low risk for exposure to arthropod bites and infection by travellers, inconsistent or inadequate counselling by travel providers, or travel conditions (e.g. oppressive heat and humidity) that challenge compliance. Although study participants received some pre-travel counselling, the advice was not standardized. Effective communication of AVPM during the pre-travel visit can be challenging due to the volume of information regarding the application of insect repellents and use of bed nets that must be relayed, the variability in insect vectors across geographic regions, and the number of commercially available AVPM products. Specific instructions that stress the safety, efficacy and correct use of AVPMs may improve the knowledge, attitudes and beliefs of travellers resulting in improved compliance.[18,19] Further research is needed to address modifiable factors associated with AVPM compliance.

Several differences in mosquito exposure and AVPM use were observed among persons travelling to malarious countries and those going to chikungunya/dengue risk regions. Participants travelling to chikungunya/dengue risk countries reported daytime mosquito bites more frequently, while nighttime bites were reported more frequently in malarious regions. The difference in biting patters could be related to the predominance of *Aedes* mosquitoes in the Caribbean and *Anopheles* mosquitoes in Africa, although this is difficult to establish without local mosquito surveillance that also accounts for *Culex* activity. Bed nets and repellents on clothing were more frequently used in malarious regions, which could be related to differences in counselling practices for prevention of malaria vs arboviral infections.

Although a lower proportion of participants travelling to chikungunya/dengue risk regions reported observing mosquitoes or receiving bites during travel, compliance with skin repellents was no different in chikungunya/dengue risk regions than malarious regions in the multivariate model. Rather it was factors associated with vector exposure, such as observing mosquitoes during travel [RR: 2.77 (95%CI: 1.76–4.36)] and travel during the rainy season [RR: 2.45 (95% CI: 1.66–3.71)] that were most strongly associated with compliance. In addition, a weak positive association was observed between the timing of repellent use and the timing of bites. It is unclear whether lack of effective chemoprophylaxis and treatment for chikungunya/dengue may have provided the impetus for AVPM compliance, or whether avoidance of nuisance bites was the driver for compliance. Nuisance bites are a concern for both military and civilian travellers and can impact daily activities, operational exercises and utilization of medical facilities during travel.[20,21] Associations between frequent arthropod bites and increasing skin repellent use have been reported in cohorts of military and civilian travellers. [18,22] Travel consultation and pre-deployment briefs should target this primary stimulus for AVPM use, and emphasize that AVPM compliance is an effective means of preventing both nuisance bites as well as serious arthropod-borne diseases.[20,23] In addition, a better understanding of the knowledge and attitudes of travellers towards vector borne diseases and use of AVPMs is important to inform a pragmatic strategy for vector avoidance during travel. A pilot study by Goodyer *et al.* evaluated a scale designed by the investigators for assessing attitudes to bite-avoidance measures in travellers, and its correlation with AVPM compliance during travel.[22] Scores on the attitude towards bite-avoidance measures scale predicted certain bite-avoidance measures, such as wearing trousers and using a repellent frequently. Development of such scales could help assess the impact of educational strategies to improve AVPM compliance.

Research in travel medicine poses unique methodological challenges including the heterogeneity of the population, travel itineraries and exposures, and recall bias on post-travel surveys. Since subjects were recruited from travel clinics and in the deployment setting, our results may not be generalizable to travellers who do not receive pre-travel care or are seen by primary care providers. In addition, self-assessment of AVPM compliance by travellers using a non-validated survey may lead to a biased estimate.[24] We did not evaluate how often travellers wore clothing that covered their arms and legs, an important AVPM against bites from mosquito and other vectors. Nonetheless, our results add to the existing literature, and are in line with the prior reports that demonstrate low AVPM compliance rates in military and civilian travellers, and that remain largely unchanged over the last decade despite an increase in availability of information.[4–6,16,18,22] In addition, we demonstrate significant variability in the use of bed nets and insect repellents on skin and clothing, among travellers going to regions with risk of malaria compared with chikungunya/dengue risk regions.

Vector borne febrile diseases continue to be a threat to deployed forces and civilian travellers. Evidenced based strategies are needed to promote optimal use of AVPM thereby reducing the risk of transmission. The results of this study suggest that efforts are needed at multiple levels in order to address poor AVPM compliance. This includes examining how people process personal risk and communications about risk, evaluating its impact on behaviour during travel, and improving access to pre-travel advice that effectively addresses the safety, efficacy and correct use of AVPMs taking into account the differential risk of disease across destinations.

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