

LANDING SITES ON THE HUMAN BODY PREFERRED BY *Aedes albopictus*

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ABSTRACT. The landing sites on the human body preferred by *Aedes albopictus* were examined. Five male volunteers wearing only shorts stood in a mosquito net enclosure containing 120 proboscis-amputated *Ae. albopictus*. In separate tests, 9 male volunteers and 1 female volunteer lay supine during the test. The number of mosquitoes landing on each site of the volunteer's body was counted, and after completion of the test, his or her body temperature was recorded. When the subject was upright, the landing site most preferred by mosquitoes was the foot. When volunteers were supine, the foot also was the most preferred landing site, but the proportion of mosquitoes landing on the foot in this position in comparison with other sites was lower than when the volunteer was in the upright position. The 2nd most preferred landing site was the hand, followed by the face. No correlation was found between preferred landing sites and body temperature. Factors other than temperature (e.g., human emanation) may influence mosquito behavior and landing site.

KEY WORDS Preferred landing site, foot, hand, body temperature, *Aedes albopictus*

INTRODUCTION

Studies have reported the landing sites on the human body preferred by *Culex quinquefasciatus* Say (Self et al. 1969), *Anopheles albimanus* Wied (Knols et al. 1994), *Anopheles atroparvus* Van Thiel, and *Anopheles gambiae* Giles (De Jong and Knols 1996). When subjects were sitting or supine, *Cx. quinquefasciatus* preferred the lower leg, whereas *Anopheles* spp. preferred upper sites of the body. In Japan, *Aedes albopictus* Skuse is the most common mosquito. In this study, we examined the correlation between landing sites on the human body that were used by *Ae. albopictus* and body temperature at those sites. We also examined landing sites on volunteers in both upright and supine positions.

MATERIALS AND METHODS

Mosquitoes: We used colonized *Ae. albopictus*, originally collected in Ogaki in Gifu Prefecture, Japan. We performed tests with 20- to 30-day-old unfed female mosquitoes, because previous tests showed that mosquitoes of this age were more avid feeders than were younger females.

Volunteers: Five healthy male volunteers, 19-30 years of age, were used in the upright position test. Nine male volunteers (including the 5 males used in the upright test), 19-30 years of age, and 1 female volunteer, 21 years of age, were used in the supine position test. The tests were conducted during evening hours, and all volunteers had not

bathed and had engaged in 1 h of light exercise. During the test, male volunteers wore only shorts. The female volunteer wore a sleeveless shirt and culottes.

Landing test: We adapted a mosquito net (150 × 100 × 180 cm) as a test cage and introduced 120 female mosquitoes into it during the evening. The proboscises of the mosquitoes were amputated before placing them into the net (Shirai et al. 2000) because mosquito bites might cause serious itching, skin damage, or hypersensitivity. Amputated mosquitoes approach humans and attempt to bite similarly to nonamputated mosquitoes. The following evening, volunteers entered the net after completing their exercises, and remained still while either upright or supine. A scorer outside the chamber counted the number of mosquitoes landing on each site of volunteer's skin or clothes every 2 min for 11 min (Fig. 1). For each position, we scored the percent landing as the percentage of the number of mosquito landings on each site compared with the total number of landings.

Skin temperature: After the landing tests, thermograms of volunteers in the upright position were recorded by a thermotracer (6T67, Nippondenki-sanei Co., Ltd., Tokyo, Japan). Furthermore, the skin temperature at each site of the body was measured by a radiant thermometer (IT-340S, Horiba Co. Ltd., Kyoto, Japan). Experiments were analyzed and evaluated statistically with the Bonferroni-Dunn test and Pearson's correlation coefficient of StatView (1998).

RESULTS

Preferred landing sites on subjects in the upright position

When in the upright position, the foot was the landing site most preferred by *Ae. albopictus*. The average number of mosquito landings on the dorsal surface of the foot was 45.6 ± 8.1 , which was sig-

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Table 1. Mean \pm SE percent (%) landing and skin temperature assessed by Pearson's correlation.

% landing	Skin temperature (°C)	<i>n</i>	<i>r</i>	<i>z</i> ¹	<i>P</i>	95% fiducial interval
5.9 \pm 1.5	31.4 \pm 0.2	85	0.011	0.099	0.921	-0.203-0.224

¹ Fisher's *r* to *z* test.

nificantly different from all other sites of the volunteer's bodies (Bonferroni-Dunn test, $P < 0.0001$; Fig. 2). The 2nd most preferred landing site was the hand (the dorsum of the hand and the palm). Many landings also were made on the lower legs and the thigh.

Preferred landing sites on subjects in the supine position

In the supine position, the foot was again the most preferred landing site when the proportion of mosquitoes landing on the dorsum and sole of the foot was combined. The 2nd most preferred landing site was the hand (the dorsum of the hand and the palm), and the next most common site was the face. The number of landings on the sole of the foot was significantly different compared with the neck, chest, abdomen, axilla, forearm, upper arm, external genitalia, anterior thigh, and anterior leg (Bonferroni-Dunn test, $P < 0.0001$; Fig. 3).

Correlation between skin temperature and landing sites

The percent of mosquitoes landing on all body parts was plotted against the skin temperature for each site (Fig. 4). No significant correlation was found between percent landing and skin temperature (Table 1).

DISCUSSION

Self et al. (1969) reported that when subjects are in sitting or supine positions, *Cx. quinquefasciatus* mainly bites their lower legs. Dekker et al. (1998) reported that *An. gambiae* distributes its bites evenly when the test person is lying on the ground, and moreover, the feet and legs are less attractive than other body parts when the feet and legs are kept in an upright position. De Jong and Knols (1996) divided the body into 3 categories of skin temperature and eccrine sweat gland densities, low, medium,

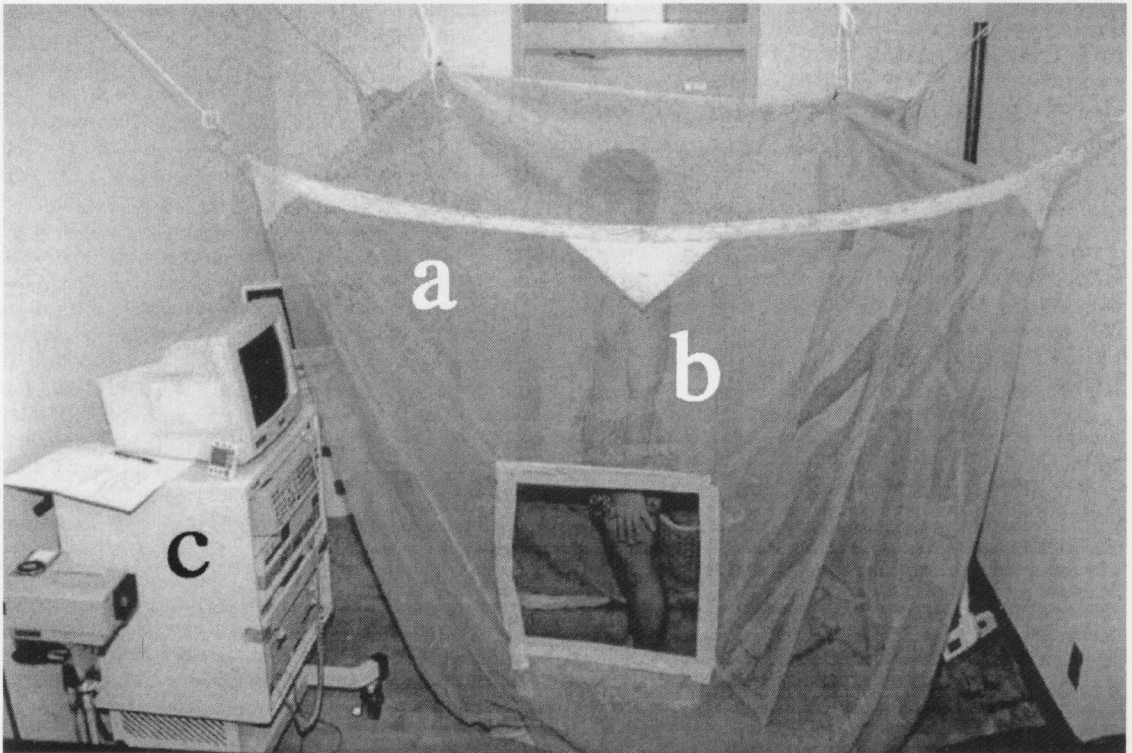


Fig. 1. A volunteer in the upright position inside a mosquito net enclosing proboscis-amputated mosquitoes. a, mosquito net; b, volunteer; c, thermotracer.

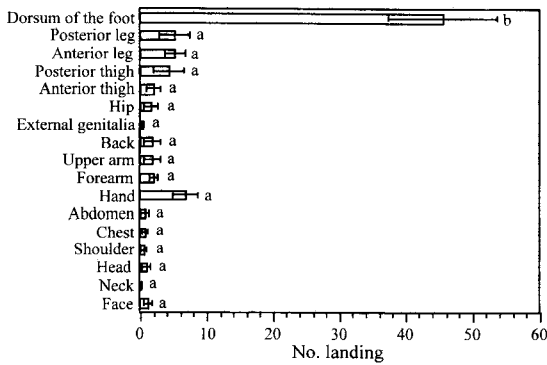


Fig. 2. Mean \pm SE number of landings on each site of upright volunteers by *Aedes albopictus* (5 replicates). Different letters show significant differences ($P < 0.0001$) by the Bonferroni–Dunn test.

and high, according to biting preference. They reported that *An. atroparvus* preferentially bites regions of high skin temperature, but that *An. gambiae* tends to bite regions of low temperature. We found no correlation between skin temperature of body sites and landing rates. The reason *Ae. albopictus* landed mostly on the foot may be that feet emanated characteristic odors, as discussed by De Jong and Knols (1996). In this study, the number of landings on the foot when in the upright position was greater than when in the supine position. This may indicate that *Ae. albopictus* ordinarily rests at a relatively low position in relation to the ground and often seeks biting sites initially at lower positions, and then flies upward to bite only if necessary. Nonetheless, the foot was preferred in the supine position as well, and this suggests that the main factor is not the position, but attractive sub-

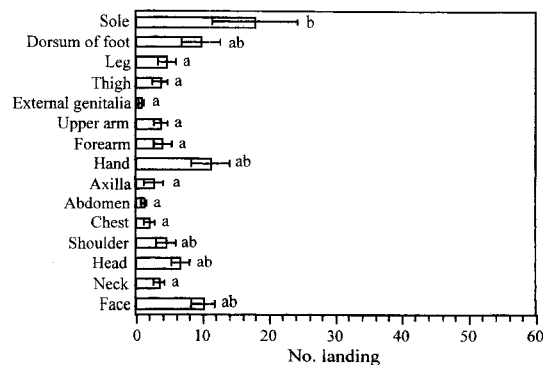


Fig. 3. Mean \pm SE number of landings on each site of supine volunteers by *Aedes albopictus* (10 replicates). Different letters show significant differences ($P < 0.0001$) by the Bonferroni–Dunn test.

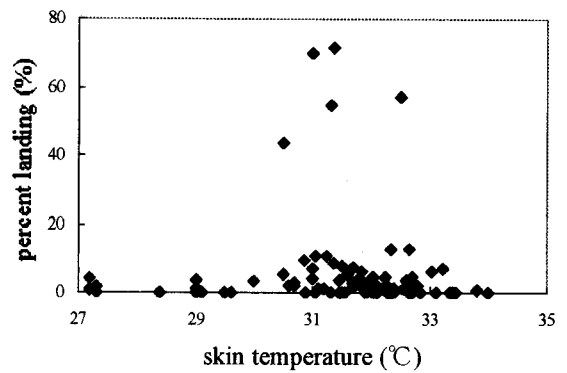


Fig. 4. Percent landing on each site of upright volunteers by *Aedes albopictus* and skin temperature measured by a radiant thermometer and supported by a thermotracer.

stances. Many people report that their feet are often bitten by mosquitoes, but one must consider that the feet and legs are frequently exposed during hot weather. Although the forearms and hands are also exposed in the summer, they are usually in motion more than the feet and legs, thus discouraging mosquito biting. Even when the subject is still and not repelling mosquitoes (as in this study), *Ae. albopictus* prefers the foot, then the leg, the hand, and the face.

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