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ALCOHOL INGESTION STIMULATES MOSQUITO ATTRACTION

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ABSTRACT. Mosquito bites should be avoided because of the risk of contracting parasitic and viral diseases such as malaria, dengue fever, and several encephalitides. Although humans have been said to suffer more mosquito bites after ingesting liquor, little is known about whether that is true. Thirteen volunteers (12 men from 20 to 58 years old and a 24-year-old woman) were chosen as test hosts and a 30-year-old man was established as a control. We measured ethanol content in sweat, sweat production, and skin temperature before and after ingestion of 350 ml of beer (ethanol concentration 5.5%) by volunteers and compared them with a control subject. Our study demonstrated that percent mosquito landing on volunteers significantly increased after beer ingestion compared with before ingestion, showing clearly that drinking alcohol stimulates mosquito attraction. However, ethanol content in sweat and skin temperature did not show any correlation between alcohol ingestion and mosquito landings. This study shows that persons drinking alcohol should be careful about their increased risk to mosquito bites and therefore exposure to mosquito-borne diseases.

KEY WORDS Ethanol ingestion, mosquito attraction, landing, sweat, *Aedes albopictus*

INTRODUCTION

The reason why people attract more mosquitoes after ingestion of alcohol has been reported to perhaps be because the body produces more carbon dioxide, more sweat, raises its temperature, or a combination of these (Yasutomi 1995). Carbon dioxide has been shown to be a mosquito attractant (Brown et al. 1951) and heat is also an important factor in attracting mosquitoes (Smart and Brown 1956, Eiras and Jepson 1994). Several studies also have reported increased mosquito attraction to sweat (Maibach et al. 1966, Khan et al. 1969, Healy and Copland 2000). Some researchers assume that humans slowed by drinking alcohol are more easily bitten by mosquitoes. But in fact, the reason why humans attract mosquitoes after drinking alcohol has not been studied and still remains unresolved. On the other hand, sweat contains ethanol after alcohol ingestion and a good correlation exists between ethanol concentration in sweat and that in blood (Kamei et al. 1998). However, a relationship between ethanol in sweat and mosquito attraction has not yet been fully studied. This purpose of this study is to solve the question of whether mosquito attraction to people after drinking alcohol is related to ethanol in sweat and skin temperature.

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MATERIALS AND METHODS

Mosquitoes and landing test: We used 4 colonies of *Aedes albopictus* Skuse, maintained in our laboratory at 24 ± 1°C, 60–70% relative humidity, and a 14:10 h light : dark photoperiod. Collection sites of the 4 colonies were Ogaki in Gifu Prefecture, Ako in Hyogo Prefecture, Tsurumi Ryokuchi in Osaka Prefecture and Ishigaki in Okinawa Prefecture, Japan. Mosquitoes used in the studies were 2–6 generations and 20- to 30-d-old unfed older females, because we had found that older female *Ae. albopictus* had higher biting rates than did 3- to 5-d-old mosquitoes. An aquarium (600 × 295 × 360 mm; NS-6M, NISSO Corporation, Tokyo, Japan) was used as a test chamber and proboscis-amputated mosquitoes were used for the tests (Shirai et al. 2000). Thirty-five proboscis-amputated mosquitoes and a plastic cup containing a 3% sugar solution were introduced into the chamber. The left forearms of 1 subject and a control were simultaneously inserted through the sleeve into the test chamber with the back of the hand facing up, while keeping a small space between the palm and the bottom surface of the test chamber (Fig. 1).

The determination of sweat and skin temperature: Skin temperatures of hands and forearms of human subjects were measured at 6 points with a radiant thermometer (IT-340S, Horiba Co. Ltd., Kyoto, Japan) before and after each attraction test. The probe of the apparatus for measuring continuous sweating rate (model Kenz-Perspiro 201, Suzuken, Nagoya, Japan) was attached to each thumb of both subjects throughout the tests. The sweat production was electrically recorded every 0.1 sec with a personal computer (Fig. 1).

The apparatus for the determination of ethanol concentration in sweat: The apparatus for measuring ethanol concentration in sweat consisted of 4 parts. A sampling probe was attached to the skin surface (made by modifying the probe used in model

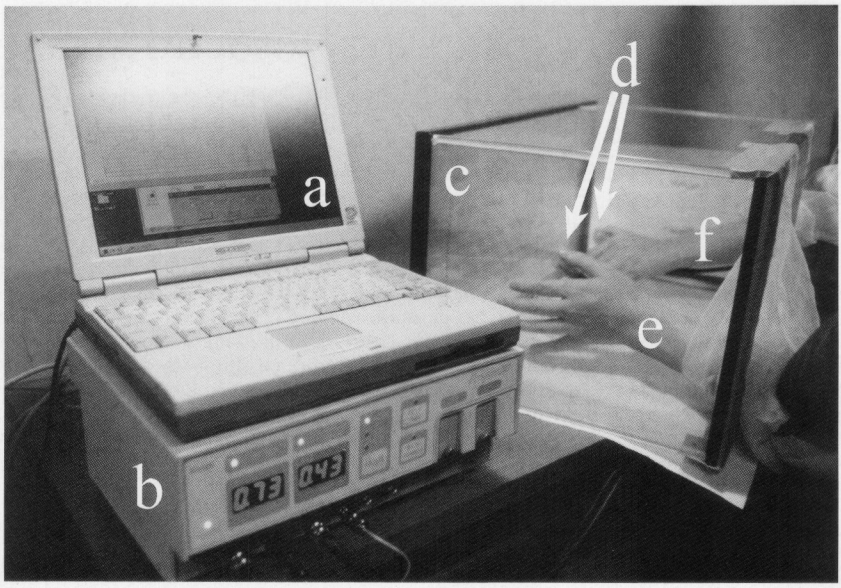

Fig. 1. The attraction test setup and the apparatus for measuring continuous sweat production. a, personal computer; b, model Kenz-Perspiro 201; c, aquarium enclosing proboscis-amputated mosquitoes; d, probes of Kenz-Perspiro 201; e, control subject's forearm; f, volunteer's forearm.

Kenz-Perspiro OSS-100, Suzuken, Nagoya, Japan). The measurement of sweating rate was accomplished by utilizing an electrostatic capacity-type hygrosensor, a trap cooled with liquid nitrogen, and a gas chromatograph with flame ionization detector (Fig. 2).

Subjects: Thirteen volunteers (12 men from 20- to 58 years old and a 24-year-old woman) were chosen as test hosts and a 30-year-old man was the control. Therefore, the 1st volunteer and a control subject were tested in the 1st test, a 2nd volunteer and the same control subject were tested in the 2nd test, and so on.

Comparison of attractiveness between subjects ingesting ethanol and control subjects: We compared the attractiveness of humans after ingesting ethanol with that of a human who did not ingest ethanol. The number of mosquitoes that landed on the hands and forearms of volunteers and controls was counted every 30 sec, and attractiveness was calculated by the total number of landings during a 10-min exposure. This preingestion attraction test was repeated 3 times, with a 3-min interval between tests. After the preingestion attraction tests,

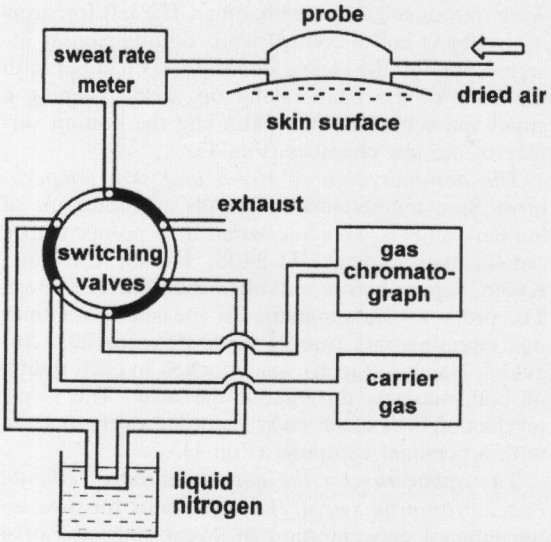

Fig. 2. Schematic diagram for the determination of ethanol in sweat (Kamei et al. 1998).

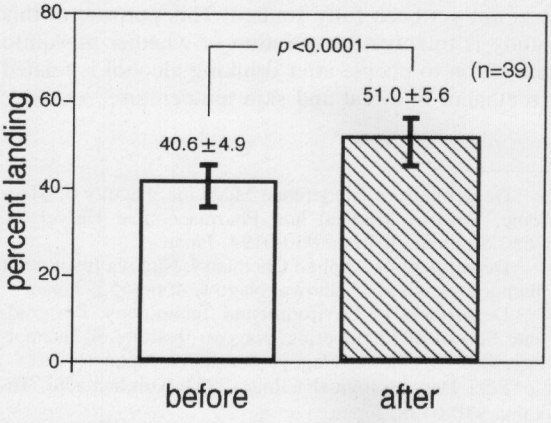

Fig. 3. Percent landing of mosquitoes on forearms before and after ethanol ingestion. Results are reported as means ± SE.

Table 1. Mean (±SE) difference of skin temperature and sweating rate before and after ethanol ingestion in groups A and R. Difference in percent landing in group A is 31.7 ± 4.7, and that of group R is −28.5 ± 5.0.

	Group A, attracting (n = 25)	Group R, repelling (n = 14)	P[1]
Difference in skin temperature (°C)	0.19 ± 0.25	−0.31 ± 0.35	NS[2]
Difference in sweating rate (mg/cm²/min)	−0.05 ± 0.02	−0.13 ± 0.04	NS

[1] By Mann–Whitney U-test.
[2] NS, not significant.

the volunteers each ingested 350 ml of beer (ethanol concentration 5.5%) during the next 1–12 min. The control subject did not drink any liquor after the preingestion test. The postingestion attraction test also was performed 3 times for 10 min each with a 3-min interval. The percent mosquitoes landing on each volunteer's forearm was calculated by 100 × (number of landings on a volunteer)/(the sum of numbers of landings on the volunteer and a control). Both percent landings were analyzed statistically by a Student's t-test. We measured skin temperature, sweat on forearms, and ethanol content in sweat with an apparatus for determination of ethanol concentration (Kamei et al. 1998). Each of the 13 volunteers was tested 3 times in 1 series of tests. Thus, 39 (13 × 3) tests were conducted. The tests were separated into 2 groups to observe the attraction (group A) and the repellency (group R) of mosquitoes after ethanol ingestion by the subjects. Statistical analysis on groups A and R was done by a Mann–Whitney U-test.

Comparison between tolerant and nontolerant subjects: On a questionnaire given to the volunteers, 5 men answered that they did not drink or could drink only a small amount of liquor (the nontolerant [NT] group), whereas 7 men and 1 woman answered that they could drink normal or large amounts (the tolerant [T] group). Group T (n = 8 × 3) and group NT (n = 5 × 3) were statistically analyzed by a Mann–Whitney U-test.

RESULTS

Mosquito landing

Mosquitoes preferred landing on forearms after ethanol ingestion by the subject. The percent of mosquitoes landing on a volunteer's forearm increased significantly after ethanol ingestion (P < 0.0001, paired t-test; Fig. 3) and showed that human forearms attract more mosquitoes after ethanol ingestion by the subject. Twenty-five of the 39 tests showed an increased number of landings after ethanol ingestion by the subject and the other 14 tests showed a decreased number of mosquito landings.

Influence of skin temperature, sweat production, and ethanol content in sweat

The skin temperature of volunteers rose in group A and declined in group R, and no significant difference was found. The sweating rate also was not significantly different between the 2 groups, and the sweating rate decreased after ethanol ingestion in both groups, but in group A it decreased less than in group R (Table 1). After ethanol ingestion, the ethanol content and the percent of ethanol increased and reached a maximum at 23–33 min, and then decreased (Fig. 4). No significant difference was observed between groups A and R for ethanol content per 30 sec, the percent of ethanol in sweat, and

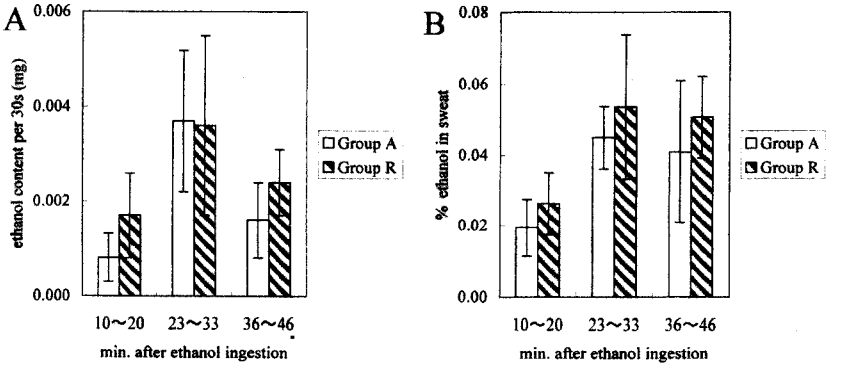

Fig. 4. Mean (±SE) ethanol content per 30 sec (A) and percent ethanol in sweat (B) in groups A and R.

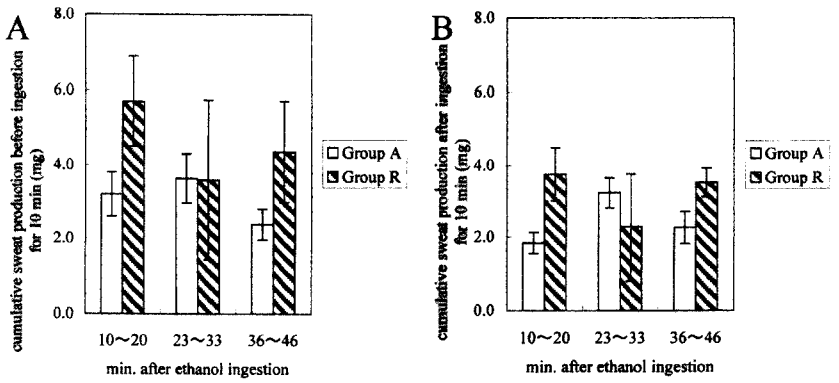

Fig. 5. Mean (±SE) cumulative sweat production before (A) and after (B) ethanol ingestion in groups A and R.

the cumulative sweat production before and after ethanol ingestion in any of those measurements (Figs. 4 and 5). In group A, the mean continuous sweat production for 10 min increased after ethanol ingestion (Fig. 6A), but sweat production decreased in group R (Fig. 6B). The cumulative sweat production during each test for volunteers and control was calculated every 10 min. The cumulative sweat production slightly decreased even after ethanol ingestion and was significantly lower than the con-

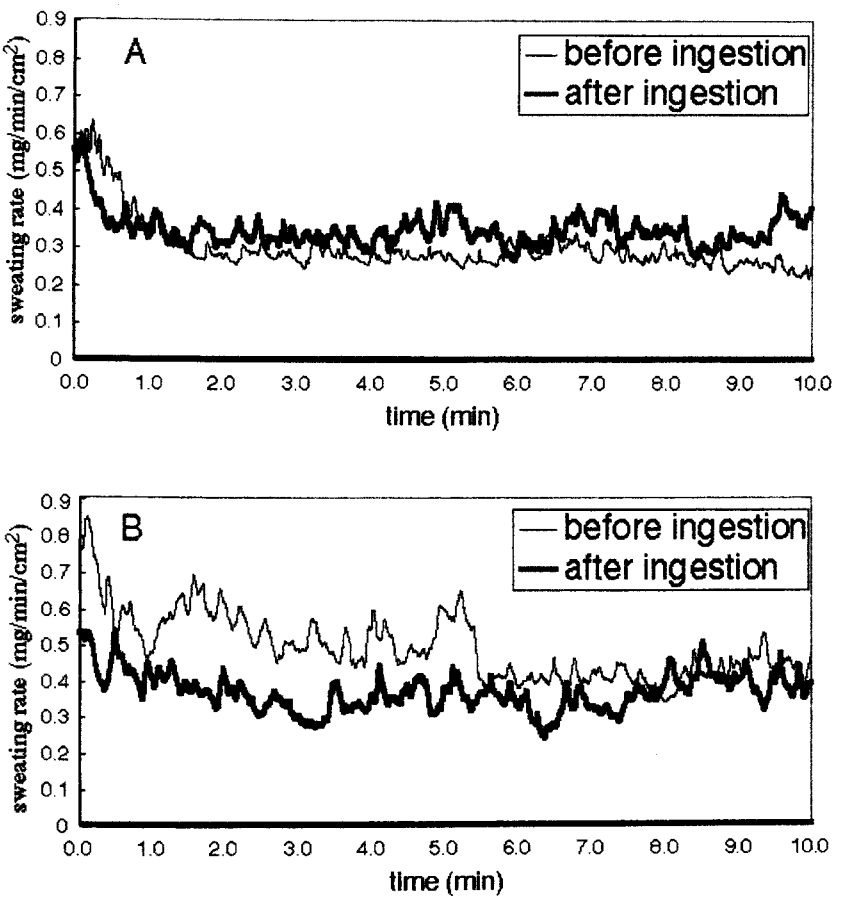

Fig. 6. Mean continuous (every 0.1 sec) sweating rate before and after ethanol ingestion for 10 min. (A) Group A (attractant); (B) group R (repellent). In (A), the sweating rate before and after ingestion is almost the same, but during the last half, the sweating rate after ethanol ingestion was slightly higher than before ingestion. In (B), the sweating rate after ethanol ingestion was less than before ingestion.

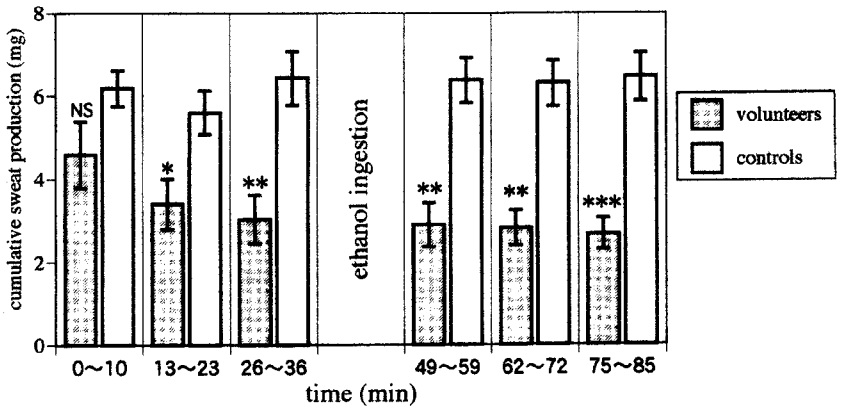

Fig. 7. Change of cumulative sweat production of volunteers (n = 13) and control at 6 times before and after ethanol ingestion. Results are reported as means ± SE. During the 1st 10 min, the cumulative sweat production between volunteers and control was not significant, but thereafter, significant differences were found. *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$ by Student's t-test. After ethanol ingestion, the cumulative sweat production of volunteers gradually decreased compared to the constant level of the control.

trol, except for the 10 min interval during the first attraction test (Fig. 7).

Comparison between tolerant and nontolerant subjects

After ethanol ingestion, group T attracted more mosquitoes than did group NT, but the difference was not statistically significant. The average skin temperature of group T rose after ingestion but that of group NT declined slightly, but again the difference was not significant. No difference was found in the sweating rate (Table 2). Group T showed a slightly higher ethanol content and percent of ethanol than did group NT at 23–33 min and at 36–46 min, but the difference was not statistically significant (Fig. 8).

DISCUSSION

Our study clearly demonstrated that ingesting ethanol results in attraction of more mosquitoes. Liquor ingestion has been reported to possibly result in the attraction of mosquitoes because of increased levels of carbon dioxide exhaled and during stillness, for example (Yasutomi 1995). In our study, exhaled carbon dioxide and that release due to the movement of forearms were excluded from consideration because of the technique used. However, carbon dioxide escaping from forearm skin would be a possible consideration. After ethanol ingestion, exhaled carbon dioxide increases with time (Mendelson 1968), and the body temperature falls slightly (Graham and Dalton 1980, Graham 1981, Fellows et al. 1984). After ethanol ingestion, skin temperatures on the arm have been reported to increase in a room at 25°C but to decrease in a room at −23°C (Livingstone et al. 1980). The body temperatures of rats that received injections of ethanol also decreased (Stewart et al. 1992). Concerning the change in sweat after ethanol ingestion, alcoholics without neurologic deficits showed more sweat responses on the palms and soles than did nonhabitual drinkers (Chida et al. 1998). In our study, the skin temperature increased in subjects that attracted mosquitoes and decreased in subjects that repelled mosquitoes. No significant difference was found between the 2 groups, but skin temperature might have some influence on mosquito landing. Because the skin temperature of alcohol-tolerant subjects also increased, whereas that of alcohol nontolerant subjects decreased, tolerance to alcohol might correlate with mosquito attraction. In this study, we demonstrated that sweat glands secreted ethanol after ingestion, as has been previ-

Table 2. Mean (±SE) difference in percent landing, skin temperature, and sweating rate in groups T and NT.

	Group T, tolerant (n = 24)	Group NT, nontolerant (n = 15)	P[1]
Difference in percent landing	20.4 ± 9.1	5.0 ± 7.6	NS[2]
Difference in skin temperature (°C)	0.27 ± 0.26	−0.38 ± 0.31	NS
Difference in sweating rate (mg/cm²/min)	−0.07 ± 0.02	−0.08 ± 0.04	NS

[1] By Mann–Whitney U-test.
[2] NS, not significant.

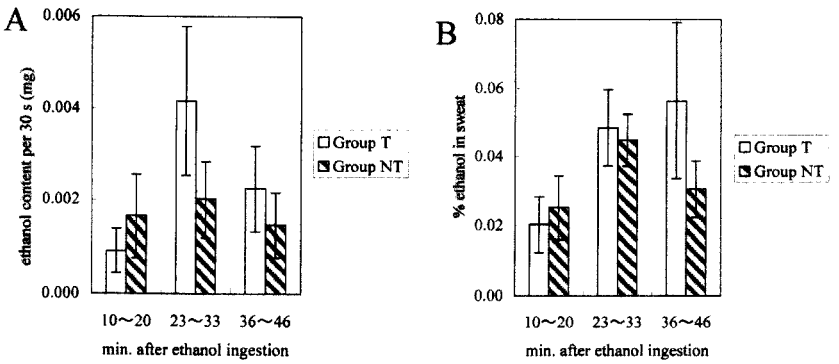

Fig. 8. Ethanol content per 30 sec (A) and percent ethanol in sweat (B) in groups T and NT.

ously reported (Kamei et al. 1998). However, very small amounts of ethanol might not be a major factor in attracting mosquitoes after ingestion. Ethanol in sweat increased from 23 to 33 min after ethanol ingestion and then decreased (Fig. 4), but mosquito landings were not influenced by this change. Sweat has been reported to attract mosquitoes (Maibach et al. 1966, Khan et al. 1969), and human sweat and 2-oxopentanoic acid have been reported to elicit mosquito landings (Healy and Copland 2000). However, other studies have shown that sweat is not universally attractive (Howlett 1910, Rudolfs 1922), but is attractive only at low vapor concentrations and is significantly repellent at high concentrations (Brown et al. 1951, Skinner et al. 1965).

In conclusion, our research indicated that humans attract more mosquitoes after ingesting ethanol. We can conclude that sweat production or skin temperature after ethanol ingestion does not attract mosquitoes but the attraction rather might be due to the presence of unknown chemical substances on the skin after ethanol ingestion.

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