
Personal protection measures against fire ant attacks

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Background: Fire ant stings lead to significant morbidity and mortality each year. Virtually no information exists in the scientific literature about the effectiveness of personal protection measures against these ants.

Objectives: To quantify the level of protection from ant stings by socks and cotton tights and to evaluate the efficacy of repellents and other chemicals in preventing stings.

Methods: Commercially obtained infant socks were fitted on a plastic doll's foot, which was touched to fire ant mounds in a series of controlled experiments. Socks and cotton tights were stretched over a human finger and placed in a fire ant mound to test the ability of ants to sting through fabric. Assays were developed to screen chemical substances for their ability to stop or prevent fire ant stings.

Results: Socks of any type reduced the number of fire ants that reached the skin and delayed the time required for ants to reach the skin above the sock level. Fire ants were unable to sting through all socks tested. Ants successfully stung both paper towels and human skin, regardless of chemical substance or repellent applied to them.

Conclusions: Socks provide some degree of protection from fire ant stings; therefore, children living in fire ant-infested areas should wear them. Fire ants appear unable to sting through many commercially available socks. Cotton tights may be useful in protecting the lower extremities of children. Fire ants are not deterred from stinging by a wide variety of insect repellents and chemical substances.

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INTRODUCTION

The red imported fire ant (IFA), *Solenopsis invicta*, is a major medical and veterinary pest that lives in many areas of the southern United States.^{1,2} Between 30% and 60% of the human population living in urban areas infested by IFAs are stung every year.^{3–6} In one study at a venom clinic in a large teaching hospital, IFAs were responsible for 42% of visits to the clinic and accounted for 59% of the total immunotherapy that was begun at that clinic.⁷ Children are more commonly stung by IFAs, because they play outdoors during summer.⁸ Reactions to IFA stings may be classified as local, systemic-allergic, or other.⁹ Local reactions may be further subdivided into (1) wheal-and-flare reactions, (2) pseudopustules, and (3) large local reactions. As for frequency, one survey of 29,300 physicians identified 32 deaths attributed to anaphylaxis caused by fire ant stings.¹⁰ That study found that patients who died of fire ant stings ranged in age from 16 months to 65 years and had usually been stung fewer than 5 times. Concerning other reactions, some evidence exists that fire ant venom may act as a neurotoxin. One 4-year-old boy in good health had 2 grand mal seizures 30 minutes after being stung on the foot by 20 IFAs.¹¹

Although at least one study has described how footwear influences exposure to ticks,¹² there are apparently no such reports that involved fire ants. Two recent reviews of hypersensitivity to Hymenoptera stings clearly recommend that

avoidance measures be undertaken for individuals at high risk of having systemic reactions to Hymenoptera in general and fire ants specifically.^{13,14} However, the authors of these articles were not able to reference any studies that detailed such avoidance measures.

Some plants have evolved ant repellent substances, such as terpenoids and lactones, to ward off leaf-cutting ants.^{15,16} In addition, the monoterpenoids, such as menthol and menthone, have been found to be somewhat repellent to IFAs in Petri dishes.¹⁷ However, to my knowledge, there are no published reports on the efficacy of repellent substances against fire ant attacks. Verbal anecdotal reports among fire ant researchers indicate that once IFAs are disturbed and in stinging mode, no repellent substance is able to ward off attack. This study was conducted to quantify the level of protection from IFA stings provided by socks and various chemical repellents.

MATERIALS AND METHODS

Doll, Socks, and Controls

For these experiments, a toy doll (Fig 1), which was 45 cm tall and made of a hard plastic surface, was used. An infant sock was placed on one of the doll's feet, covering the foot, ankle, and lower leg (treatment). The other foot and leg served as the control, with a line marked at a level at the top edge of a similar imaginary sock. For each type of sock used in the study, a binder clamp was applied near the upper sock rim to hold it tightly against the doll's leg. Assorted socks tested on the doll were purchased from Walmart and Target stores (Fig 2). Table 1 gives a breakdown of sock type, source, and brand. Socks were infant size (0–6 months) and varied in style and texture. Anklet-style

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Figure 1. Toy doll used in fire ant personal protection experiments.



Figure 2. Socks and cotton tights tested for protective ability against fire ant attacks.

socks had no collar at the top, whereas bootie-style socks were more tube-like, with a top edge that could be turned down to make a collar-like top at the leg-sock interface. A wire device was constructed out of electric fence wire to fit under the collar in one set of bootie sock experiments to hold out the collar, making a gap between the sock and collar (Fig 3). In the sting-through experiments, one additional type of footwear, cotton tights, was tested.

Ant Mounds, Weather, and Protocol

For all experiments, 3 IFA mounds in the author's yard (Jackson, MS) were chosen. All mounds were approximately equal in size (approximately 40 cm in diameter). All experiments, with the exception of the repellent tests, were conducted on 3 dates in mid-April 2004 (April 9, 16, and 17) between 10:00 AM and 2:00 PM to reduce variability in ant response. Sky condition was partly cloudy on each date, with temperatures between 75°F and 85°F. For each observation,

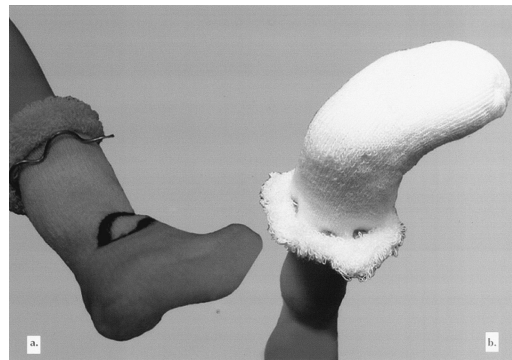


Figure 3. Wire device used to hold sock collar open (a) and wire device in place on sock (b).

the top of the ant mound was initially disturbed and then the test sock or control gently touched to the surface of the mound. Testing was repeated using the other 2 mounds with the sequence varied as to which mound was disturbed first, second, or third.

Number of Ants Reaching the Skin at 10 Seconds

Six different infant socks were tested in their ability to impede fire ants from reaching skin level. In each case, a test sock was placed on the doll foot and the foot touched to a fire ant mound as described herein (Fig 4). The number of ants reaching the skin at 10 seconds was recorded. For the control, the number of ants reaching the line drawn on the other foot (top of sock level) in 10 seconds was recorded (Fig 4). Three replicates each of treatments and controls were performed. All ants were removed from the doll and socks before each replicate.

Time for Ants to Reach the Skin

The same experiments were repeated with all 6 socks, except this time, the time was recorded for any one ant to reach the



Figure 4. Doll foot with test sock placed in disturbed fire ant mound (a) and doll foot with no sock used as control (b). (This is a merged picture; this procedure was not performed simultaneously.)

Table 1. Protection Provided by Socks From Fire Ant Stings

	Sock A	Sock B	Sock C	Sock D	Sock E	Sock F	Sock F with wire device*	All socks (including wire)
Sock type†	Anklet	Anklet	Bootie	Anklet	Anklet	Bootie	Bootie	Anklet and bootie
Size	0-6 mo	0-6 mo	0-6 mo	0-6 mo	0-6 mo	0-6 mo	0-6 mo	0-6 mo
Material thickness	3.0 mm	3.0 mm	4.5 mm	2.9 mm	2.0 mm	4.1 mm	4.1 mm	
Source and brand	Walmart, Faded Glory	Walmart, Faded Glory	Walmart, The Baby Connection	Walmart, Faded Glory	Target, Carter's	Walmart, Faded Glory	Walmart, Faded Glory	All brands
Mean No. of ants that reached skin above sock at 10 seconds vs control‡	1 vs 5.7	0 vs 5.7	1.7 vs 5	2.7 vs 4.7	2.7 vs 8	2.7 vs 5	0.33 vs 5.3	1.57 vs 5.62
<i>t</i> test <i>P</i> value	.03	.04	.17	.3	.01	.09	.05	<.001
Mean No. of seconds required to reach skin above sock vs control‡	8.3 vs 5.3	9.7 vs 5.7	8 vs 5.3	9 vs 4.7	7 vs 4.3	7.7 vs 4.3	15 vs 6	9.24 vs 5.1
<i>t</i> test <i>P</i> value	.06	.05	.13	.03	.01	.005	.01	<.001

* Sock with wire device at top to hold collar out and open.

† In addition to sock type, the socks also had various degrees of weave texture.

‡ Three replications of each, averaged.

skin. Controls were the times required to reach the line drawn on the other doll foot (top of sock level). Three replicates of treatments and control were performed.

Socks Experiments

The same 6 socks and a set of cotton tights were tested as to whether fire ants could sting through the material. Small cross-sectional pieces taken from duplicate socks and from cotton tights were removed using sharp scissors. The diameter of these pieces were measured with a Ken-a-Vision micrometer slide under a dissecting (binocular) microscope. For the sting-through experiments, the author's finger was used to both fit the socks and receive stings (Fig 5a). Each sock was clamped with binder clips on the author's finger to hold it close to the skin and then touched to a fire ant mound to allow ants to sting it (Fig 5b). No binder clip was used for the tights; they were simply pulled close against the author's skin (Fig 5c and d). Three replicates of each sock type and the tights were performed. All ants were cleaned off the socks before each new replicate began.

Repellents Experiments

Various insect repellents and other chemical substances were tested as to their ability to prevent fire ant stings (Fig 6). In an initial screening, paper towels were twisted in a tube-like fashion and folded. The towels were then soaked with each chemical substance to be tested and then touched to a disturbed fire ant mound (Fig 7). Presence or absence of stinging fire ants on the paper towels was then noted. In a second, more quantified assay, fire ants were carefully collected from the author's yard and placed in a Petri dish. No evidence of ant injury or unusual behavior of the ants once inside the Petri dishes was noted. Four small squares or rectangles approximately 4×4 cm were drawn with a marker on the dorsal surface of the author's forearm. A similar square or rectangle was drawn on the volar surface of that same arm, which functioned as the control site (Fig 8a). Various chemical substances were carefully applied with a cloth to the treatment blocks. The control block had no substances applied. One fire ant at a time was picked out of the dish and placed on the arm in the control block. If it stung the author (Fig 8b), it was immediately moved to a treatment block to see if it would sting there. Some ants would not sting in the control block and therefore were not evaluated in treatment blocks. Five different ants were evaluated for each repellent or substance eval-



Figure 5. Ant ability to sting through socks (a), socks with stinging ants (b), tights stretched over finger (c), and ants stinging tights (d).



Figure 6. Repellents and other chemicals tested for repellency against fire ants.



Figure 7. Paper towel test showing example of repellent tested (a), towel saturated with repellent (b), and ants stinging towel (c)

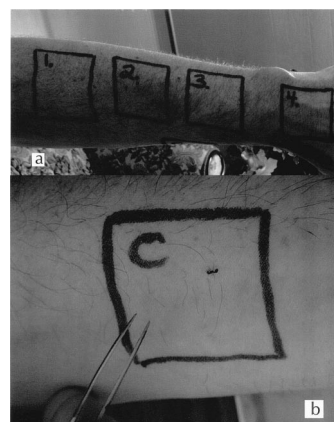


Figure 8. Blocks drawn on arm for repellency tests (a) and control block on underside of arm with ant stinging (b).

uated. To prevent interference or possible mixing of substances, no more than 4 substances were tested at a time. Several days (and many washings with soap and water) were allowed to pass before testing on the skin was resumed with new or different substances.

Statistical Analyses

Paired *t* tests were used to compare mean numbers of fire ants and times in both controls and treatments. All statistical analyses were calculated with SAS statistical software.¹⁸

RESULTS

Protection From Ants by Socks

During all experiments, many ants attached to the socks, attempting to sting (Fig 9). On average, socks of any type reduced the number of fire ants that reached the skin by approximately one third (Table 1). Sock types A, B, and E were associated with significantly fewer ants transversing to skin. Sock F, which contained a wire device to hold out the collar, making a gap between the sock and collar, also slowed ants in reaching the skin ($P = .05$).

In the second analysis, socks almost doubled the time required for fire ants to reach the skin (average, 8.28 seconds with socks vs 4.93 seconds without socks). Sock types B, D, E, and F were associated with significantly shorter times for ants to reach the skin. Sock F with the wire device produced a highly significant ($P = .01$) difference in time to reach skin when compared with controls. When data from all sock types were combined (including the one with wire device), the overall delay in time to reach skin afforded by socks was strikingly significant ($P < .001$).

Protection From Ants by Repellent Substances

In the paper towel assay, fire ants stung the towels regardless of the presence of the following chemical substances: 7.0% DEET, 20% DEET, 95% DEET, 0.5% permethrin, 100% turpentine, 100% witch hazel, sulfur, camphor, and pine tar. In the tests on a human arm, fire ants successfully stung in every test, regardless of potential repellent tested, and produced typical pseudopustular lesions (Fig 10).¹⁹ Given the opportunity, ants stung 5 times (100%) of 5 opportunities on



Figure 9. Sock covered in stinging ants.

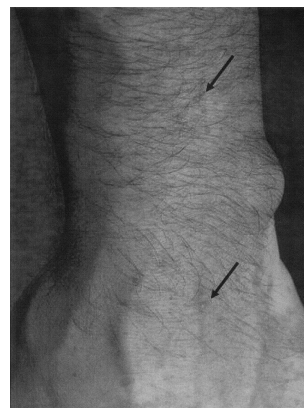


Figure 10. Fire ant sting lesions on arm after 1 day.

skin with every chemical tested except sulfur (4/5; 80%) and 20% DEET (4/5; 80%).

DISCUSSION

Not all individual sock types produced statistically significant results in either number of ants that reached the skin or in the amount of time required to reach the skin. This may have been due to low sample size and low ant numbers in the experiments. More importantly, regardless of sock type or thickness, fire ants were apparently unable to sting through socks, even thin cotton tights. Whether tights in actual use are stretched over a child's skin tighter (and thus thinner) than the degree of stretching the author used in these tests is unknown. Nonetheless, fire ant inability to sting through tights is an important finding, because it may be possible to protect infants' and toddlers' legs from ant attack by clothing them in cotton tights.

As for chemical repellency against fire ant attack, ants successfully stung human skin in all tests with 2 possible exceptions: ants only stung 4 (80%) of 5 times when treatment blocks contained sulfur or 20% DEET. These results might at first be interpreted as a repellent effect but are actually counterintuitive in light of the other data. If fire ants successfully stung through 95% DEET, why would they be repelled by a lower concentration (20%)? Also, ants showed no inhibition in the paper towel tests, aggressively stinging paper towels with a variety of substances on them. Finally, in an effort to retest the repellency of sulfur, a sock was saturated with the chemical and placed in a disturbed ant mound. The ants aggressively stung the sock (Fig 11).

These data help elucidate the effectiveness of personal protection methods against fire ants, a subject on which only a paucity of information currently exists.^{13,14} Socks provide some degree of protection from fire ant stings; therefore, children living in fire ant-infested areas should wear them. Wearing socks gives the child or caregiver a few extra seconds to see and possibly remove attacking ants. In addition, fire ants appear unable to sting through many commercially available socks; attacking fire ants must crawl above sock level to reach exposed



Figure 11. Child's sock saturated with sulfur and placed in disturbed fire ant mound (note ant stinging [arrow]).

skin. Perhaps most importantly, cotton tights may be most useful in protecting the lower extremities of children.

Unfortunately, attacking fire ants are not deterred by a wide variety of insect repellents and other chemical substances. Although not every repellent on the market was tested in this study, these data suggest that currently available chemical repellents are useless against fire ant attack. These negative data indicate that personal protection against fire ant stings must involve other aspects of human behavior, such as recognition and avoidance of the ant mounds and feeding trails.

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