

COMPARATIVE EFFICACY OF INSECT REPELLENTS AGAINST MOSQUITO BITES

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ABSTRACT

Background. The worldwide threat of arthropod transmitted disease, with their associated morbidity and mortality, underscores the need for effective insect repellents. Multiple chemical, botanical, and “alternative” repellent products are marketed to consumers. We sought to determine which products available in the United States provide reliable and prolonged complete protection from mosquito bites.

Methods. We conducted studies involving 15 volunteers to test the relative efficacy of seven botanical insect repellents; four products containing N,N-diethyl-m-toluamide (DEET); a repellent containing IR3535; three repellent-impregnated wristbands; and a moisturizer that is commonly claimed to have repellent effects. These products were tested in a controlled laboratory environment in which the species of the mosquitoes, their age, their degree of hunger, the humidity, the temperature, and the light – dark cycle were all kept constant.

Results. DEET – based products provided complete protection for the longest duration. Higher concentrations of DEET provided longer-lasting protection. A formulation containing 23.8 percent **DEET** had a mean complete protection time of **301.5 minutes**. The **IR3535**-based repellent protected for an average of **22.9 minutes**. All other **botanical repellents** we tested provided protection for a mean duration of **less than 20 minutes**. Repellent-impregnated **wristbands** offered **no protection**.

Conclusions. **Currently available non-DEET repellents do not provide protection for durations similar to**

those of DEET-based repellents and cannot be relied on to provide prolonged protection in environments where mosquito-borne disease are a substantial threat.

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INSECT – TRANSMITTED disease remains a major source of illness and death worldwide. Mosquitoes alone transmit disease to more than 700 million persons annually. Malaria kills 3 million persons each year, including 1 child every 30 seconds.

Protection from arthropod bites is best achieved by avoiding infested habitats, wearing protective clothing, and using insect repellent. In many circumstances, applying repellent to the skin may be the only feasible way to protect against insect bites. Given that a single bite from an infected arthropod can result in transmission of disease, it is important to know which repellent products can be relied on to provide predictable and prolonged protection from insect bites. Commercially available insect repellents can be divided into two categories – synthetic chemicals and plant derived essential oils. The best known chemical insect repellent is N, N-diethyl-m-toluamide (DEET). Many consumers, reluctant to apply DEET to their skin, deliberately seek out other repellent products. We compared the efficacy of readily available alternatives to DEET – based repellents in a controlled laboratory environment.

METHODS

Product Selection

In January 2001, we purchased a total of 16 products for testing, choosing repellents with national, rather than local distribution. Seven widely available botanical repellents were included in the study. Multiple concentrations and formulations of DEET are readily available. We chose and tested three DEET-based repellents (ranging from 4.75 to 23.8 percent DEET) that we believe represented the range of commonly purchased repellents in the United States. We also tested a controlled release 20 percent DEET formulation to determine whether it had a longer duration of action. The only synthetic repellent containing IR3535 that is available in the United States and three wristbands impregnated with either DEET or citronella were also tested. Finally, we tested the efficacy of a proprietary moisturizer that is commonly believed to have repellent effects.

RESULTS

Of the products tested, those containing DEET provided the longest lasting protection. The complete-protection times of DEET-based repellents correlated positively with the concentration of DEET in the repellent. The formulation containing 23.8 percent DEET protected for an average of 301.5 minutes. There was a statistically significant difference in complete protection time between each DEET-based repellent and the product with the next higher concentration of DEET.

No non-DEET repellent fully evaluated in this study was able to provide protection that lasted more than 1.5 hours.

The IR3535-based repellent protected against mosquito bites for an average of 22.9 minutes. The citronella-based

repellent we tested protected for 20 minutes or less. There was no significant difference in protection time between the slow-release formulation containing 12 percent citronella and the formulation containing 5 percent citronella or the two formulations containing 10 percent citronella. The repellent containing only 0.05 percent citronella provided less protection than the Skin-So-Soft mineral-oil-based moisturizer (Avon). **Repellent-impregnated wristbands**, containing either 9.5 percent DEET or 25 percent citronella (by weight), protected the wearer for only **12 to 18 seconds, on average**.

In our study, the greatest risk of overestimation of complete-protection times would affect the repellents that were tested with once-hourly insertion into the cage. According to our protocol, however, hourly insertions were only used by subjects who found that a repellent initially protected them for more than four hours. Only the two highest-concentration DEET-based repellents in our study (20 percent and 23.8 percent DEET) qualified for once-hourly insertions by some of the subjects, and the range of protection these repellents afforded (180 to 360 minutes) is consistent with previously published reports of the efficacy of DEET. Any rounding errors resulting from the intervals between insertions into the cage would also tend to overestimate the efficacy of the other repellents we tested, and 11 of the 12 non-DEET products still had mean complete-protection times of less than 23 minutes.

DISCUSSION

Protection against arthropod bites is best achieved by avoiding infested habitats, wearing protective clothing and applying insect repellent. The insect repellents that are currently available to consumers are either synthetic

chemicals or are derived from plants. The most widely marketed chemical-based insect repellent is DEET, which has been used worldwide since 1957. DEET is a broad-spectrum repellent that is effective against many species of mosquitoes, biting flies, chiggers, fleas and ticks. **The protection provided by DEET is proportional to the logarithm of the dose: higher concentrations of DEET provide longer-lasting protection**, but the duration of action tends to plateau at a concentration of about 50 percent. Most commercially available formulations now contain 40 percent DEET or less, and the **higher concentrations are most appropriate to use under circumstances in which the biting pressures are intense, the risk of arthropod transmitted disease is great, or environmental conditions promote the rapid loss of repellent from the surface of the skin.** In our study, a formulation containing 23.8 percent DEET provided an average of five hours of complete protection against *A. aegypti* bites after a single application. **Depending on the formulation and concentration tested, DEET-based repellents have been shown in other studies to provide complete protection against arthropod bites for as long as 12 hours, even under harsh climatic conditions.**

The most recent addition to the synthetic insect repellents on the market in the United States is **IR3535**. In our tests, this repellent fared poorly, yielding a mean complete-protection time that was one quarter that of the lowest-concentration DEET product we tested (22.9 vs 88.4 minutes).

Skin-So-Soft Bath Oil, which consumers commonly claim has a repellent effect on insects, provided only a mean of **9.6 minutes of protection** against aedes bites in our study. This extremely limited repellent effect has previously been documented in other studies.

Thousands of plants have been tested as potential botanical sources of insect repellent. Most plant-based insect repellents currently on the market contain essential oils from one or more of the following plants: citronella, cedar, eucalyptus, peppermint, lemongrass and geranium. **All botanical repellents** that we tested in our initial studies, regardless of their active ingredients and formulations, gave **very short-lived protection**, ranging from a mean of about **3 to 20 minutes**.

Most alternatives to topically applied repellents have proved to be ineffective. No ingested compound, including **garlic** and **thiamine (vitamin B1)**, has been found to be capable of repelling biting arthropods. Small, wearable devices that emit sounds that are purported to be abhorrent to biting mosquitoes have also been proved to be ineffective. In our study, **wristbands** impregnated with either DEET or citronella similarly **provided no protection** from bites, consistent with the known inability of repellents to protect beyond 4 cm from the site of application.

Multiple factors play a part in determining how effective any repellent will be: these factors include the species of the biting organisms and the density of organisms in the immediate surroundings: the user's age, sex, level of activity, and biochemical attractiveness to biting arthropods; and the ambient temperature, humidity and wind speed. As a result, a given repellent will not protect all users equally. Examination of the ranges of complete-protection times in Table 1 shows variation in the ability of each repellent to protect different subjects.

Our study shows that **only products containing DEET offer long-lasting protection after a single application**. Certain plant-derived repellents may provide short-lived efficacy. Frequent re-application of these repellents would partially compensate for their short duration of action. However, when one

is travelling to an area with prevalent mosquito-borne disease that could be transmitted through a single bite, the use on non-DEET repellents would seem ill advised. **Given our findings, we cannot recommend the use of any currently available non-DEET repellent to provide complete protection from arthropod bites for any sustained outdoor activity.**

Although this study shows that DEET-based products can be depended on for long-lasting repellent, they are not perfect repellents. DEET may be washed off by perspiration or rain, and its efficacy decreases dramatically with rising outdoor temperatures. DEET is also a plasticizer, capable of dissolving watch crystal, the frames of glasses and certain synthetic fabrics.

Despite the substantial attention paid by the lay press every year to the safety of DEET, this repellent has been subjected to more scientific and toxicologic scrutiny than any other repellent substance. The extensive accumulated toxicologic data on DEET have been reviewed elsewhere. **DEET has a remarkable safety profile after 40 years of use and nearly 8 billion human applications. Fewer than 50 cases of serious toxic effects have been documented in the medical literature since 1960, and three quarters of them resolved without sequelae.** Many of these cases of toxic effects involved long-term, heavy, frequent or whole-body application of DEET. **No correlation has been found between the concentration of DEET used and the risk of toxic effects.** As part of the Reregistration Eligibility Decision on DEET, released in 1998, the Environmental Protection Agency reviewed the accumulated data on the toxicity of DEET and concluded that **“normal use of DEET does not present a health concern to the general population”**. When applied with common sense, DEET-based repellents can be expected to provide a

safe as well as a long-lasting repellent effect. Until a better repellent becomes available, DEET-based repellents remain the gold standard of protection under circumstances in which it is crucial to be protected against arthropod bites that might transmit disease.