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Original Article

Prevalence and Susceptibility Status of Body Louse (*Pediculus humanus humanus*) (Anoplura: Pediculidae) to Deltamethrin in Urmia City, Iran (2024)

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Abstract

Background: The body louse spreads diseases such as epidemic typhus and louse-borne relapsing fever and has shown resistance to various insecticides. While deltamethrin is used to treat infestations in some countries, research on its effectiveness against body lice is limited. This study assessed the susceptibility of body lice to deltamethrin using a bioassay.

Methods: Body lice specimens were collected from an addiction treatment camp in Urmia City, West Azerbaijan Province, Iran. They were treated in 5 cm Petri dishes lined with 1 ml of various concentrations of deltamethrin (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, 1.28, and 2.56 ppm) in acetone. Thirty lice were tested per concentration, with mortality recorded after 24 hours. Lethal concentrations of 50% and 90% (LC_{50} and LC_{90}) were calculated using Minitab and compared with SPSS. The regression line was plotted in Excel 2013.

Results: A positive correlation was observed between the concentrations of deltamethrin and probit mortality in the regression analysis. The calculated LC_{50} and LC_{90} values for deltamethrin against body lice were 0.11 ppm and 2.15 ppm, respectively.

Conclusions: These findings suggest that the body lice population was susceptible to deltamethrin, suggesting its potential as an alternative treatment, pending further clinical studies.

Keywords: Bioassay; *Pediculus humanus;* Insecticide resistance; Pyrethroid; Iran

Introduction

Pediculosis is a common ectoparasitic infestation worldwide. Lice, which are brown or gray wingless insects, have been spread through human migration for thousands of years. They have a soft, relatively leathery, dorsoventrally flattened body. Both males and females can feed at any time of day or night. Human lice are found in all parts of the world, but more frequently occur in temperate regions. Although improvements in living conditions have reduced the prevalence of body lice (*Pediculus humanus humanus*) in many societies, infestations remain a global concern (1–3). Body lice are more resilient to environmental conditions than head lice and can survive for over 72 hours off a human host (3, 5, 6).

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Despite advancements in personal care products and hygiene practices, the prevalence of body lice is increasing in developing countries, particularly among the growing homeless population. Body lice are typically found in the fibers, seams, and folds of clothing, especially in undergarments that are worn close to the body (4, 5). The parasite leaves the clothes to feed on the blood of its host, which is why it is sometimes referred to as a clothes louse. This process of leaving the clothes and returning to the body's surface occurs repeatedly (4, 6, 7). Individuals infested with body lice for an extended period may experience changes in their skin, becoming mottled and hardened, leading to a condition known as vagrant/vagabond disease. The bites can cause systemic symptoms such as fatigue, irritability and lethargy, as well as severe pruritus (itching) due to an allergic reaction (8). Body lice are vectors of several dangerous diseases, including epidemic typhus, recurrent epidemic fever and trench fever (2, 4, 5, 8–21).

Body lice are more common in situations that follow natural disasters or wars, as these events often lead to crowded living conditions. They are also frequently found in communal environments, such as drug addiction treatment centers. To effectively treat body lice infestations, it is important to improve personal hygiene. This includes bathing regularly, shaving excess body hair and washing lice-infested clothing, bedding, and towels in hot water (at least 55 ˚C). Additionally, ironing affected items and using pediculicide medications can help eliminate the infestation (22). Studies have indicated that lice around the world have developed resistance to several treatments, including DDT, lindane, permethrin, malathion, carbaryl and ivermectin (14, 23–42). However, no resistance has been reported to date for spinosad, dimeticone, isopropyl myristate, 1, 2-octanediol, or benzyl alcohol (28). Permethrin is considered safe for mammals and is frequently used to treat lice infestations. Nonetheless, various studies have identified resistance to permethrin at both the molecular and clinical levels (43–57). The susceptibility status of the body louse to deltamethrin has been evaluated in laboratory studies. Deltamethrin demonstrated the highest "knockdown" effect among tested insecticides (including permethrin, malathion, fenitrothion and dieldrin), meaning it was the most effective at quickly incapacitating and killing body lice. However, resistance to deltamethrin has been reported in some louse populations, often associated with cross-resistance to other pyrethroids like permethrin and sumithrin (51, 58). This laboratory-based bioassay study was conducted to evaluate the efficacy of the synthetic pyrethroid deltamethrin against body lice.

Materials and Methods

Body lice were collected from the Yaghmorali addiction treatment camp, located in Urmia City, West Azerbaijan Province (37.55°N, 45.08°E), in 2024 (Fig. 1).

The infested individuals reported no prior exposure to insecticides. A total of 504 lice were collected, but only 372 undamaged adult male and female lice, which showed no signs of injury such as broken legs or crushing, were selected for testing. The time between collecting the lice from clothing and starting the tests was less than one hour. Tests were conducted in the laboratory of Urmia University of Medical Sciences, located within a 4-kilometer radius of the sample collection site.

The contact toxicity of deltamethrin was assessed using a standard World Health Organization (WHO) filter paper contact bioassay (59). Specifically, WHO has suggested using a concentration of 0.025% deltamethrin for these tests.

In this study, a serial dilution was prepared. For the ex vivo pediculicide assay, filter papers (Whatman No. 1) were treated with 1 ml of various concentrations of deltamethrin (97% technical grade) dissolved in acetone (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, 1.28 and

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2.56 ppm). After drying for 24 hours under laboratory conditions, the treated filter papers were placed in 5 cm Petri dishes, each containing ten body lice (either adults or third instar nymphs) exposed to each dose. According to the WHO protocols for testing insecticide susceptibility of lice, the diagnostic exposure time (the period during which lice are exposed to a standard concentration of an insecticide like deltamethrin) is determined based on baseline susceptibility data. In this study, an exposure time of 24 hours was considered to ensure a high probability of killing all routinely susceptible lice (59).

Each experiment was repeated three times. Acetone alone was used for the control group. The tests were conducted at a temperature of 28±1°C and 90±1% relative humidity, in darkness. Mortality was recorded after 24 hours by counting the number of dead or paralyzed lice, determined by observing the movements of their antennae, gut and legs, with or without external stimulation (59, 60). The vital signs of the lice were checked using a binocular loupe. Lethal concentrations of 50% and 90% (LC_{50} and LC_{90}) were calculated using Minitab software. Independent sample t-tests were used in IBM SPSS Statistics 2009 to compare mean mortality percentages between each deltamethrin concentration and the control, assessing the statistical significance of lethal effects and validating susceptibility differences among lice populations.

Results

Among the 315 individuals living in the camp, 287 (91%) were infested with body lice, with ages ranging from 15 to 76 years. Only 28 individuals were not infested at all. Among those infested, 184 people had between 1 and 25 lice, while 119 individuals had between 25 and 50 lice. Additionally, 41 people had more than 50 lice. The infection was observed in 72% of cases on the upper body and 28% on the lower body, leading to severe itching and wounds around the bite sites (Fig. 2). It is important to note that this camp was exclusively for men.

The contact toxicity of deltamethrin against body lice showed a significant difference in mean mortality depending on the concentration used. Specifically, the regression analysis revealed a positive correlation between chemical concentrations and probit mortality, indicating that body lice susceptibility to the treatment was dose dependent. As shown in Figure 3, mortality rates increased as the concentration of deltamethrin rose.

Probit analysis of the mortality rate of lice at different doses is presented in Table 1. The LC_{50} and LC_{90} values of deltamethrin against body lice were determined to be 0.11 ppm and 2.15 ppm, respectively. No mortality was observed in the control groups. The heterogeneity factors were determined to be less than 1, which confirms the validity of the data (see Table 1). Since the significance level is greater than 0.150, the coefficient of heterogeneity (calculated as the chi-square value divided by the degrees of freedom) is not used in calculating the confidence limits. If the coefficient of heterogeneity exceeds 1, the data plot should be examined, as this indicates that the data do not fit the model. However, considering the P-values of the model and the coefficient of heterogeneity being less than 1, we can conclude that the observed data fit well with the probit model.

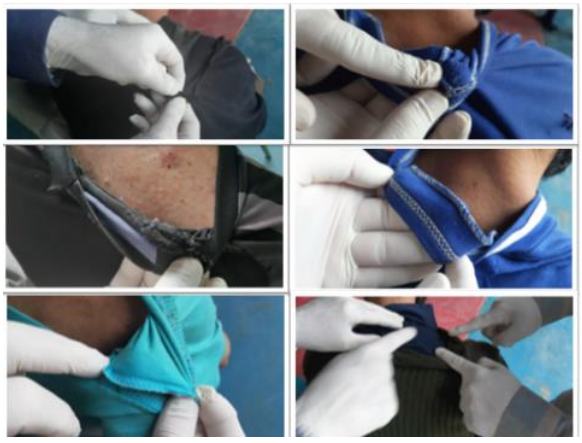

Fig. 1. Field collection of body lice from clothing seams in the Yaghmorali addiction treatment camp, Urmia, Iran (2024). The image illustrates the sampling sites and the collection procedure

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Table 1. Probit analysis of deltamethrin contact toxicity against adult and late-instar body lice (*Pediculus humanus humanus*) collected in Urmia, Iran (2024). LC_{50}, LC_{90}, 95% confidence limits, slope, and χ^2 goodness-of-fit values are presented

Pediculicide	A	B	LC_{50} (ppm) CI: (LCL- UCL)	LC_{90} (ppm) CI: (LCL- UCL)	χ^2 (df)	Sig
Deltamethrin	6.8806	1.0007	0.11 (0.07–0.15)	2.15 (1.52–2.86)	7	0.15 < sig*

A: y-intercept; B: the slope of the line; LC_{50}: lethal concentration causing 50% mortality; LC_{90}: lethal concentration causing 90% mortality; LCL: Lower Confidence Limit; UCL: Upper Confidence Limit; χ^2: heterogeneity about the regression line; df: degree of freedom; Sig: represents no heterogeneity in the tested population

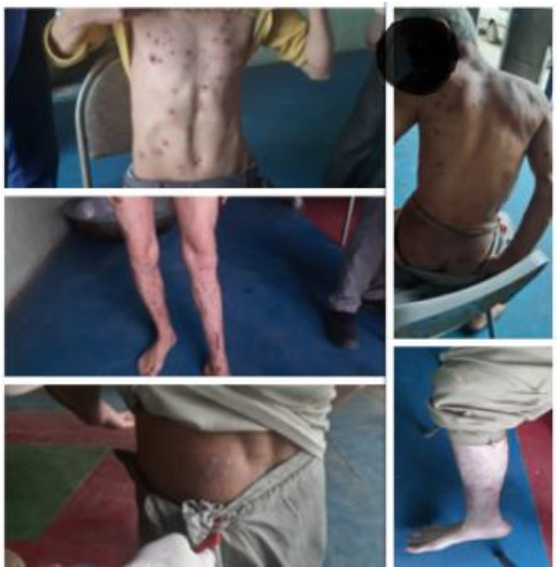

Fig. 2. Representative skin lesions associated with heavy body-louse infestation among residents of the same camp, showing excoriation and inflammation due to repeated bites

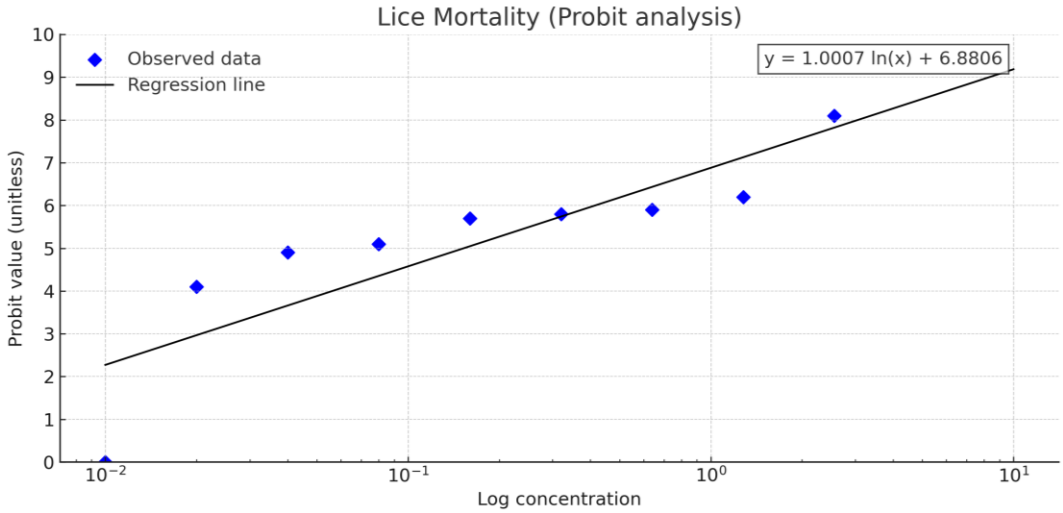

Fig. 3. Probit regression of mortality versus $\log_{10}$ (Deltamethrin concentration) for body lice from Urmia, Iran. Observed mortalities (points) and fitted probit line with 95% confidence limits are shown

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Discussion

Body lice have been reported in various populations, including homeless people, those affected by war, and in communal settings such as addiction treatment centers, refugee camps, prisons, barracks, and care facilities for the elderly and disabled (14).

Some studies have also documented cases of body lice among villagers and nomadic groups. For instance, Moradi et al. (41) found that 69% of residents in the Yaghmorali addiction treatment center were infested with body lice. In our study, we found that 91% of individuals were affected by body lice, indicating a significant infestation linked to poor hygiene conditions. The recent relocation of the camp contributed to the outbreak, as the quarantine facility for newcomers was non-functional and clean clothing was inadequately provided. Although bathrooms and laundry facilities were constructed, there was a shortage of detergents and hot water was unavailable before the relocation. Consequently, lice were discovered on the residents' clothing.

Individuals infested with body lice experienced severe skin complications, including intense itching. The lack of clean clothing, bedding and sleeping materials led to increased anxiety and irritability among those affected. A common issue in these settings is insufficient access to hygiene facilities, which facilitates the prevalence of body lice infestations. The importance of personal hygiene in preventing lice infestations is widely recognized today (62). It is crucial to promptly treat individuals infested with body lice to prevent widespread infestations among inmates and to reduce the risk of outbreaks of louse-borne diseases.

Pyrethroids are commonly used to treat pediculosis; however, their overuse has resulted in resistance among lice populations. Studies indicate widespread pyrethroid resistance in lice worldwide, with higher frequencies of the knockdown resistance (kdr) mutant alleles in countries where these compounds are widely used. The prevalence of homozygous kdr mutants suggests that there is increased selection pressure from insecticides due to the excessive use of these products. In Iran, these pyrethroids are primarily distributed for free by the health system, as they are more affordable compared to other effective treatment options. It has been recommended that, in addition to washing clothes infested with body lice, infested clothes, sheets, and bedding be sprayed with 5% deltamethrin.

This study determined the LC_{50} and LC_{90} values of deltamethrin using bioassay methods. Detecting resistance via bioassay is challenging and the lack of standardized protocols complicates cross-study comparisons (61). However, including a negative control group without mortality helps ensure the validity of the findings. Further optimization of in vitro rearing systems could enable new advances in the fight against lice infestations and lice-borne infections (62, 63). Due to difficulties in sustaining a permanent laboratory colony and the short lifespan of lice once removed from their host, there have been few published studies on the lice's resistance in laboratory settings. A study was conducted to evaluate the susceptibility of head lice to four insecticides: permethrin, sumithrin, deltamethrin and carbaryl. This assessment was performed using in vitro bioassays. In contrast, permethrin, sumithrin and carbaryl did not show significant differences in mortality rates, with their baseline confidence intervals being ten times lower than that of deltamethrin. These findings align with those of Mumcuoglu et al. (58), who assessed the susceptibility of head lice to malathion, deltamethrin, permethrin, fenitrothion and dieldrin. Their study demonstrated that deltamethrin produced the highest knockdown effect, followed by permethrin and malathion. Their findings are consistent with ours, confirming that the lice population we tested remains susceptible to deltamethrin. In comparative terms, deltamethrin tends to be more effective than other insecticides, but re-

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sistance development is a growing concern, especially due to repeated and improper use of pyrethroids that expose lice to sub-lethal doses, facilitating tolerance (64).

A limitation of this study was the sample size, which precluded a comparative efficacy analysis with other insecticides. As a result, we chose to focus exclusively on deltamethrin, since previous molecular investigations have shown that body lice are resistant to permethrin (43). The 102 collected specimens were nymphs for which we did not have a suitable insectarium for rearing and were excluded from the study. Another limitation of this study was that infected individuals were afraid that their secret would be exposed. We examined each person in a separate room. We also overcame this problem by providing clean clothes, free medication and detergent, and ensuring confidentiality.

Standardized WHO protocols ensured methodological rigor. Deltamethrin dose-response curves were generated in controlled conditions. Acetone-only controls confirmed effects were insecticide-attributable. Mortality was consistent across triplicates. Probit analysis yielded reliable LC_{50}/LC_{90} values (CI), with good data fit (heterogeneity factor <1, P>0.150). Triplicate experiments enhanced reliability. Trained personnel using binocular loupes minimized errors. Lice collection-to-testing time was <1 hour, reducing bias. Temperature, humidity and darkness were controlled. Only undamaged adult lice were used. Control mortality was <5% (or Abbott's-corrected when 5–20%).

In summary, while deltamethrin is currently one of the most effective insecticides against body lice, resistance is emerging and can be linked to cross-resistance with other pyrethroids, necessitating careful resistance monitoring and integrated pest management strategies (58). Deltamethrin has not been used in Iran for the control of head or body lice. In some countries, this insecticide is available to the public as a licensed product (65–67). The findings of this study indicate that the body lice population is susceptible to deltamethrin, suggesting that it could be a viable alternative to current treatments if necessary, provided it is available in an acceptable licensed formulation. In the context of the Iranian health system, resistance monitoring could be implemented through periodic bioassay testing of lice collected from different regions, coordinated by provincial Centers for Communicable Disease Control under the Ministry of Health. Routine surveillance in addiction treatment centers, shelters and other high-risk settings would allow early detection of resistance and timely adjustments to treatment guidelines.

Conclusions

This study demonstrates that the body louse population in Urmia is susceptible to deltamethrin, as evidenced by the low LC_{50} and LC_{90} values. Given the increasing resistance to permethrin and other common insecticides, deltamethrin offers a promising alternative for controlling body louse infestations, especially in general and vulnerable populations, making it a suitable candidate for randomized controlled trials (RCTs), particularly for controlling louse-borne diseases in emergency settings. However, the emergence of pyrethroid resistance globally highlights the need for continuous resistance surveillance, standardized bioassays and integrated management strategies. While laboratory bioassays confirm the efficacy of deltamethrin, clinical trials with licensed formulations are necessary to validate its practical use for lice control in Iran and similar areas. Improved personal hygiene, coupled with access to effective insecticides such as deltamethrin, remains essential to prevent the spread of lice and associated diseases.

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Ethical consideration

The ethical committee has ethically approved this research; IR.UMSU.REC.1404.167. Informed consent was obtained from the camp residents.

Conflict of interest statement

The authors declare there is no conflict of interest.

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