International Journal of Biology Sciences

ISSN Print: 2664-9926
ISSN Online: 2664-9934
NAAS Rating (2025): 4.82
IJBS 2025; 7(7): 200-205
www.biologyjournal.net
Received: 20-06-2025
Accepted: 24-07-2025

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Pediculus humanus capitis: A multidisciplinary review of infestation, impact, and intervention

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DOI: https://www.doi.org/10.33545/26649926.2025.v7.i7c.455

Abstract
Head lice infestations represent a notable public health issue, especially among children aged 5 to 13 years. These ectoparasites feed on human blood, causing intense itching and discomfort, which may lead to secondary bacterial infections due to scratching. Beyond physical symptoms, infestations carry significant social stigma, often resulting in embarrassment, isolation, and bullying factors that can negatively affect a child's mental health and academic performance. Treatment options include over-the-counter and prescription medications, as well as non-chemical methods like wet combing, though multiple applications are often necessary. Effective management requires comprehensive education for parents, teachers, and healthcare providers, emphasizing correct product use, repeated treatments, and routine head checks. Dispelling myths and discontinuing outdated no-nit policies in schools are also crucial. Promoting evidence-based, less disruptive approaches can improve health outcomes and reduce the social burden associated with lice infestations.

Keywords: Head lice, public health, secondary infection, social stigma

Introduction
Lice are obligatory, blood-feeding ectoparasites that infest a wide variety of birds and mammals; to date, over 550 species have been identified [1, 2]. Among these, three lice species specifically parasitize humans: *Pediculus humanus capitis* (head louse), *Pediculus humanus humanus* (body louse), and *Pthirus pubis* (pubic louse). Body lice have historically been significant vectors of serious diseases, including epidemic typhus, trench fever, and relapsing fever, thus posing major public health concerns [1]. Head lice infestations (*Pediculosis capitis*) are more prevalent, especially among children aged 5 to 13 years worldwide, and are an important public health challenge despite not being a direct disease vector [3,4,8,14]. This review explores the biology and life cycle of head lice, the influence of environmental and socioeconomic factors on infestation prevalence, genetic diversity, behavioural and social consequences, and the spectrum of treatment options ranging from chemical pediculicides to herbal remedies. Furthermore, it contextualizes the historical impact of lice on disease transmission and highlights future prospects for prevention and community health strategies. By synthesizing current research and practical knowledge, this review aims to guide effective management of head lice infestations and reduce their physical, psychological, and social burden.

Methodology
The present narrative review synthesizes scientific literature and public health reports on head lice infestations, focusing on epidemiology, clinical features, social impact, and treatment strategies. A comprehensive search was performed in databases including PubMed and Google Scholar using keywords such as head lice OR *Pediculus humanus capitis* AND lifecycle AND prevalence AND epidemiology AND social stigma AND school going children AND treatment. This review primarily focused on studies published within the last ten years to ensure relevance and reflect current trends in head lice research. Studies selected covered prevalence data, treatment efficacy, risk factors, and preventive measures, with an emphasis on research from developing countries and school-age populations. The review integrates data from experimental studies, clinical trials, and public health recommendations to present a balanced, up-to-date overview [4, 12, 23, 28, 29]. Figure. 1 illustrates the PRISMA flow diagram outlining the study selection process.

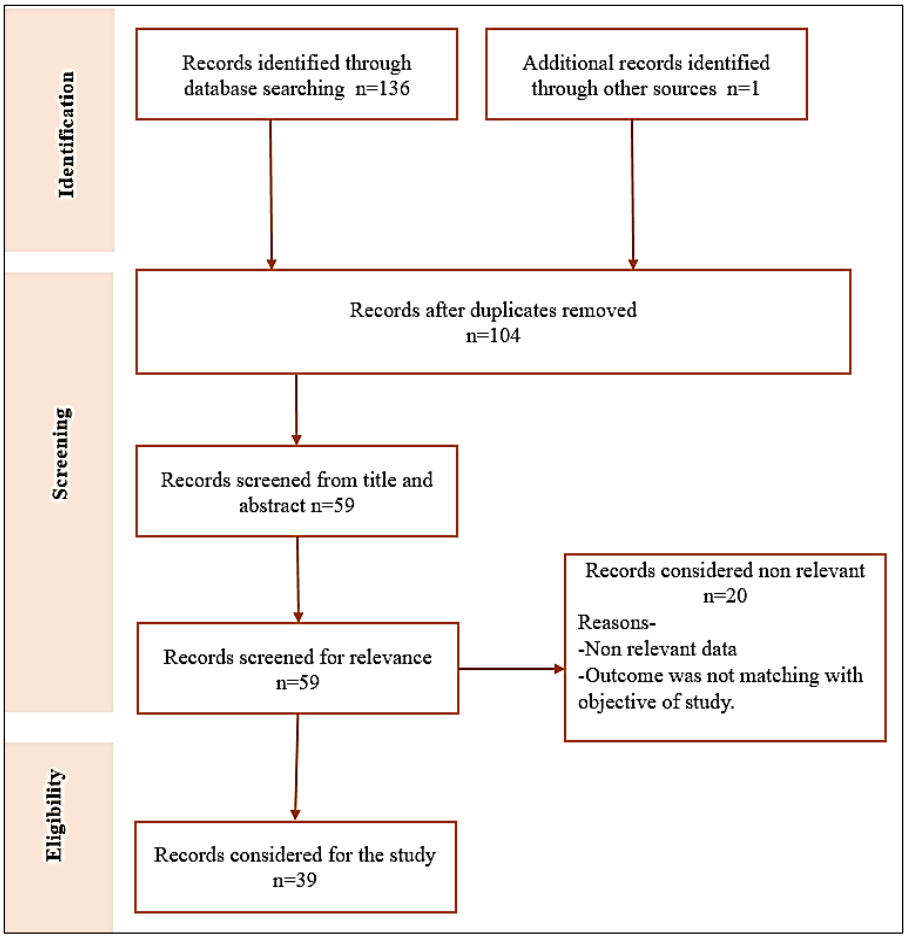

Fig 1: PRISMA Flowchart representing the methodology of the scoping review.

Dynamic life cycle of human head lice

The lifecycle of head lice is complex and closely tied to the host's scalp environment. It consists of three stages: egg (nit), nymph, and adult, (Figure. 2) each with specialized adaptations enabling survival and reproduction [7, 8].

Eggs or Nits: Female lice attach eggs firmly to hair shafts within 1-2 mm of the scalp where humidity and temperature are optimal for development. The eggs are elliptical and measure approximately 0.8-1 mm in length, encapsulated by a sticky nit sheath that prevents detachment. Eggs typically hatch within 6 to 10 days [8]. The female head louse can lay up to 10 eggs every 24 hours, usually at night, and can lay anywhere from 50 to 150 eggs in her lifetime, with the possibility of reaching 300 eggs. [8, 9].

Nymph Stage: Newly hatched nymphs resemble miniature adults but undergo three molts over 9 to 12 days before reaching maturity. During this phase, they are particularly vulnerable to environmental changes and treatments [9,10].

Adult Lice: Mature adults measure between 2 to 3 mm and feed multiple times daily on human blood. Females can lay approximately 10 eggs per day, ensuring continuation of the infestation cycle [10]. The morphology of female lice, such as the V-shaped posterior, helps them cling tightly to hair during egg laying, which complicates nit removal [8]. Adults prefer dark, warm regions of the scalp, such as behind the ears and at the nape of the neck, which are ideal microhabitats for survival [11].

Fig 2: Developmental Progression of Hatched Eggs (A to E) in Control Groups (Distilled Water)

Fig 3: Head lice infestation in young women showing (A) multiple lice and nits, (B) blood- feeding lice viewed via trichoscope**.**

Behavioural adaptations and survival strategies

Head lice exhibit behavioural patterns that optimize their survival and reproduction on the host. They are negatively phototaxis and tend to avoid light, spending most of their time nestled close to the scalp to maintain moisture and avoid detection [11, 12]. Their feeding behaviour involves using specialized mouthparts to pierce the skin and inject saliva containing anticoagulants, facilitating blood extraction [6]. Lice can survive temporary water immersion by tightly gripping the hair shafts and minimizing respiration, which is crucial during activities like bathing or swimming. This physiological adaptation complicates eradication efforts that rely solely on washing or water immersion [12].

Influence of climate and geography

Climate and geography significantly influence head lice prevalence. Studies from Ardabil province, Iran, demonstrate that infestation rates rise during autumn due to cooler temperatures and the use of warm clothing, which promote closer head contact among schoolchildren [15]. Variations in altitude and temperature also affect lice survival and transmission rates. These findings underscore the need for seasonally adjusted lice management strategies in different geographic regions [15].

Genetic diversity and resistance mechanisms

Genetic studies reveal considerable diversity among global head lice populations, with multiple clades reflecting both ancient and recent human migrations [16, 17]. Genetic markers have identified two primary clades with subpopulations showing regional specificity [16]. Of critical public health concern is the emergence of knockdown resistance (kdr) mutations in the lice voltage-sensitive sodium channel gene, which confer resistance to widely used pyrethroid insecticides such as permethrin [18]. The increasing frequency of these mutations in countries like Thailand suggests the need for continuous monitoring and the development of alternative treatments [18].

Socioeconomic and personal hygiene factors

Head lice infestations disproportionately affect children in low socioeconomic settings with overcrowded living conditions and limited access to hygiene resources. Rural residence, large families, and lower parental education are correlated with higher infestation rates [19-22, 24, 25]. Personal factors such as hair length, thickness, and texture also influence lice retention, with long, thick hair offering more niches for lice to cling to and reproduce [20]. Regular hair washing and combing remain critical preventative measures in controlling infestation [19].

Transmission and re-infestation

Transmission primarily occurs via direct head-to-head contact, common in school and daycare environments. Indirect transmission through shared personal items such as combs, hats, and headphones is also documented but less frequent [5, 19, 21, 23]. Re-infestation remains a significant challenge, often caused by incomplete nit removal or repeated exposure to infested contacts or environments. Effective control requires treating all affected individuals and educating families to prevent reinfestation [26, 27].

Social impact and psychological effects

Beyond physical discomfort, head lice infestations lead tonotable social stigma, bullying, and psychological distress among children [4, 13, 28]. The associated embarrassment and fear of exclusion can reduce self-esteem and cause school absenteeism. Parents may delay treatment due to stigma, exacerbating infestation duration. Public health education and community support are essential to combat misconceptions, reduce stigma, and promote timely treatment [28, 29].

Treatment options

Non-Chemical Methods

Mechanical removal of lice and nits using fine-toothed combs remains a cornerstone of treatment, especially in light of growing insecticide resistance. Wet combing, or bug-busting, involves systematic combing of damp hair every 3 to 4 days for two weeks, exceeding the lice egg incubation period to prevent maturation [29, 30, 31, 32]. Hot air devices are emerging as safe, chemical-free alternatives [33].

Chemical Pediculicides

Traditional pediculicides include permethrin, malathion, and lindane, which target the lice nervous system. Their efficacy depends on proper application and compliance; treatment

failure is commonly due to improper use or reinfestation rather than resistance, though resistance is increasing [31]. Application guidelines vary, with repeat treatments necessary to kill newly hatched lice (Table 1).

Table 1: Chemical agents for head lice treatment

Chemical Agents	Mode of Action	Side Effects	Usage Instruction	References
Permethrin	Inhibits the repolarization of sodium channels, resulting in respiratory failure and the mortality of lice.	Muscle spasms, convulsions, restlessness, and impaired coordination.	Apply the 1% cream rinse to both the hair and scalp, allowing it to remain for a duration of 10 minutes before rinsing thoroughly. The effects will persist for a period of two weeks. It is advisable to repeat this process after 7 to 10 days.	[34,35]
Malathion	A cholinesterase inhibitor results in the buildup of acetylcholine, which ultimately leads to the mortality of both lice and their eggs.	The substance exhibits a high level of flammability, poses a risk of respiratory depression upon ingestion, has an unpleasant odor, and can cause irritation to the skin and eyes	Apply a 0.5% lotion to dry hair and allow it to air dry. After 8 to 12 hours, rinse the lotion out. If live lice remain, repeat the process in 7 to 9 days.	[34]
Lindane	Gamma-aminobutyric acid inhibitor causing stimulation of the central nervous system and respiratory failure.	Potential neurotoxic effects, suppression of bone marrow function, contraindications for pregnant individuals, seizure disorders, and hypersensitivity to the product.	Apply 1% shampoo to dry hair and allow it to sit for 10 minutes before rinsing. Leave the lotion on overnight and rinse it off the following morning. This process should be repeated every 7 to 10 days	[34]

Herbal and Natural Remedies

Herbal treatments have gained popularity as alternatives due to concerns over chemical toxicity and resistance. Custard apple seed extract has been shown to be as effective as permethrin in clinical trials [36, 37]. *Pongamia pinnata* leaf extracts demonstrate substantial anti-lice effects, especially in preventing nymph development [38]. Neem seed extract shampoos block oxygen to lice eggs, inhibiting hatching after just a 5-minute treatment [39].

Future prospects and community health efforts

Innovative approaches including electronic lice combs, heat therapy, and natural repellents provide safer and potentially more effective options [34]. Mobile applications and online platforms enhance detection accuracy and access to treatment advice. Community programs featuring education, stigma reduction, and support groups are critical for managing outbreaks and improving mental health outcomes [28, 29]. Consistent public health policies and collaborative efforts between schools, healthcare providers, and families are essential to sustainably control head lice infestations.

Conclusion

An integrated approach to head lice management combining thorough mechanical removal, judicious use of chemical or herbal treatments, and sustained community education is necessary for effective control. Repeated treatment applications and family-wide checks prevent reinfestation.

Addressing the social stigma associated with pediculosis is essential to encourage timely treatment and reduce school exclusion. Ongoing research into resistance patterns and novel therapies promises to improve future management strategies. Through coordinated efforts, head lice infestations can be managed more effectively, minimizing their physical and psychosocial impacts on affected individuals and communities.

Acknowledgements
We appreciate the support from the Institute and management of Ramniranjan Jhunjhunwala College, Mumbai. We are also grateful for the valuable insights and suggestions provided by my guide.

Conflict of interest
Not available.

Financial support
Not available.

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