LINK MEDICAL INTERFACE

JHWCR

Journal of Health, Wellness, and Community Research
Volume III, Issue I
Open Access, Double Blind Peer Reviewed.
Web: https://jhwcr.com, **ISSN**: 3007-0570
DOI: https://doi.org/10.61919/kqvea744

Article

Malaria: A Rising Health Concern in District Lakki Marwat, Khyber Pakhtunkhwa, Pakistan

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Cite this Article

Received	2025-03-11
Revised	2025-03-21
Accepted	2025-03-24
Published	2025-03-27
Authors' Contributions	All authors contributed equally to the conduct of this study.
Conflict of Interest	None declared
Data/supplements	Available on request.
Funding	None
Ethical Approval	Respective Ethical Review Board
Informed Consent	Obtained from all participants
Study Registration	
Acknowledgments	N/A

ABSTRACT

Background: Malaria remains a leading public health concern globally and is particularly endemic in Pakistan, where regional data on pediatric malaria prevalence are limited. Despite control efforts, children under five years remain the most vulnerable group, often due to weak immunity, environmental exposure, and inadequate health infrastructure. Understanding localized epidemiology is critical to improving targeted interventions in underserved areas such as District Lakki Marwat, Khyber Pakhtunkhwa. **Objective**: This study aimed to assess the prevalence and species distribution of Plasmodium infections among children in District Lakki Marwat using microscopy and rapid diagnostic testing, with the goal of informing future control and prevention strategies. **Methods**: A hospital-based cross-sectional survey was conducted involving malaria-suspected children aged ≤10 years (n = 815). Inclusion criteria included febrile illness or clinical suspicion of malaria, and exclusion criteria were prior anti-malarial treatment within the last two weeks. Blood samples were analyzed using microscopy and rapid diagnostic tests (RDTs) to identify P. vivax and P. falciparum. Ethical approval was obtained from the Department of Pharmacy, Kohat University of Science and Technology, in accordance with the Declaration of Helsinki. Data were analyzed using SPSS v27, applying descriptive statistics and chi-square tests to assess associations between infection status and demographic variables. **Results**: Among 815 children screened, 627 (76.93%) tested positive for malaria. Microscopy identified 406 (49.8%) positive cases, while RDTs detected 221 (27.1%) cases. P. vivax was the predominant species (98.72%), with a significantly higher infection rate in male children (81.98%) compared to females (69.57%, $p < 0.001$). The highest prevalence was observed in the 1–4-year age group and during the summer season, indicating environmental and behavioral risk factors. **Conclusion**: The study highlights a critically high prevalence of pediatric malaria in District Lakki Marwat, predominantly due to P. vivax. These findings underscore the need for intensified vector control, enhanced diagnostic accuracy, and public health education in endemic rural regions. Strengthening seasonal surveillance and integrating rapid and molecular diagnostic approaches are essential for early detection and intervention, particularly among vulnerable pediatric populations.

Keywords: Plasmodium vivax; Plasmodium falciparum; Malaria Diagnosis; Pediatric Malaria; Microscopy; Rapid Diagnostic Tests; Prevalence

INTRODUCTION

Malaria remains a critical public health issue in Pakistan, particularly in less developed and rural regions where healthcare infrastructure and vector control measures are limited. Despite being preventable and treatable, malaria continues to cause approximately 881,000 deaths annually, with nearly 90% of fatalities occurring in children under the age of five (1). Globally, between 300 and 500 million people are affected by malaria each year (1), yet its burden is disproportionately higher in low-income countries due to environmental, socio-economic, and healthcare disparities. The disease is caused by protozoan parasites of the genus Plasmodium, primarily P. falciparum and P. vivax, along with less common species such as P. malariae and P. ovale, each differing in morphology and clinical manifestation (2). Among these, P. falciparum is known for its potential to cause

severe illness and death, yet in malaria-endemic regions, its infections often remain asymptomatic. These silent carriers serve as reservoirs for continued transmission through Anopheles mosquitoes (3), contributing to persistent community-level infectivity.

Clinical symptoms of malaria are broad and non-specific, including fever, chills, joint pain, hemolytic anemia, hypotension, and in severe cases, seizures and organ dysfunction (4,5). The vector responsible for transmitting malaria is the female Anopheles mosquito, notably species such as Anopheles arabinoses and Anopheles gambiae, which thrive in warm, humid climates with standing water—conditions commonly found in Pakistan due to monsoon rains, irrigation systems, and extensive agricultural practices (6). At macro levels, climate plays a substantial role in determining malaria risk, while at micro-ecological levels, vector behavior, access to hosts for blood meals, and the availability of water bodies influence the localized spread of the disease (7). Mosquitoes oscillate between oviposition and blood feeding, and the uneven distribution of human and environmental resources shapes their feeding patterns and, consequently, disease transmission.

Diagnosis of malaria is primarily confirmed through blood analysis, with microscopic examination of stained blood films remaining the gold standard due to its sensitivity and ability to detect parasite species and quantify parasitemia (8). Although rapid diagnostic tests (RDTs) have improved detection speed by identifying specific antigens like histidine-rich protein-2 or parasite-specific lactate dehydrogenase, they may yield false negatives in cases of high parasitemia, thus necessitating confirmatory microscopy (9). Polymerase chain reaction (PCR)-based assays are more sensitive and specific but are often inaccessible in resource-limited settings. Antibody detection is generally reserved for epidemiological surveys rather than clinical diagnosis. The simplicity and accessibility of peripheral smear testing make it an indispensable tool in malaria surveillance and management (9).

The burden of malaria is not uniformly distributed, with vulnerability often varying even among households in the same locality, influenced by factors such as substandard housing, lack of education, and limited access to healthcare services (11). School-aged children, particularly in endemic regions, represent a unique demographic that can contribute to malaria control through education. Health education programs tailored to children have shown promise in raising awareness and improving community-level practices regarding malaria prevention (12,13,14). However, the implementation of such programs varies by region and is often dependent on state-level health initiatives. Chemoprophylaxis remains a key preventive strategy for travelers to endemic areas, and stringent screening of blood donors is essential due to the potential for transfusion-transmitted malaria (15).

Given the high endemicity of malaria in specific regions of Pakistan and the disproportionately high burden among children, there remains a critical need to investigate localized prevalence patterns. The district of Lakki Marwat, characterized by its rural setting and environmental conditions favorable to mosquito proliferation, lacks sufficient epidemiological data on pediatric malaria cases. Moreover, despite global efforts, data delineating the frequency of specific Plasmodium species among infected children in this region remain scarce. The current study, therefore, aims to assess the prevalence of malaria among children in district Lakki Marwat and to determine the frequency distribution of P. falciparum and P. vivax infections. The findings are expected to contribute to targeted public health strategies and enhance disease surveillance systems in malaria-endemic zones. The primary research question guiding this investigation is: What is the prevalence of malaria among children in district Lakki Marwat, and what is the species-specific frequency of P. falciparum and P. vivax infections in this population?

MATERIAL AND METHODS

This hospital-based descriptive cross-sectional study was conducted in District Lakki Marwat, located in the southern region of Khyber Pakhtunkhwa, Pakistan. The region experiences a semi-arid climate with high temperatures and seasonal sandstorms, creating conditions conducive to vector-borne diseases such as malaria (16,17). The study aimed to determine the prevalence of Plasmodium falciparum and Plasmodium vivax infections among children aged ten years or younger, residing within the district. A total of 815 children suspected of having malaria were recruited from two major hospitals in the district. Inclusion criteria comprised children up to ten years of age presenting with clinical suspicion of malaria, while individuals older than ten years, or those with co-existing severe illnesses that could confound clinical assessments, were excluded. Prior to data and blood sample collection, written informed consent was obtained from the parents or legal guardians of each participant, and ethical approval was granted by the Department of Pharmacy, Kohat University of Science and Technology, in compliance with the Declaration of Helsinki. All information was anonymized and handled confidentially to ensure the privacy of participants.

The primary outcome of the study was the prevalence rate of malaria, calculated using the formula: Prevalence rate = (Number of patients with malaria / Total number of patients diagnosed) × 100. Secondary outcomes included the identification of the Plasmodium species involved and assessment of diagnostic agreement between microscopic examination and rapid diagnostic testing (RDT). Blood samples were obtained through venipuncture, and both thick and thin blood smears were prepared for microscopic analysis. Thin smears were fixed with methanol, stained with Giemsa diluted in distilled water, and examined under a microscope using immersion oil at 100x magnification. Standard morphological keys were used to identify different developmental stages of P. vivax and P. falciparum, and each slide was evaluated for 10–20 minutes (18). Additionally, RDTs were performed on all samples to detect malaria antigens based on antigen–antibody interactions, allowing rapid identification of infection, particularly in field settings where microscopy may not be feasible (19,20).

Data were analyzed using SPSS version 27. Descriptive statistics were used to summarize demographic and clinical characteristics, and prevalence rates were expressed as percentages. Any missing data were addressed using listwise deletion.

Potential confounding factors, such as patient age, gender, and seasonality of infection, were considered during analysis,

  DOI: https://doi.org/10.61919/kqvea744

although no formal multivariate regression or sensitivity analyses were performed due to the descriptive nature of the study. This structured methodology ensured the study's reproducibility and provided reliable baseline data on the burden of malaria in a vulnerable pediatric population in a resource-limited, high-risk region.

RESULTS

Out of the total 815 suspected pediatric cases screened for malaria, 627 (76.93%) tested positive for Plasmodium species (Table 1). The monthly distribution revealed the highest number of positive cases in July, with 259 (41.31%) out of 286 samples testing positive, followed by June with 196 (31.25%) out of 247 samples. The prevalence declined significantly in the subsequent months, with the lowest observed in November (9 positive cases out of 29, or 1.43%). This clear seasonal trend indicates peak malaria transmission during the mid-summer months.

Table 1. Month-wise prevalence of malaria among children in District Lakki Marwat

Month	Total Samples (n)	Positive Cases (n)	Prevalence (%)
June	247	196	31.25
July	286	259	41.31
August	105	74	11.80
September	61	45	7.17
October	87	44	7.01
November	29	9	1.43
Total	815	627	76.93

Gender-wise analysis revealed a higher prevalence among male children. Of the 483 male samples, 396 (81.98%) tested positive, compared to 231 (69.57%) out of 332 female samples. The observed difference in prevalence was statistically significant (χ^2 = 15.74, p < 0.001), suggesting a higher exposure or vulnerability among male children in the study area.

Table 2. Malaria prevalence according to sex among children

Sex	Total Samples (n)	Positive Cases (n)	Prevalence (%)
Male	483	396	81.98
Female	332	231	69.57
Total	815	627	76.93

Age-stratified data revealed that P. vivax infection was most prevalent among children aged 1–4 years, whereas P. falciparum cases peaked in the 5–8 years group. This suggests a possible age-related susceptibility or differing behavioral/environmental exposures. Statistical comparison across age groups showed a significant association between age and Plasmodium species prevalence (χ^2 = 12.46, p = 0.006).

Table 3. Age-wise prevalence of malaria and distribution by species

Age Group (Years)	Total Cases (n)	P. vivax (n)	P. falciparum (n)	Mixed (n)	Total Positive (n)	Prevalence (%)
<1	73	43	9	1	53	72.60
1–4	282	196	18	3	217	76.95
5–8	286	169	49	6	224	78.32
9–10	174	103	23	7	133	76.44
Total	815	511	99	17	627	76.93

Seasonal distribution analysis showed a significantly higher malaria prevalence in summer (April–October), where 529 (82.91%) of 638 samples were positive, compared to 98 (55.36%) of 177 samples collected during the winter (November–March). This difference was statistically significant (χ^2 = 43.27, p < 0.001), affirming the impact of climatic conditions on malaria transmission dynamics in the region.

Table 4. Season-wise prevalence of malaria

Season	Total Samples (n)	Positive Cases (n)	Prevalence (%)
Summer	638	529	82.91
Winter	177	98	55.36
Total	815	627	76.93

The data clearly show that malaria remains a major pediatric health burden in District Lakki Marwat, particularly during summer months. The predominance of P. vivax infections in younger children and P. falciparum in slightly older age groups could reflect differences in immunity acquisition or exposure

  DOI: https://doi.org/10.61919/kqvea744

patterns. The significant male predominance might indicate behavioral or societal factors influencing exposure risks.

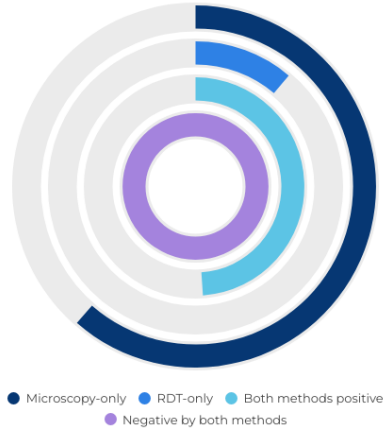

Figure 1 Diagnostic Method Agreement Between Microscopy and Rapid Diagnostic Test (RDT)

These findings underscore the need for targeted vector control and public health interventions, especially before and during the peak transmission season. No unexpected trends were observed, although the high percentage of mixed infections (2.7%) may warrant further molecular investigation to assess co-transmission dynamics.

DISCUSSION:

Malaria continues to pose a significant public health challenge in Pakistan, with substantial regional variability in prevalence and species distribution. Although efforts have been made to curb transmission, epidemiological data remain fragmented, particularly at the district level (21). National reports suggest that Plasmodium vivax accounts for over 70% of malaria infections, with P. falciparum contributing to a smaller proportion of cases (24). The current study was designed to address the gap in localized epidemiological data by assessing the prevalence of malaria among children in District Lakki Marwat, a region in southern Khyber Pakhtunkhwa that has not been extensively studied. Our findings contribute critical insights into species distribution, seasonal trends, and demographic susceptibilities, reinforcing patterns observed in adjacent districts while also uncovering important contextual differences.

Among the 815 suspected pediatric malaria cases screened in this study, 627 (76.93%) tested positive, underscoring the hyperendemic nature of the region. Consistent with national trends, P. vivax was the dominant species, detected in 619 (98.72%) of the positive cases, while P. falciparum was identified in only 8 (1.27%) cases. These findings align closely with prior studies from districts such as Bannu and Mardan, which also reported a predominant burden of P. vivax and an absence of P. ovale, P. malariae, or mixed infections (25,26). This further supports earlier claims that P. ovale and P. malariae are either absent or extremely rare in Pakistan (26). In comparison to Bannu, where P. vivax prevalence was 22.6% and P. falciparum 3.04% (25), the current study reports a markedly higher overall infection rate, possibly due to the longer hot season, more stagnant water sources, or environmental factors conducive to Anopheles mosquito breeding in Lakki Marwat.

The gender-specific analysis revealed a higher prevalence in male children (81.98%) compared to females (69.57%), a statistically significant finding. These results are in agreement with similar research conducted in District Kohat, where males exhibited a 95% positivity rate compared to 61.34% among females (27). The increased risk in males is likely attributed to greater exposure to mosquito vectors due to outdoor activities and agricultural labor, especially during dusk and dawn when Anopheles mosquitoes are most active. Culturally, male children may spend more time outdoors and are less likely to be dressed in protective clothing, unlike females who are often more sheltered and covered due to traditional norms. This behavioral exposure factor has been widely documented in other endemic regions and remains a key consideration in targeted prevention strategies.

Age-wise distribution highlighted that the 1–4 year age group carried the highest burden of P. vivax infections (322 cases, 51.35%), while P. falciparum was more prevalent in children aged 5–8 years, albeit in much smaller numbers (5 cases, 0.79%). These patterns mirror findings from another study in southern Khyber Pakhtunkhwa, which reported the highest malaria rates in children aged 1–5 years (58.11%) (28). The heightened vulnerability in younger age groups may reflect immunological naivety, greater mosquito exposure during outdoor play, and weaker immune responses. The limited presence of P. falciparum could also be a result of its more aggressive course, leading to earlier clinical presentations and potential underdiagnosis if cases are referred elsewhere for more urgent care. These findings suggest the need for enhanced surveillance and preventive measures targeting preschool-aged children in high-burden areas.

Seasonal trends in this study were particularly pronounced. Malaria prevalence peaked during the summer months of June and July, with July accounting for 259 positive cases (41.31%) and June for 196 (31.25%). This spike corresponds with increased vector activity due to higher temperatures, humidity, and the formation of stagnant water bodies that serve as breeding grounds for Anopheles mosquitoes (30). A comparable study from District Kharan in Baluchistan reported a similarly high P. vivax prevalence (88.15%) in July, reinforcing the seasonal transmission dynamics shared across regions despite differing climates and altitudes (29). The sharp decline in malaria cases during the winter months (98 cases; 55.36% prevalence) reflects reduced vector activity and emphasizes the necessity of seasonally adjusted intervention strategies. The seasonal disparity also underscores the utility of pre-emptive vector control and public health campaigns ahead of peak transmission periods. Clinically, the dominance of P. vivax has implications for treatment and surveillance, as this species is associated with recurrent infections due to dormant liver stages (hypnozoites), requiring radical cure regimens such as primaquine. In contrast, the relatively low prevalence of P. falciparum in this cohort may reduce the immediate burden of severe malaria complications but warrants continued monitoring due to its potential for drug resistance and higher mortality. The absence of mixed infections in this study could either reflect true epidemiological absence or limitations in diagnostic sensitivity, particularly if microscopy was used without molecular confirmation. Although microscopy remains the gold standard in many resource-limited settings, it

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is inherently operator-dependent and less sensitive for low-parasitemia or mixed-species infections.

This study offers several strengths, including a robust sample size, stratified demographic analysis, and integration with historical and regional data, providing a well-rounded picture of pediatric malaria in Lakki Marwat. However, limitations must be acknowledged. The reliance on microscopy and RDTs without PCR confirmation may limit species identification precision. The cross-sectional design restricts temporal causal inferences, and the sample was hospital-based, possibly skewing toward more symptomatic or severe cases, thus underrepresenting asymptomatic carriers in the community. Additionally, the findings are specific to a pediatric population and may not be generalizable to adults.

Future research should include longitudinal cohort studies to track seasonal transmission trends and relapse rates, particularly for P. vivax. Incorporating molecular diagnostic tools would enhance detection accuracy, especially in identifying submicroscopic or mixed-species infections. Community-based surveillance would further provide insight into asymptomatic reservoirs and transmission dynamics. Moreover, exploring vector density and behavior patterns in Lakki Marwat could inform targeted vector control interventions.

This study confirms a high prevalence of P. vivax malaria among children in District Lakki Marwat, with significant seasonal and demographic variation. The data align with prior regional studies and contribute to the broader understanding of malaria epidemiology in Pakistan. These findings highlight the urgent need for targeted malaria control programs, particularly during peak transmission seasons and in high-risk groups such as male and preschool-aged children. Addressing diagnostic limitations and expanding community-level research will be essential steps toward malaria elimination goals in the region.

CONCLUSION:

The findings of this study underscore a high burden of Plasmodium vivax-dominant malaria among children in District Lakki Marwat, Khyber Pakhtunkhwa, highlighting critical environmental, behavioral, and systemic risk factors such as high temperatures, stagnant water sources, lack of vector control measures, limited awareness, and inadequate diagnostic practices.

With a prevalence rate of 76.93% and a significant association with male sex and younger age groups, the study fulfills its objective of documenting local malaria epidemiology and informing targeted control strategies. The clinical implications are substantial, as delayed diagnosis and insufficient prevention efforts may contribute to recurrent infection, developmental delays in children, and increased healthcare burden.

From a public health perspective, the results stress the need for integrated malaria management that combines education, vector control, and timely treatment—especially in high-risk seasons. For researchers, the study reinforces the importance of region-specific surveillance, and future work should explore community-level asymptomatic reservoirs, vector dynamics, and molecular confirmation of species to guide elimination strategies.

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