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Flood Impact on Malaria Prevalence in district Nowshera, Khyber Pakhtunkhwa (KP) Pakistan

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ABSTRACT
Malaria is an important vector-borne disease transmitted through the bite of infected *Anopheles* mosquitoes. It is a climate-sensitive disease, and its transmission is strongly influenced by climatic factors, particularly flooding, in malaria-endemic regions. The present study aimed to determine the prevalence of malaria before and after flooding in the general population of District Nowshera, Khyber Pakhtunkhwa, Pakistan. A total of 10,381 suspected malaria cases were recorded from July to October 2022 from 14 healthcare centers across District Nowshera. Malaria was diagnosed using microscopy and rapid diagnostic tests (RDTs). Of the total suspected cases, 980 (9.44%) were confirmed positive for malaria. The prevalence of malaria was 8.72% before the flood and increased to 9.94% after the flood. *Plasmodium vivax* was the predominant species during both the pre-flood and post-flood periods, followed by *Plasmodium falciparum*, while mixed infections (*P. vivax* and *P. falciparum*) were recorded at the lowest frequency. Before the flood, malaria incidence was slightly higher among females, whereas after the flood, males showed a higher prevalence than females. Age-wise analysis revealed that the highest number of malaria cases occurred in individuals aged >15 years, followed by those aged 5–14 years, while the lowest prevalence was observed among children aged 0–4 years.

Keywords: Flooding, *Plasmodium Falciparum, Anopheles* Mosquitoes, Predominant Species, Microscopy

Introduction

Malaria remains one of the most significant global public health challenge because of its high morbidity and mortality, particularly in tropical and subtropical regions, where it imposes substantial social and economic burdens on vulnerable communities (Duguma et al., 2023; Al-Awadhi et al., 2021). It is a vector-borne disease caused by protozoan parasites of the genus Plasmodium and is transmitted to humans through the bite of infected female Anopheles mosquitoes (Escalante et al., 2019; Fikadu & Ashenafi, 2023). Five plasmodium species are known to infect humans, of which *Plasmodium falciparum* is the most pathogenic and is responsible for the majority of severe malaria cases and malaria-related deaths (Anwar, 2024; Zekar & Sharman, 2024). Following transmission, the parasite initially multiplies in the liver before invading red blood cells, leading to clinical manifestations such as fever, chills, headache, anemia, cerebral malaria, respiratory distress, multi organ dysfunction, and, in severe cases, death (Markwalter et al., 2024; Milner, 2018; Mousa et al., 2020). Infants under five years of age, pregnant women, individuals living with HIV/AIDS, and other immune compromised populations are particularly susceptible to malaria because of their reduced immunity (Abossie et al., 2020; Aliyo et al., 2024; Duguma et al., 2023).

Despite considerable progress in malaria prevention and control over the past two decades, malaria remains a major global health concern. According to the World Health Organization (WHO), approximately 263 million malaria cases were reported across 83 endemic countries in 2023, reflecting a resurgence in disease burden following recent setbacks in malaria control programmes (Obeagu & Obeagu, 2024). Earlier WHO reports estimated 241 million malaria cases and 627,000 malaria-related deaths worldwide in 2020, with children under five years accounting for the majority of fatalities (Duguma et al., 2023). Furthermore, the emergence of resistance to antimalarial drugs and insecticides, together with behavioral adaptations in mosquito vectors, has complicated malaria prevention and elimination efforts in endemic regions (Sharma & Awasthi, 2015;

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Escalante et al., 2019; Obeagu & Obeagu, 2024). Since malaria transmission varies considerably with geographical and environmental conditions, continuous epidemiological surveillance is essential for developing effective prevention and control strategies (Duguma et al., 2023; Woyessa et al., 2004).

Climate change has emerged as one of the principal drivers of the emergence and re-emergence of infectious diseases by increasing the frequency and intensity of extreme weather events, including floods, heavy rainfall, droughts, and heat waves (Intergovernmental Panel on Climate Change, 2021; El-Sayed & Kamel, 2020; Akhtar, 2020; Megersa & Luo, 2025; Romanello et al., 2021). These climatic changes have profound implications for public health by promoting the transmission of vector-borne diseases, malnutrition, respiratory illnesses, and other health conditions (Megersa & Luo, 2025; El-Sayed & Kamel, 2020; Romanello et al., 2021). Malaria is considered one of the most climate-sensitive vector-borne diseases because temperature, rainfall, and humidity directly influence mosquito survival, breeding, biting behaviour, parasite development, and transmission dynamics. Increased temperatures accelerate the mosquito life cycle and shorten the parasite's incubation period within the vector, whereas rainfall and stagnant water provide ideal breeding habitats for Anopheles mosquitoes (Megersa & Luo, 2025; Biswas, 2022; Egbendewe-Mondzozo et al., 2011; Mordecai et al., 2020).

Floods are among the most frequent and destructive natural disasters, particularly in developing countries. Besides causing loss of life, population displacement, and damage to infrastructure, floods facilitate the transmission of infectious diseases by contaminating water supplies, disrupting sanitation systems and healthcare services, and creating stagnant water bodies that serve as breeding sites for *Anopheles* mosquitoes (Khan et al., 2026; Acosta-España et al., 2024). Consequently, outbreaks of malaria, dengue fever, diarrhoeal diseases, leptospirosis, typhoid fever, hepatitis, and other infectious diseases commonly occur following flooding events (Tan et al., 2025; Asadgol et al., 2020). Disease transmission is further intensified by overcrowded temporary shelters with inadequate sanitation and limited access to healthcare services (Ahern et al., 2005).

Pakistan is highly vulnerable to flooding because of monsoon rainfall, river overflows, and changing climatic conditions (Khan et al., 2026; Neumayer et al., 2014). The devastating floods of 2022 were among the worst natural disasters in the country's history, inundating nearly one-third of Pakistan, displacing more than 33 million people, and causing 1,739 deaths. The floods severely damaged healthcare infrastructure and sanitation systems, resulting in widespread outbreaks of infectious diseases in the affected districts. According to the National Disease Surveillance Reports, more than 1.6 million malaria cases were reported following the floods, highlighting malaria as one of the major public health consequences of the disaster (Iqbal et al., 2023; Khan et al., 2026). District Nowshera in Khyber Pakhtunkhwa was particularly vulnerable to post-flood malaria outbreaks because of favorable environmental conditions for mosquito breeding and increased human exposure.

Despite the well-established association between flooding and malaria transmission, epidemiological information from flood-affected districts of Khyber Pakhtunkhwa remains limited. Most previous studies have relied on passive surveillance systems or have focused on other provinces, particularly Sindh, leaving important knowledge gaps regarding the burden of malaria and associated risk factors in flood-affected areas of District Nowshera (Iqbal et al., 2023; Noji, 2000). Therefore, post-flood surveillance is essential for assessing malaria prevalence, identifying vulnerable populations, and generating evidence to support effective disease prevention and vector control strategies during future flooding events.

Therefore, the present study aimed to evaluate the impact of the 2022 floods on malaria prevalence in District Nowshera, Khyber Pakhtunkhwa, Pakistan, using a post-flood surveillance approach. Specifically, the study assessed the distribution of malaria infections by determining the prevalence of Plasmodium species before and after the flood. In addition, gender-specific differences in malaria prevalence were investigated, and the distribution of malaria among different age groups was evaluated to better understand the epidemiological pattern of malaria in the flood-affected population.

Materials and Methods

Study Area

The study was conducted in District Nowshera, Khyber Pakhtunkhwa, Pakistan, to investigate the prevalence of malaria. The district is geographically located at 34.01625119884551° N and 71.98884376575045° E. According to the 2023 national census, District Nowshera has a population of 1,740,705 with 259,911 households. Administratively, the district is divided into three tehsils: Nowshera, Pabbi, and Jahangira. The district is served by a well-established healthcare network comprising District Headquarters (DHQ) Hospital, Rural Health Centers (RHCs), Basic Health Units (BHUs), Civil Dispensaries (CDs), Medical Teaching Institutions (MTIs), and numerous private healthcare facilities. Malaria surveillance data for the present study were collected from healthcare facilities distributed across the district. District Nowshera is traversed by the Kabul River, which originates in the Hindu Kush Mountains and extends approximately 700 km before joining the Indus River at Khairabad near Attock. The study encompassed malaria cases reported from communities located along the Kabul and Indus River systems across all three tehsils of District Nowshera, where environmental conditions are favorable for mosquito breeding and malaria transmission. The geographical location of the study area is presented in Figure 1.

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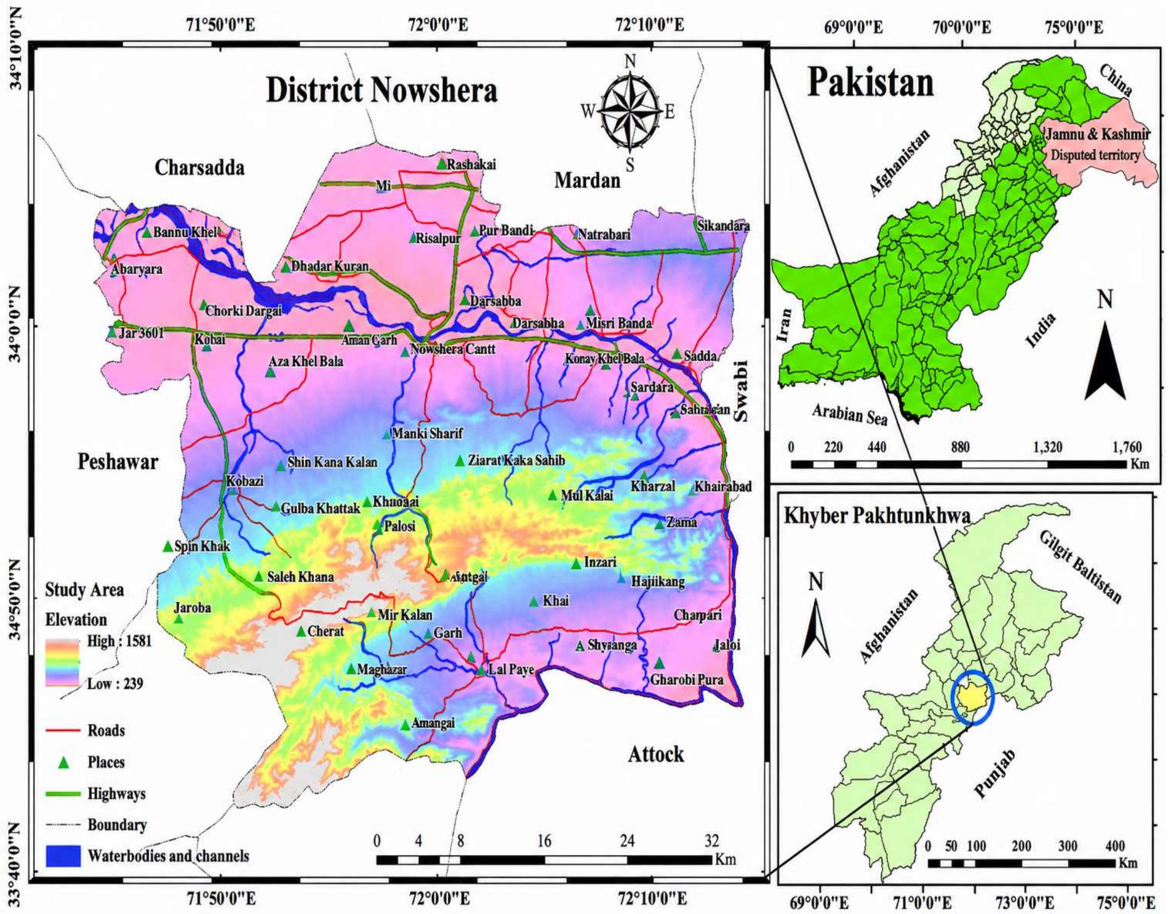

Figure 1. Map of district Nowshera Khyber Pakhtunkhwa (KP) Pakistan

Study Design and Data Collection

A retrospective post-flood surveillance study was conducted using malaria records collected from 14 healthcare facilities in District Nowshera, Khyber Pakhtunkhwa, Pakistan, between July and October 2022. Data were obtained from District Headquarters (DHQ) Hospital, Rural Health Centers (RHCs), Basic Health Units (BHUs), Category-D Hospitals, Civil Hospitals, and Civil Dispensaries (CDs) located across the three tehsils of the district. Information on confirmed malaria cases, patient demographics, and Plasmodium species was compiled and organized to assess the prevalence and distribution of malaria within the study population.

Study Population

The study population comprised patients with confirmed malaria who were diagnosed at the selected healthcare facilities during the study period. Demographic information was categorized according to gender, age group, and infecting Plasmodium species. For age-wise analysis, patients were classified into three categories: Category A (0–4 years), Category B (5–14 years), and Category C (>14 years).

Malaria Diagnosis

Malaria diagnosis at the selected healthcare facilities was performed using standard diagnostic procedures, including microscopic examination and rapid diagnostic tests (RDTs). Microscopic diagnosis was conducted using Giemsa-stained thick and thin

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blood smears for the detection and identification of Plasmodium species, whereas RDTs were used to detect malaria-specific antigens in blood samples. Records of laboratory-confirmed malaria cases and the corresponding Plasmodium species were retrieved from the healthcare facilities and used for prevalence analysis.

Statistical Analysis

The collected data were analyzed using Sigma Plot version 14.0. Descriptive statistics were used to summarize the data, and the results are presented as percentages and mean ± standard error of the mean (SEM). The prevalence of malaria before and after the flood was summarized in tabular form. Graphical presentations and percentage calculations were prepared using Microsoft Excel.

Results

Current Month-wise Prevalence

A total of 10,381 individuals suspected of malaria were screened at healthcare facilities located across different areas of District Nowshera between July and October 2022 to determine the prevalence of malaria before and after the flood. Among the suspected cases, 980 (9.44%) were confirmed positive for malaria, whereas 9,401 (90.56%) tested negative. The month-wise prevalence of malaria in District Nowshera is presented in figure 2 and Table 1.

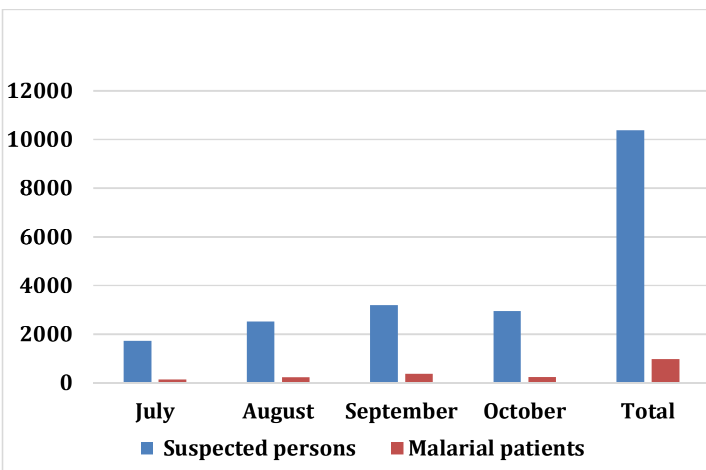

Figure 2. Month wise report of the prevalence of malaria

Table 1. Month wise report of the prevalence of malaria

Month wise		July	August	September	October	Total
Total Suspects		1727	2518	3191	2945	10381
Malarial patients		141	229	377	233	980
Gender-wise	Male	68	112	200	125	505
	Female	73	117	177	108	475
Specie-wise	*P. vivax*	139	226	364	218	947
	P. falciparum	2	3	10	15	30
	Mixed Spp.	0	0	3	0	3

Age-wise	0 – 4 year	17	8	21	15	61
	4 – 15 year	38	67	127	73	305
	15+ year	86	154	229	145	614

Species-wise Prevalence

The diagnostic results obtained through microscopy and rapid diagnostic tests (RDTs) showed that, among the 980 confirmed malaria cases, 947 (96.63%) were infected with Plasmodium vivax, 30 (3.06%) with Plasmodium falciparum, and 3 (0.31%) had mixed infections (*P. vivax* and *P. falciparum*). *Plasmodium vivax* was the predominant malaria parasite identified in the study population, followed by *P. falciparum*, whereas mixed infections were detected at a very low frequency. No cases of *P. malariae, P. ovale,* or *P. knowlesi* were detected during the study period. The species-wise distribution of malaria in District Nowshera is presented in Figure 3.

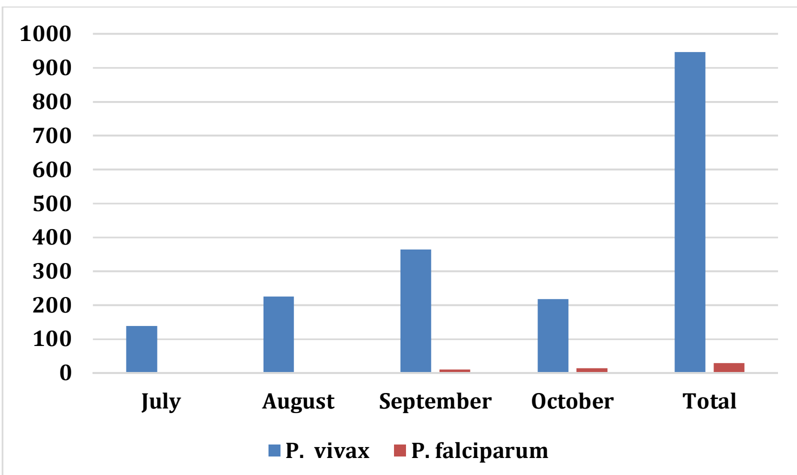

Figure 3. Species wise report of the prevalence of malaria

Gender-wise Prevalence

Gender-wise analysis revealed a slightly higher prevalence of malaria among males, with 505 (51.53%) confirmed cases, compared with 475 (48.47%) cases among females. The distribution of malaria cases according to gender is illustrated in Figure 4.

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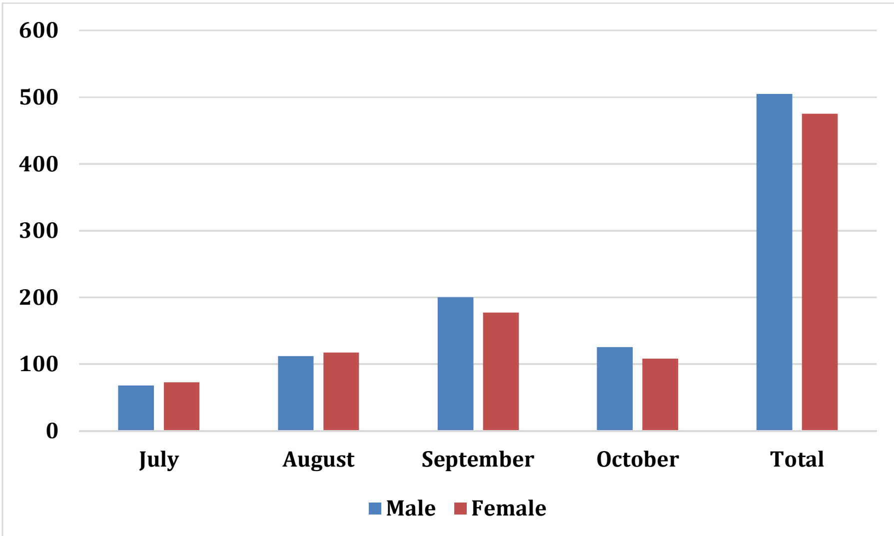

Figure 4. Gender wise prevalence of malaria in each month

Age-wise Prevalence

To evaluate age-specific prevalence, the study population was categorized into three age groups: Group A (0–4 years), Group B (5–14 years), and Group C (≥15 years). The highest prevalence of malaria was recorded in Group C (62.65%), followed by Group B (31.12%), whereas Group A (6.22%) showed the lowest prevalence. The age-wise distribution of malaria cases is presented in Figure 5.

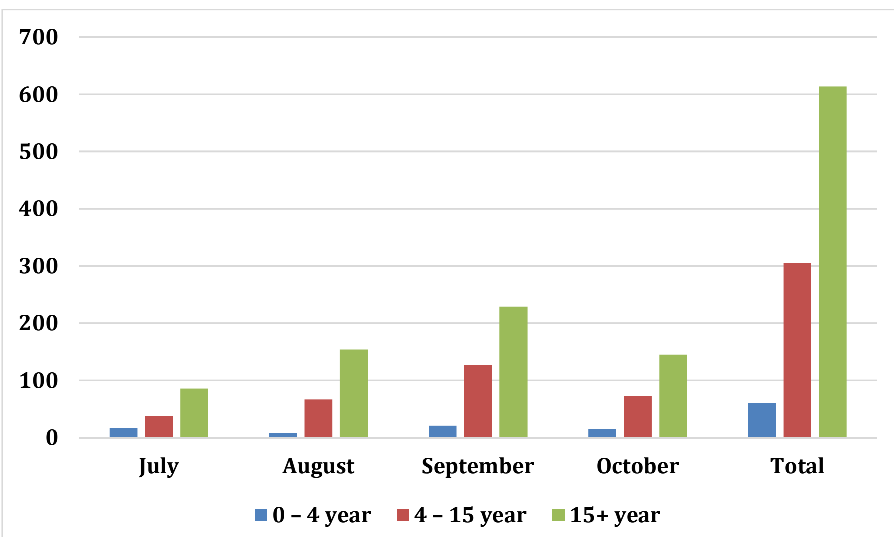

Figure 5. Age wise report of the prevalence of malaria

Prevalence of Malaria Before and After Flood

Pre-flood and Post-flood Overall Prevalence

A total of 4,245 suspected malaria cases were recorded before the flood (July–August 2022), of which 370 (8.72%) were confirmed positive for malaria. Following the flood (September–October 2022), 6,136 suspected cases were reported, among which 610 (9.94%) were confirmed positive. The descriptive statistical analysis (Mean ± SEM) of malaria prevalence before and after the flood is presented in Table 2.

Table 2. Statistical analysis (Mean ± SEM) of malaria prevalence before and after the flood

S: NO		Pre-Flood	Post-Flood
Months		July-August	September-October
Total Suspects		4245	6136
Malarial patients		370 (8.72%)	610 (9.94%)
Sex-wise	Male	12.86 ± 3.83	23.21 ± 11.23
	Female	13.57 ± 4.30	20.36 ± 10.51
Specie-wise	*P. vivax*	26.07 ± 7.93	41.57 ± 20.66
	P. falciparum	0.36 ± 0.25	1.79 ± 1.13
	Mixed Sp.	0 ± 0	0.21 ± 0.21
Age-wise	0 - 4	1.79 ± 1.13	2.57 ± 1.56
	14-May	7.50 ± 2.85	14.29 ± 7.38
	15+	17.14 ± 4.70	26.71 ± 12.70

Gender-wise Prevalence

Before the flood, 370 malaria cases were confirmed, including 180 (48.65%) males and 190 (51.35%) females, indicating a slightly higher prevalence among females. After the flood, 610 malaria cases were recorded, comprising 325 (53.28%) males and 285 (46.72%) females. These findings indicate that malaria prevalence shifted from being slightly higher among females before the flood to being higher among males after the flood. The gender-wise distribution of malaria cases before and after the flood is shown in Figure 6.

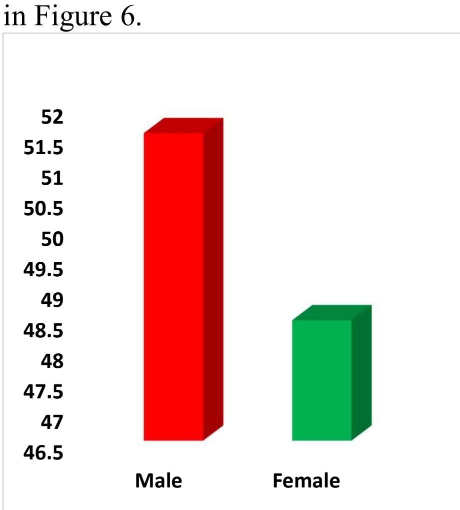

Figure 6. Gender wise prevalence of malaria

Species-wise Prevalence

Before the flood, 370 malaria cases were confirmed, of which 365 (98.65%) were caused by *P. vivax* and 5 (1.35%) by *P. falciparum*. No mixed infections were detected during the pre-flood period. Following the flood, 582 (95.41%) cases were attributed to P. vivax, 25 (4.10%) to P. falciparum, and 3 (0.49%) were mixed infections (*P. vivax* and *P. falciparum*). Although the prevalence of *P. vivax* decreased slightly after the flood, it remained the predominant malaria parasite throughout the study period. Conversely, the prevalence of P. falciparum showed a slight increase following the flood. The species-wise distribution of malaria before and after the flood is presented in Figure 7.

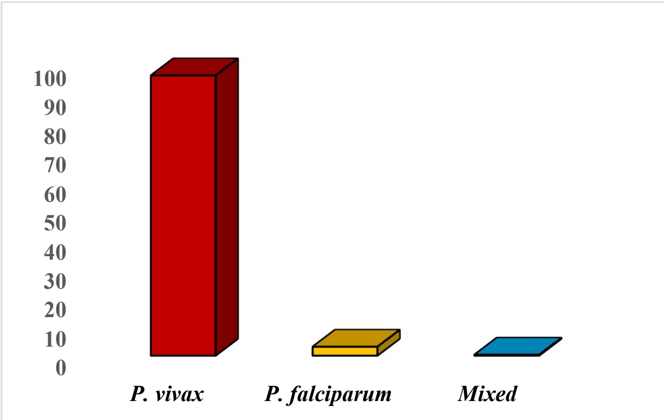

Figure 7. Species wise report of the prevalence of malaria

Age-wise Prevalence

Before the flood, 25 (6.76%) malaria cases were recorded in Group A (0–4 years), 105 (28.38%) in Group B (5–14 years), and 240 (64.86%) in Group C (≥15 years), indicating the highest prevalence in Group C and the lowest in Group A. After the flood, 36 (5.90%) cases were reported in Group A, 200 (32.79%) in Group B, and 374 (61.31%) in Group C. Similarly, Group C remained the most affected age group, followed by Group B, whereas Group A continued to show the lowest prevalence. The age-wise prevalence of malaria before and after the flood is presented in Figure 8.

Overall, individuals aged ≥15 years (Group C) exhibited the highest prevalence of malaria during both study periods. Following the flood, the prevalence in Group C showed a slight decline, whereas the prevalence among individuals aged 5–14 years (Group B) increased slightly compared with the pre-flood period. The prevalence in Group A (0–4 years) remained the lowest throughout the study.

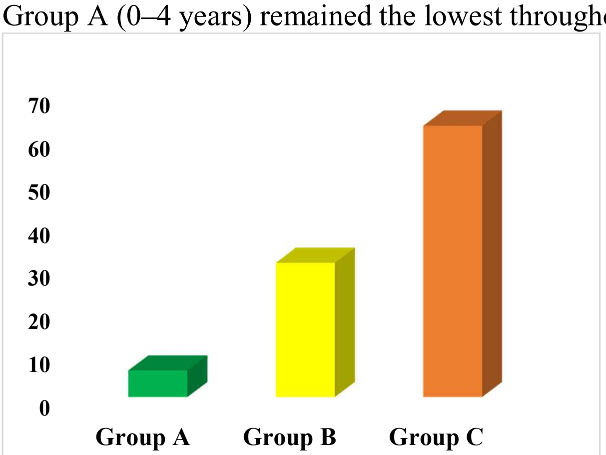

Figure 8. Age wise report of the prevalence of malaria

Discussion

The present study reported an overall malaria positivity rate of 9.44%, indicating that malaria remains a significant public health concern in District Nowshera. A recent epidemiological investigation conducted in the same district reported a malaria positivity rate of 10.2%, further confirming the endemic nature of malaria despite ongoing control and prevention efforts (Baig et al., 2025). The prevalence observed in the present study

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was lower than that reported from District Dera Ismail Khan (12.2%) (Bashir et al., 2019) and District Malakand (26.7%) (Khan et al., 2019). These regional variations may be attributed to differences in climatic conditions, vector abundance, healthcare infrastructure, socioeconomic status, and public awareness regarding malaria prevention. Conversely, the prevalence recorded in the present study was higher than that reported from Balochistan (6.01%) (Bibi et al., 2020), suggesting geographical differences in malaria transmission dynamics.

Gender-wise analysis demonstrated a slightly higher prevalence of malaria among males (51.53%) than females (48.47%). These findings are consistent with a recent study from District Nowshera, which reported that 63.2% of malaria cases occurred in males and 36.8% in females (Baig et al., 2025). Similar observations have been reported from Swat Valley, where males accounted for 59.87% of malaria cases (Syed et al., 2020), District Shangla, where 65.24% of infections occurred among males (Rahman et al., 2017), and Quetta, where male patients constituted 76.44% of reported cases (Sumbal et al., 2020). The higher prevalence among males may be associated with greater occupational and outdoor activities, resulting in increased exposure to mosquito bites, particularly during peak vector activity.

Species-wise analysis revealed that *P vivax* was the predominant malaria parasite, accounting for 96.63% of all confirmed cases, followed by P. falciparum (3.06%) and mixed infections (0.31%). These findings are consistent with those reported by Baig et al. (2025), who identified *P. vivax* (93.0%) as the dominant malaria species in District Nowshera, followed by P. falciparum (4.7%) and mixed infections (2.3%). Similar patterns have also been reported from District Peshawar, where *P. vivax* accounted for 94.3% of malaria cases (Zeb et al., 2015), and District Pishin, Balochistan, where 94.9% of infections were caused by *P. vivax* (Farooq et al., 2020). In contrast, Zafar et al. (2019) reported a comparatively lower prevalence of *P. vivax* (62.23%) and higher proportions of P. falciparum (28.75%) and mixed infections (10.01%) in Multan, indicating regional variation in the distribution of Plasmodium species.

Age-wise analysis demonstrated that individuals aged ≥15 years exhibited the highest prevalence of malaria, followed by those aged 5–14 years, whereas children aged 0–4 years had the lowest prevalence. Similar findings were reported by Baig et al. (2025), who observed the highest malaria frequency among individuals aged 11–20 years, followed by those aged 21–30 years, indicating that adolescents and adults constitute the most affected population groups. Comparable results have also been reported from District Killa Saifullah, where individuals aged ≥14 years showed the highest malaria positivity (Umer et al., 2017), and District Mardan, where adults aged ≥18 years experienced the greatest malaria burden (Usman et al., 2022). The higher prevalence among adults may be associated with increased occupational exposure, agricultural activities, and prolonged outdoor residence, which elevate the likelihood of contact with infected Anopheles mosquitoes.

One of the primary objectives of the present study was to assess the impact of the 2022 floods on malaria prevalence in District Nowshera. The findings demonstrated that malaria prevalence increased from 8.72% before the flood to 9.94% after the flood, indicating that flooding contributed to an increase in malaria transmission. Floods create extensive stagnant water bodies that serve as ideal breeding habitats for Anopheles mosquitoes. Furthermore, flood-related disruption of sanitation systems, damage to healthcare infrastructure, population displacement, and increased human exposure to mosquito vectors may collectively enhance malaria transmission. Similar observations were reported from Khartoum, Sudan, where malaria incidence increased from 11%

before flooding to 19% after flooding and reached 21–46% among febrile patients (Woodruff et al., 1990). Likewise, Sáenz et al. (1995) reported a significant increase in malaria incidence following floods in Costa Rica, which was attributed to the expansion of mosquito breeding sites and increased human-vector contact. Similar associations between flooding and increased malaria transmission have also been documented by Yé et al. (2007) and Ding et al. (2014), who identified flooding and climatic variability as important environmental drivers of malaria epidemics. Furthermore, Li et al. (2007) observed that the post-flood malaria burden was greater among males and older individuals because of their increased involvement in outdoor occupations, emergency response activities, and post-disaster recovery efforts. The findings of the present study support previous evidence that flooding can enhance malaria transmission and emphasize the importance of strengthening disease surveillance, vector control programmes, environmental management, and timely public health interventions in flood-prone regions.

Conclusion

The present study provides valuable epidemiological evidence on malaria prevalence before and after the 2022 floods in District Nowshera, Khyber Pakhtunkhwa, Pakistan. An overall malaria prevalence rate of 9.44% was recorded, with prevalence increasing from 8.72% before the flood to 9.94% after the flood, indicating that flooding contributed to increased malaria transmission. *P. vivax* remained the predominant malaria parasite throughout the study, whereas *P. falciparum* and mixed infections occurred at much lower frequencies. Malaria was more prevalent among males after the flood and was highest in individuals aged 15 years and above, suggesting that occupational and environmental exposure may influence disease transmission. The findings highlight the influence of flooding on malaria epidemiology by creating favorable breeding habitats for mosquito vectors and disrupting environmental sanitation and healthcare services. Strengthening malaria surveillance, integrated vector management, environmental sanitation, early diagnosis, prompt treatment, and community awareness programmes is essential to reduce the burden of malaria in flood-prone areas. These findings provide baseline information for policymakers and public health authorities to develop effective malaria prevention and control strategies during future flood events.

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