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# Strong seasonality and Plasmodium vivax predominance of malaria in Malakand Division, Pakistan: a multi-district hospital-based study

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**Research Article**

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# Abstract

**Background:** Though malaria is still a health issue in Khyber Pakhtunkhwa province, little information exists on the occurrence of malaria in Malakand Division as a whole. Thus, we measured the prevalence and number of various malaria species in hospitals in the Malakand Division and assessed how it differed by district, age, sex, and month of occurrence.

**Methods:** We carried out a hospital-based cross-sectional study between March 2025 and February 2026 in seven district headquarters hospitals and 22 private hospitals located in Malakand Division. All symptomatic patients of various age groups were enrolled consecutively. A finger-prick blood sample was analyzed using thick and thin smears, the Giemsa method, and a rapid diagnostic test. The definition of prevalence was established with 95% confidence intervals, while the associations were determined using chi-square tests and logistic regression.

**Results**. A total of 14,667 patients were examined, and 9,631 were found positive (prevalence 65.7%; 95% CI 64.9–66.4). Among the positive cases, Plasmodium vivax accounted for 87.8% and P. falciparum for 9.3%, while mixed infection accounted for 2.9%. There were significant variations in prevalence in different districts, from 12.8% in Lower Chitral to 82.0% in Lower Dir (Shangla 79.5%; $p < 0.001$); there were no cases in Upper Chitral. The gender-specific examination showed higher prevalence in males than females (69.1% vs 61.2%; OR 1.42, 95% CI 1.32–1.52). Age-wise, the prevalence was highest among 16–40-year-olds (83.7%) as compared to children (64.2%) and those aged 40 years and above (48.1%). There was a peak prevalence of 79.0% in August, and June–September accounted for 82.8% of positive cases.

**Conclusions:** Malaria prevalence among the symptomatic individuals in the Malakand Division was high, seasonal, and highly influenced by the P. vivax species, and higher in adults and males. The results support district- and season-based control strategies and the need for species-specific diagnosis. Community and molecular studies should be carried out to determine the prevalence of malaria in the population.


# Introduction

Malaria is caused by Plasmodium protozoan parasites [1, 5]. In terms of mortality from infectious diseases, this is among the leading causes of death and causes 20 million clinical cases annually as well as about 600,000 deaths among women and children around the globe [2]. According to estimates, some 3.3 billion people are currently at risk of malaria infection [3]. Malaria is rare in developed countries, but remains one of the most common infections caused by Plasmodium in developing countries. About half of the world's population resides in places where malaria is present, such as Afghanistan, Iraq, Iran, Pakistan, India, Bangladesh, some parts of Africa, the Middle East, Central America, and South America [4].

Humans are infected by five different species of Plasmodium, including *Plasmodium falciparum*, *Plasmodium vivax, Plasmodium ovale, Plasmodium malariae*, and *Plasmodium knowlesi* [6]. Among these species, Plasmodium knowlesi is recognized to be a zoonotic species of primate origin that may infect humans [7, 8]. Female Anopheles mosquitoes are responsible for spreading this parasite [9]. Out of all the species of Anopheles, there are 41 important species that form a dominant group responsible for the transmission of malaria [10]. In Pakistan, the most common species is *Plasmodium vivax*, followed by *Plasmodium falciparum*, which is reported in Balochistan, southern Punjab, and Sindh provinces [11].

Even with quick testing technologies (RDTs) allowing the rapid identification of antigens and PCR tests that have good levels of sensitivity, diagnosing malaria is normally confirmed through blood testing with microscopic analysis of blood smears as this is considered the best method diagnostic method due to its efficacy, low chance of errors, and ability to identify the species of parasites and evaluate their number [15].

Due to its geographic position, dependence on agriculture and water resources, and poor disaster preparedness facilities, Pakistan is very sensitive to climate change. Numerous flooding incidents in Pakistan are associated with an increased incidence of malaria. Climate change, poor vector control, and inadequate health services are most probably the reasons for many malaria occurrences [12, 13]. According to the World Health Organization, Pakistan is among the seven countries in the Eastern Mediterranean region that account for 98% of the malaria incidence in the region. Around 217 million people are at medium malaria risk, and 63 million are at high risk. Around 470,000 cases of malaria and 800 deaths occurred in 2020 [14]. Malakand Division in Khyber Pakhtunkhwa, Pakistan, bears a substantial malaria burden, yet comprehensive, division-wide epidemiological data are lacking. Therefore, this study aimed to determine malaria prevalence among symptomatic patients across Malakand Division and describe its distribution by district, age group, gender, month of presentation, and Plasmodium species (P. vivax, P. falciparum, and mixed infections). The findings are intended to provide baseline evidence to support targeted malaria control and elimination efforts in the region. Malakand Division in Khyber Pakhtunkhwa, Pakistan, is severely affected by malaria, but detailed epidemiological data are not available at the division level. Therefore, this study was intended to assess the prevalence of malaria among symptomatic patients in Malakand Division, with a description of the distribution of malaria by district, age, gender, month of presentation, and species of Plasmodium. The results are expected to provide baseline data for the introduction of targeted malaria eradication strategies in the area.

## Methodology

# Study site

The Malakand Division, located in the northern part of Khyber Pakhtunkhwa (KP), Pakistan, is the largest division of the province in terms of area, with a total area of around 31,162 km², and has a population of about 10 million as per the census of 2023[16]. The division consists of 8 districts: Buner, Lower Chitral,

Lower Dir, Malakand, Shangla, Swat, Upper Chitral, and Upper Dir. The Malakand Division has its geographical location between 36.07 and 36.40°N and 71.43 and 73.85°E, with deep valleys and high mountains of the Hindu Kush and western Himalayas surrounding it. The elevation ranges between [500] m in the plains of southern Malakand district and over [7,000] m in the region of Chitral. The region branched into many agro-ecological zones, with semi-arid, sub-humid, and sub-tropical types of climates in the southern region to dry cold temperate zone in northern region of the area which can affect the transmission of the case of malaria [17, 18].

## Study Design and Setting

We carried out a hospital-centered cross-sectional investigation over a span of 12 months, from March 2025 to February 2026, in Malakand Division, Khyber Pakhtunkhwa, Pakistan. Patients showing symptoms were recruited from District Headquarters (DHQ) hospitals and private hospitals in eight districts of the division, namely Buner, Lower Chitral, Lower Dir, Malakand, Shangla, Swat, Upper Chitral, and Upper Dir. Patients were sourced from 7 DHQ hospitals and 22 private hospitals.

## Study Population and Sampling

The study population consisted of all patients of any age and either sex who resided in Malakand Division and presented with clinical symptoms suggestive of malaria (fever, chills, headache, sweating, or other compatible features). Patients were recruited consecutively during the study period and stratified into three age groups: children (1–15 years), young adults (16–40 years), and older adults (≥ 41 years).

## Eligibility criteria

Eligibility criteria for patients were (i) residency in Malakand Division, (ii) showing clinical signs of malaria, and (iii) providing informed consent (or consent from parents or guardians for minors and patients incapable of giving consent). Exclusion criteria consisted of (i) residency outside Malakand Division, (ii) refusal to participate, and (iii) use of antimalarial drugs within two weeks of enrolment.

## Sample Collection

The area was properly cleaned with 70% alcohol to maintain aseptic conditions, after which capillary blood was drawn via the standard finger-prick technique with the help of sterile disposable lancet. Samples were used for both microscopic examination and rapid diagnostic testing (RDT).

# Microscopic Examination

Thick and thin blood smears were prepared on clean, labelled glass slides. Thin smears were fixed in absolute methanol; thick smears were left unfixed and air-dried. Both were stained with [3–10] % Giemsa solution diluted in distilled water (pH 7.2). Slides were examined under a light microscope at 100× oil-immersion magnification. Thick smears were used to detect parasites and thin smears for species identification, using standard morphological keys for the developmental stages of *Plasmodium falciparum* and *Plasmodium vivax* (WHO guidelines). Each slide was examined for 10–20 minutes (approximately [100–200] oil-immersion fields) before being declared negative. Mixed infection was defined as the presence of both species in the same patient. Slides were read by [two] independent, experienced microscopists, with discrepancies resolved by a senior microscopist.

## Rapid Diagnostic Tests

Rapid diagnostic testing was performed using the SD Bioline Malaria Ag Pf (or Pf/Pan) kit (Abbott / Standard Diagnostics, Korea), according to the manufacturer's instructions, and results were read within the specified time.

## Ethical Considerations

The study adhered to the principles outlined in the Declaration of Helsinki. Approval for the study was obtained from the appropriate local health authorities prior to data collection. Participants were made aware of the purpose and procedures of the study and their participation was ensured to be voluntary and they could opt out of the study at any time and without facing any repercussions. In the case of children and people who were unable to give consent, written consent was acquired from a parent or a guardian. Throughout the study, confidentiality was maintained; no personal information was included in the data collected and only aggregate results were released. Patients with a positive test result were referred for treatment as per the standard protocol.

# Data Collection

Demographic and clinical data, including age, sex, district of residence, and month of presentation, were recorded using a structured data collection form and, where available, extracted from hospital records.

# Statistical Analysis

Statistical analysis was conducted using SPSS software version 27. A map was made using ArcGIS. Descriptive statistics helped in analyzing demographic and clinical features, whereas prevalence was determined as % with 95% confidence intervals, as in:

**Prevalence (%)** = Number of malaria positive patients ÷ Total number of patients examined) × 100

Prevalence for separate species (P. falciparum, P. vivax, mixed) was estimated in the same way. To find the association of infection with age group, sex, month, and district, the chi-square test (or Fisher's exact

test for expected counts < 5) was used. Age, sex, month, and district as potential confounding factors were adjusted for using multivariable logistic regression, shown as adjusted odds ratios with 95% confidence intervals. P-value < 0.05 was taken as statistically significant. Missing data were treated using listwise deletion.

## Results

# Overview of results

A total of 14,667 patients with symptoms of malaria were examined in eight districts throughout the Malakand Division from March 2025 to February 2026. Of these individuals, 9,631 (65.7%; 95% CI: 64.9–66.4) tested positive for malaria. Most of these malaria-positive individuals were found to have Plasmodium vivax (87.8% of malaria-positive individuals), and 9.3% had P. falciparum malaria, while 2.9% had a mixture of both.

The prevalence of malaria varied between districts, ranging from 12.8% in Lower Chitral to 82.0% in Lower Dir, but Shangla also had a high prevalence of 79.5%. Lower Dir and Shangla together accounted for 47.4% of all malaria-positive cases. In addition, it was observed that males had more malaria-positive cases than females (69.1% vs 61.2%).

Young adults aged 16–40 years were found to be the most susceptible to malaria (83.7%), while older adults (48.1%) and children (64.2%) were less affected.

Transmission follows a clear seasonal pattern. It rose from 23.0% in March of 2025 to a high of 79.0% in August, then decreased back down to 31.1% in February 2026. June through September represented 82.8% of the total positive cases, with July and August alone accounting for 60.5%. All relations are statistically significant ($p < 0.001$).

# District-wise prevalence

Prevalence varied considerably in all seven districts ($\chi^2 = 1254.99$, df = 6, $p < 0.001$; Cramér's V = 0.29; Table 4). The highest prevalence was seen in Dir Lower (82.0%; 2,432/2,966) as well as in Shangla (79.5%; 2,133/2,682), Buner (62.1%; 1,621/2,611), Swat (59.8%; 1,107/1,850), Dir Upper (54.5%; 923/1,693), and Malakand (53.8%; 1,376/2,560). Chitral Lower had the lowest prevalence (12.8%; 39/305). Dir Lower and Shangla combined accounted for 47.4% of the positive cases. There were no cases detected in Upper Chitral due to its cold climate and unfavorable condition for mosquitoes.

Table 1
District-wise prevalence of malaria

| District | Patients examined (n) | Malaria positive (n) | Malaria negative (n) | Prevalence (%) | 95% CI lower (%) | 95% CI upper (%) |
|---|---|---|---|---|---|---|
| Dir Lower | 2,966 | 2,432 | 534 | 82.0 | 80.6 | 83.4 |
| Shangla | 2,682 | 2,133 | 549 | 79.5 | 78.0 | 81.1 |
| Buner | 2,611 | 1,621 | 990 | 62.1 | 60.2 | 63.9 |
| Malakand | 2,560 | 1,376 | 1,184 | 53.8 | 51.8 | 55.7 |
| Swat | 1,850 | 1,107 | 743 | 59.8 | 57.6 | 62.1 |
| Dir Upper | 1,693 | 923 | 770 | 54.5 | 52.1 | 56.9 |
| Chitral Lower | 305 | 39 | 266 | 12.8 | 9.0 | 16.5 |
| Chitral Upper | 0 | 0 | 0 | NA* | NA | NA |
| Total | 14,667 | 9,631 | 5,036 | 65.7 | 64.9 | 66.4 |

*No patients were examined in Chitral Upper, so prevalence cannot be calculated. Pearson's chi-square test (seven districts with data): $\chi^2 = 1254.99$, df = 6, $p < 0.001$. Cramér's V = 0.29.

# Gender-wise Prevalence

Malaria prevalence was significantly higher in males (69.1%; 95% CI: 68.1–70.1; 5,748/8,320) than in females (61.2%; 95% CI: 60.0–62.4; 3,883/6,347) ($\chi^2 = 99.86$, df = 1, $p < 0.001$; Table 2). Males had 1.42 times higher odds of malaria positivity than females (crude OR = 1.42; 95% CI: 1.32–1.52). Males accounted for 59.7% (5,748/9,631) of all positive cases, and females for 40.3%. The effect size was small (Cramér's V = 0.08).

Table 2
Prevalence of malaria by gender

| Gender | Patients examined (n) | Malaria positive (n) | Malaria negative (n) | Prevalence (%) | 95% CI |
|---|---|---|---|---|---|
| Male | 8,320 | 5,748 | 2,572 | 69.1 | 68.1–70.1 |
| Female | 6,347 | 3,883 | 2,464 | 61.2 | 60.0–62.4 |
| Total | 14,667 | 9,631 | 5,036 | 65.7 | 64.9–66.4 |

Pearson's chi-square test: $\chi^2 = 99.86$, df = 1, $p < 0.001$. Cramér's V = 0.08. OR = odds ratio.

# Age-wise Prevalence

Malaria prevalence differed significantly among the three age groups ($\chi^2 = 1374.58$, df = 2, $p < 0.001$; Table 2). The highest prevalence was recorded in young adults aged 16–40 years (83.7%; 95% CI: 82.6–84.7; 4,206/5,028), followed by children aged 1–15 years (64.2%; 95% CI: 62.9–65.6; 3,132/4,876), and the lowest in older adults aged over 40 years (48.1%; 95% CI: 46.7–49.6; 2,293/4,763). Compared with children, young adults had 2.85 times higher odds of infection (crude OR = 2.85; 95% CI: 2.59–3.13), whereas older adults had lower odds (crude OR = 0.52; 95% CI: 0.48–0.56). Young adults accounted for 43.7% of all positive cases, followed by children (32.5%) and older adults (23.8%). All pairwise differences between age groups were significant ($p < 0.001$ for each comparison, which remained significant after Bonferroni correction). The effect size was moderate (Cramér's V = 0.31).

Table 3
Prevalence of malaria by age group

| Age group | Patients examined (n) | Malaria positive (n) | Malaria negative (n) | Prevalence (%) | 95% CI |
|---|---|---|---|---|---|
| Children (1–15 years) | 4,876 | 3,132 | 1,744 | 64.2 | 62.9–65.6 |
| Young adults (16–40 years) | 5,028 | 4,206 | 822 | 83.7 | 82.6–84.7 |
| Older adults (> 40 years) | 4,763 | 2,293 | 2,470 | 48.1 | 46.7–49.6 |
| Total | 14,667 | 9,631 | 5,036 | 65.7 | 64.9–66.4 |

Pearson's chi-square test: $\chi^2 = 1374.58$, df = 2, $p < 0.001$. Cramér's V = 0.31. OR = odds ratio.

# Monthly-wise prevalence

Malaria prevalence varied significantly across the 12 months of the study ($\chi^2 = 1283.83$, df = 11, $p < 0.001$; Table 5). Prevalence was lowest in March 2025 (23.0%; 32/139) and rose steadily through the spring and early summer, reaching 43.8% in April, 48.3% in May, and 62.7% in June. The peak occurred in July and August 2025, when prevalence reached 76.6% (2,674/3,489) and 79.0% (3,156/3,997), respectively. Prevalence then fell to 56.7% in September and remained at 48.6% in October and 48.4% in November, before declining further to 40.7% in December, 37.9% in January 2026 and 31.1% in February 2026. The four months from June to September accounted for 11,004 (75.0%) of all patients examined and 7,974 (82.8%) of all positive cases, with July and August alone contributing 60.5% of positive cases. The effect size was moderate (Cramér's V = 0.30).

Table 4
Monthly distribution of malaria cases

| Month | Patients examined (n) | Malaria positive (n) | Malaria negative (n) | Prevalence (%) | 95% CI | Share of all positive cases (%) |
|---|---|---|---|---|---|---|
| March 2025 | 139 | 32 | 107 | 23.0 | 16.0–30.0 | 0.3 |
| April 2025 | 459 | 201 | 258 | 43.8 | 39.3–48.3 | 2.1 |
| May 2025 | 943 | 455 | 488 | 48.3 | 45.1–51.4 | 4.7 |
| June 2025 | 2,464 | 1,546 | 918 | 62.7 | 60.8–64.7 | 16.1 |
| July 2025 | 3,489 | 2,674 | 815 | 76.6 | 75.2–78.0 | 27.8 |
| August 2025 | 3,997 | 3,156 | 841 | 79.0 | 77.7–80.2 | 32.8 |
| September 2025 | 1,054 | 598 | 456 | 56.7 | 53.7–59.7 | 6.2 |
| October 2025 | 957 | 465 | 492 | 48.6 | 45.4–51.8 | 4.8 |
| November 2025 | 610 | 295 | 315 | 48.4 | 44.4–52.3 | 3.1 |
| December 2025 | 246 | 100 | 146 | 40.7 | 34.5–46.8 | 1.0 |
| January 2026 | 190 | 72 | 118 | 37.9 | 31.0–44.8 | 0.7 |
| February 2026 | 119 | 37 | 82 | 31.1 | 22.8–39.4 | 0.4 |
| Total | 14,667 | 9,631 | 5,036 | 65.7 | 64.9–66.4 | 100 |

Pearson's chi-square test: $\chi^2 = 1283.83$, df = 11, $p < 0.001$. Cramér's V = 0.30.

# Species-wise prevalence

Of the 14,667 symptomatic patients examined, 9,631 (65.7%; 95% CI: 64.9–66.4) were positive for malaria parasites (Table 1). *Plasmodium vivax* was the predominant species, detected in 8,456 patients (87.8% of positive cases; 57.7% of all patients examined), followed by *P. falciparum* in 897 patients (9.3% of positive cases; 6.1% of all patients examined). Mixed infections with both species were found in 278 patients (2.9% of positive cases; 1.9% of all patients examined). *P. vivax* was therefore about 9.4 times

more common than *P. falciparum* among single-species infections. Including mixed infections, *P. vivax* was present in 90.7% of all positive cases (8,734/9,631) and *P. falciparum* in 12.2% (1,175/9,631).

Table 5
Overall prevalence of malaria and species distribution

| Variable | Number (n) | % Of patients examined (N = 14,667) | 95% CI | % Of positive cases (n = 9,631) | 95% CI |
|---|---|---|---|---|---|
| Malaria positive | 9,631 | 65.7 | 64.9–66.4 | 100 | |
| Malaria negative | 5,036 | 34.3 | 33.6–35.1 | | |
| *P. vivax* | 8,456 | 57.7 | 56.9–58.5 | 87.8 | 87.1–88.5 |
| *P. falciparum* | 897 | 6.1 | 5.7–6.5 | 9.3 | 8.7–9.9 |
| Mixed infection (*P. vivax* + *P. falciparum*) | 278 | 1.9 | 1.7–2.1 | 2.9 | 2.6–3.2 |

# Discussion

This hospital-based study of 14,667 symptomatic patients across Malakand Division found an overall malaria prevalence of 65.7% (95% CI 64.9–66.4). *P. vivax* accounted for 87.8% of positive cases. Prevalence differed significantly by district, age group, sex, and month. It was highest in Lower Dir (82.0%) and Shangla (79.5%), among young adults aged 16–40 years (83.7%), among males (69.1%), and in July–August. Because our denominator is symptomatic patients attending health facilities, “prevalence” here means hospital-based prevalence among suspected cases, not community prevalence.

Our overall prevalence is much higher than in earlier facility-based studies from the same area. Reported prevalence in Lower Dir was 12.2% in 2011 [19], 12.2% in 2013 [22], 39.5% in 2013–14 [20], and 12.1% in 2017 [26]. Our Lower Dir estimate (82.0%) exceeds all of these. The same pattern holds for other districts. Earlier studies reported 9.11% in Swat in 2017–18[21], 6.86% in Buner in 2001 [22], and 22.38% in Malakand [23]. Several explanations are plausible, and we cannot separate them with our data. First, transmission may have increased. A five-year surveillance study in neighbouring Shangla reported the test positivity rate rising from 3% in 2020 to 32% in 2023, then falling to 27% in 2024 [24]. Floods and climate change have also been linked to rising malaria in Pakistan [25]. Second, the populations tested differ. One Swat study used passive case detection across district hospitals, basic health units, and private clinics [30], which can give lower prevalence than symptomatic patients at hospitals. Third, prevalence depends on how microscopy and RDT results were combined. Fourth, 75.0% of our patients

were examined between June and September, so the overall figure is weighted toward the high-transmission season. Earlier studies sampled different periods, which limits direct comparison.

Lower Dir and Shangla contributed 47.4% of positive cases but 38.5% of patients examined, so part of their share reflects sampling. Zaman et al. found higher prevalence in Lower Dir (19.7%) than in Swat (9.11%) and suggested proximity to Afghanistan, refugee movement and limited awareness and health services [21]. The low prevalence in Lower Chitral (12.8%, n = 305) and no reported cases in Upper Chitral fit the north–south gradient described in Shangla. There, high-altitude northern areas have seasonal interruption of transmission under cold winter temperatures [24].

Prevalence was higher in males than females (69.1% vs 61.2%; OR 1.42), consistent with other studies in the region. Reported prevalence in males vs females was 24.5% vs 15.0% [20], 13.3% vs 10.7% [19], 13.6% vs 10.6% [26], 13.3% vs 12.3% [21], 17.66% vs 11.44% [27] and 7.10% vs 6.52% [22]. Males made up 58.7% [28], 62.12% [29], and 54% [24] of cases in studies that reported only case shares. Authors commonly attribute this to males working outdoors and being less covered [20,28,21]. The effect in our data was small (Cramér's V = 0.08). Males were also 56.7% of patients examined, so differences in care-seeking may contribute. We did not measure occupation or exposure.

Published findings fall into two patterns, and our data follow the second. Some studies found the highest prevalence, or the largest share of cases, in children aged 1–10 years [26,22,29]. Others found peaks in adolescents and adults: 11–20 years [19], 21–30 years [20], 31–40 years [27], and 67% of cases aged ≥15 years [24]. Age bands differ across studies, which limits comparison. In our data, prevalence was highest in 16–40-year-olds (83.7%) and lowest in those over 40 (48.1%). Earlier authors explained adult peaks with greater outdoor activity [20], and Shangla et al. pointed to occupational or behavioural exposure and returning migrant labourers [24]. These explanations are plausible for our findings, but we did not collect exposure, mobility, or immunity data.

Transmission was strongly seasonal. Prevalence peaked in July–August (76.6% and 79.0%), and June–September contributed 82.8% of positive cases. Other studies in the area also found peaks in August [20, 26,22], August–October [30], September [27], or autumn [19]. Authors attribute summer and autumn peaks to monsoon rains and temperatures suitable for vector breeding, and to low winter temperatures that slow parasite development in the mosquito [20,19]. We did not record climate variables, so this remains an inference. Prevalence stayed at 31–41% in December–February. In Shangla, relapses from *P. vivax* hypnozoites were proposed to sustain cases in low-transmission seasons [24], though we cannot test relapse here. Winter and March estimates rest on small samples (119–246 patients per month) and have wide confidence intervals.

*Plasmodium vivax* predominated (87.8% of positives), as in other studies from the region: 94.3% [19], 92.8% [26], 99.07% [21], 99.47% [28] and 95% [24]. Calculated from reported counts, it was 76.2% in Lower Dir in 2013–14 [20] and 84.3% in Buner [22]. *P. falciparum* (9.3%) is within the reported range. Reports include 0.53% [28], 0.93% [21], 3.9% [19], 4.6% [24], 7.2% [26], and 21% [27]. A Malakand study

reported 40.4% among 47 positives [23], a very small sample. Mixed infection (2.9%) was intermediate between 0.4% [24], 1.7% [19], and 8% [27]. Several studies detected none [20,21,22,23,30].

# Conclusion

In this 12-month, multi-district study of 14,667 symptomatic patients attending hospitals in Malakand Division, the hospital-based prevalence of malaria was 65.7% (95% CI 64.9–66.4). *Plasmodium vivax* accounted for 87.8% of positive cases, *P. falciparum* for 9.3% and mixed infection for 2.9%. Prevalence varied widely between districts, from 12.8% in Lower Chitral to 82.0% in Lower Dir. It was also high in Shangla (79.5%), and no patients were examined in Upper Chitral. Prevalence was higher in males than females (69.1% vs 61.2%). It was highest among adults aged 16–40 years (83.7%) and lowest among those over 40 (48.1%). Transmission was strongly seasonal, peaking in July–August, and June–September accounted for 82.8% of positive cases. Because the study was facility-based and did not include climate, exposure, or molecular data, these findings describe patients seeking care and not the general population, and the reasons behind the patterns remain to be tested. The results nonetheless support district- and season-targeted control, particularly in Lower Dir and Shangla before and during the monsoon months, together with species-specific diagnosis. Community-based prevalence surveys, PCR confirmation, and linked climate data are needed to estimate population burden and identify the drivers of transmission in this region.

4. Recommendations

Each recommendation is tied to a result you have. Present them as “should be considered”, not as proven.

1. Target season. June–September held 75.0% of patients and 82.8% of positives. Prevalence was already rising from April (43.8%), so vector control and case-management preparation should be in place before June.
2. Target districts. Prioritise surveillance and control in Lower Dir (82.0%) and Shangla (79.5%).
3. Target groups. Young adults (83.7%) and males (69.1%) should be priority groups for prevention messaging. Children also had high prevalence (64.2%) and should not be neglected.
4. Surveillance. Standardise facility reporting across districts. Chitral needs better coverage: Lower Chitral had 305 patients, and Upper Chitral had none.
5. Research. Conduct community-based prevalence surveys.

# Declarations

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# Author Contribution

Usman Khan → U.K.Majid Khan → M.K.M.K. and U.K. conceived the study, performed the experiments, analysed the data, and wrote the main manuscript text. All authors reviewed the manuscript.

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# Figures

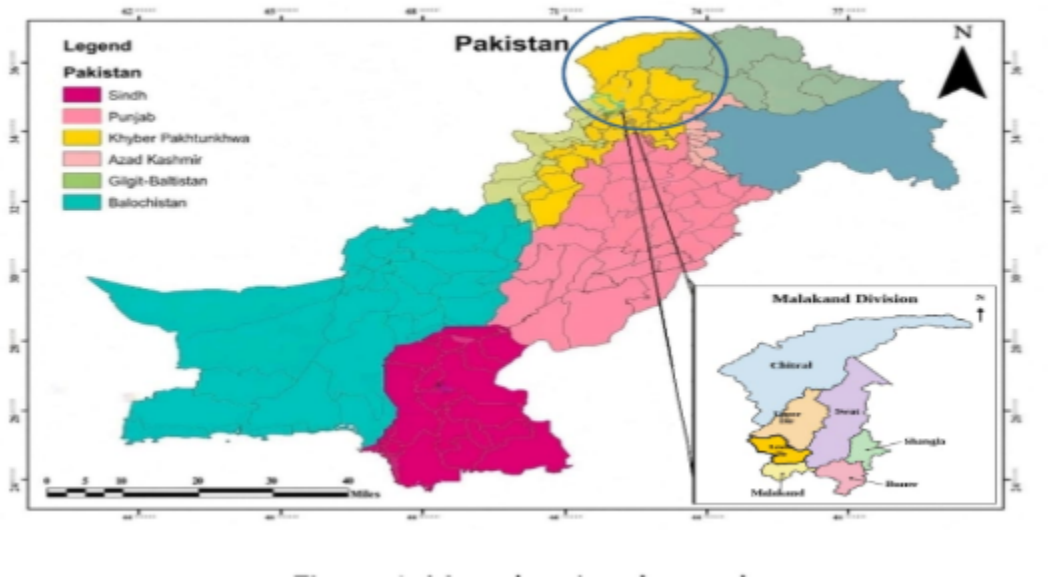



**Figure 1**

Unnumbered image in the methodology section.