Volume 3, Number 3, 2026

Pages 1026-1038

Bioscience Insights

ISSN: 3080-3489 (Print)
ISSN: 3080-3497 (Online)

BiosciInsights.com

# EPIDEMIOLOGICAL DETERMINANTS OF MALARIA IN DISTRICT LOWER DIR, PAKISTAN: A SYSTEMATIC REVIEW

**Usman Khan[1], Majid Khan[*2], Raees Ahmad[3], Majid Khan[4], Atta Ullah[5], Izhar Ullah[*6], Muhammad Numan[7], Zakir Ullah Khan[8], Muhammad Yaseen Khan[9], Faiza Shakeel[10], Syed Aizaz[11], Sajid Ullah[12]**

*[1, *2,4,5, *6,7,8,9,10,11,12]Department of Zoology, Government Post Graduate College Timargara*
*[3]Department of Zoology, University of Malakand*

[1]syedusmankhan4@gmail.com, [*2]zoologistmajidkhan@gmail.com, [3]ahmadraees544@gmail.com, [4]majidkhansawan@gmail.com, [5]atta807345@gmail.com, [*6]emcizharullah@gmail.com, [7]muhammadnumanmn2001@gmail.com, [8]zakirullah8891@gmail.com, [9]muhammadyaseenk83@gmail.com, [10]faizashakeel622@gmail.com, [11]miasayedaizaz@gmail.com, [12]sajidullah.khan.436@gmail.com

https://doi.org/10.5281/zenodo.23727420

**Article Information**

***Article History***

| | |
|---|---|
| Received: | June 19, 2026 |
| Revised: | August 19, 2026 |
| Accepted: | September 07, 2026 |
| Available Online: | October 28, 2026 |

**Keywords:**
*Malaria; Plasmodium vivax; prevalence; determinants; Lower Dir*

***Copyright @Authors***
**Corresponding Authors: ***
**Majid Khan, Izhar Ullah**

**Abstract**

*Malaria is still a serious public health concern in Pakistan, particularly in endemic districts such as Lower Dir. This systematic review* ***investigates*** *the malaria prevalence and its determinants. Following PRISMA guidelines, we searched the following databases: PubMed, ScienceDirect, Embase, Emcare, and Google Scholar for articles regarding malaria in Lower Dir published between January 2013 and July 2026. Eligible studies reported laboratory-confirmed (microscopy and/or RDT) malaria prevalence stratified by demographic or environmental* ***variables.*** *Nine studies met inclusion criteria. Positivity ranged from 12.2% to 39.5% in community/hospital populations (median 15%), with a higher rate (81.3%) in a pediatric cohort. Male positivity exceeded female positivity (ratios of 1.2:1 to 1.6:1). Age-related risk varied, with peaks in young children (<10–11 years) or adults (11–40 years) across studies. Transmission peaked in the period of June–October and decreased during the months of December–February. The highest prevalence was recorded in Timargara, whereas Samarbagh recorded the lowest prevalence.* Plasmodium vivax *was predominant in all studies (71–99.5% of cases), followed by* Plasmodium falciparum *(0.5–23.8%); mixed infections were rare (≤8%), with no* Plasmodium malariae *or* Plasmodium ovale *detected. Important socio-economic factors for transmission at this location were low education, joint-family pattern, low income, as well as poor sanitation conditions. The results confirm moderate endemicity*

*of* Plasmodium vivax *malaria in Lower Dir, mainly determined by sex, age, seasonality, geography, and socioeconomic factors.*

## 1 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 spread this parasite [9]. Of all Anopheles species, 41 are important and form the dominant group responsible for malaria transmission [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].

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].

Infectious diseases present serious issues within global health, requiring unique consideration and multifaceted strategies [15]. Infectious diseases such as malaria can affect large populations and can also have a significant economic impact on the regions in which they take place [16]. There are many hurdles in fighting the problems posed by malaria in Pakistan; Khyber Pakhtunkhwa, and in particular Lower Dir district, has a high rate of malaria incidence. Therefore, we carried out an investigation in order to find out what contributes to malaria incidence. The findings of this research will allow communities to implement adequate preventive measures and give the authorities the necessary information for their strategies regarding malaria prevention in Lower Dir.

## 2 Methodology

### 2.1 Study site description

This study was carried out in District Lower Dir, which lies within the Khyber Pakhtunkhwa province of Pakistan. All seven tehsils of the district, which include Balambat, Khall, Lal Qilla, Adenzai, Timargara, Samarbagh, and Munda, were considered for the present study. District Lower Dir is situated in the foothills of the Lesser Hindu Kush ranges, lying between latitudes 34°37' and 35°07' N and longitudes 71°31' and 72°14' E. It extends over an area of 1,583 km$^2$ as per [17]. It is bounded on the north by the District Upper Dir, on the eastern side by District Swat, and on the southern side by the District Malakand.

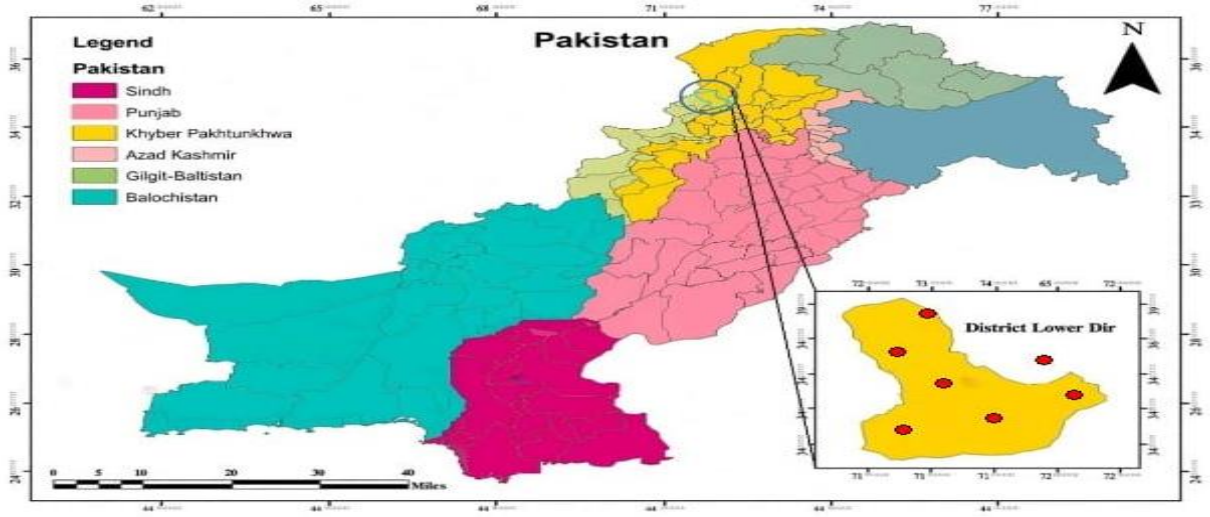



Figure 1. Geographical location of District Lower Dir, Khyber Pakhtunkhwa, Pakistan, showing its seven tehsils and geographical boundaries.

**2.2 Method of Searching**

This review utilized the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. Research papers related to malaria were identified through online databases for the determinants of malaria in Lower Dir: PubMed, ScienceDirect, Embase, Emcare, and Google Scholar. Several titles and keywords were used for relevant papers. A study map was created through ArcGIS Pro (Version 3.7.1)

**2.3 Study Selection**

This review discusses primary epidemiological studies done exclusive in District Lower Dir, Khyber Pakhtunkhwa, Pakistan and published in reputable journals during the time frame of 2013 to July, 2026. For inclusion, studies should present original malaria prevalence statistics confirmed in the laboratory (microscopy and/or RDT) and conducted in Lower Dir. They must also have given malaria prevalence categorically in accordance with at least one parameter of environment or demographics, such as age, gender, month/season, etc. Only two studies first [20] reported figures for Lower Dir and District Swat together. Consequently, the figures from this study related to Lower Dir were only used in this review. The second [49] reported some other determinants from the whole province.

**2.4 Data Extraction**

The variables that have been identified from the studies include: total sample size, duration of study, overall positivity rate, positivity with respect to sex, positivity with respect to age groups, positivity according to month or season, positivity according to tehsil/union council area, and species distribution (*P. vivax*, *P. falciparum*, mixed infection). All variables reported in studies were put in a table, as they were reported in the original work, without any further analysis of the data due to lack of availability of primary data. However, while study populations were different (general/community population, hospital patients with symptoms, and pediatric patients only), it was decided to compare the prevalence figures descriptively instead of accumulating them in one summary statistic.

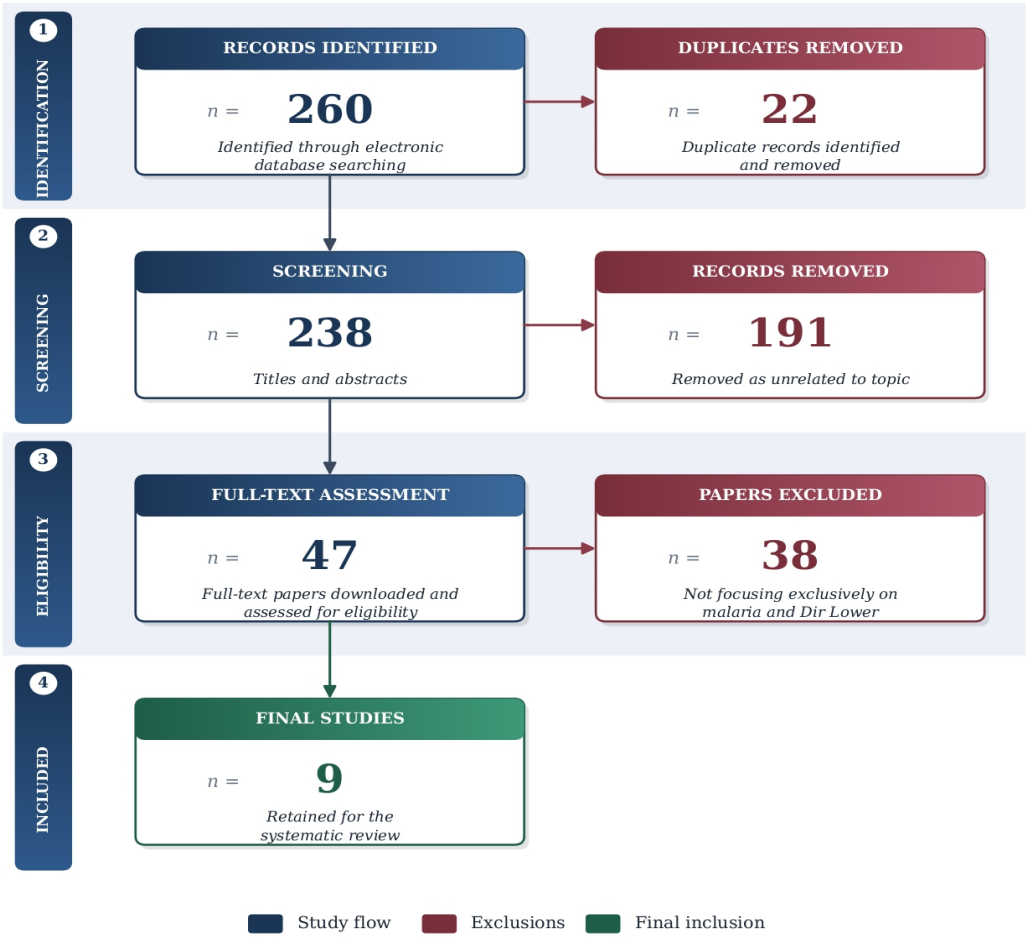



*Fig. 2 Flowchart summarizing the criteria applied for study inclusion and exclusion.*

### 2.5 Overview of Included Studies

**Table 1. Demographic and methodological profile of the nine reports evaluated in the current systematic review.**

| Citation (Author, Date) | Study period | Location within Lower Dir | Sample (n) | Positive (n, %) | Diagnostic method |
|---|---|---|---|---|---|
| Ahmad *et al.*, 2013 [21] | Jan–Dec 2003 | Lal Qilla (single tehsil) | 1,091 | 189 (17.3%) | Microscopy |
| Zeb *et al.*, 2015 [25] | Jan–Dec 2011 | Timargara, Munda, Maidan, Samar Bagh, | 3,760 | 460 (12.2%) | Microscopy + RDT |
| Shah *et al.*, 2016 [18] | Oct 2013–Sep 2014 | District-wide (7 tehsils) | 821 | 324 (39.5%) | Microscopy |
| Dad *et al.*, 2019 [23] | Mar–Sep 2017 | District-wide (7 tehsils) | 2,395 | 292 (12.2%) | RDT |
| Ullah *et al.*, 2019 [19] | Jan–Dec 2013 | District-wide (7 tehsils) | 1,750 | 214 (12.2%) | Microscopy |

| Citation (Author, Date) | Study period | Location within Lower Dir | Sample (n) | Positive (n, %) | Diagnostic method |
|---|---|---|---|---|---|
| Zaman *et al.*, 2022 [20] | Dec 2017–Nov 2018 | Lower Dir (+ District Swat, reported separately) | 904 (Lower Dir) | 178 (19.7%, Lower Dir) | Microscopy |
| Shan *et al.*, 2024 [24] | Jan–Dec 2023 | Tehsil Samar Bagh (6 union councils) | 1,925 | 289 (15.0%) | Microscopy |
| Khan *et al.*, 2025 [22] | 1-year hospital survey | District-wide, children ≤10 y, 5 public hospitals | 815 children / 4,312 samples (multiple samples per child) | 3,505 (81.3%) High percentage is due to hospital-based study | Microscopy + RDT |
| (Haq *et al.*, 2026) [49] | Jan 2022 -Dec 2022 | Some determinants in the province, including Dir | 768 | Describe other determinants like education, poverty, etc. | Cross-sectional survey |

## 3 Results

### 3.1 Overall Prevalence

The overall malaria positivity that has been reported in Lower Dir is in the range of 12.2% [23] to 39.5% [18] among hospital-referred/general populations and in a cohort based on pediatric hospitals by Khan *et al.* (2025) where the levels were found to be significantly higher prevalence 81.3% [22]. Excluding this outlier, the positivity levels in the other seven studies, based on community and hospitals respectively, were between 12% and 20%, with around 15% being the median of the many samples taken, showing that the level of endemicity remained stable at a moderate level.

### 3.2 Sex as a Determinant

All of the studies carried out demonstrated a sex-disaggregated prevalence. The prevalence in males was higher than that in females, as shown in Table 2. This is the only factor that was consistently identified in all relevant literature.

**Table 2. Sex-wise malaria positivity reported across studies.**

| Study | Male positivity | Female positivity | Male: Female ratio (approx.) |
|---|---|---|---|
| Ahmad *et al.*, 2013 | 58.7% | 41.3% | 1.4 : 1 |
| Zeb *et al.*, 2015 | 13.3% | 10.7% | 1.2 : 1 |
| Shah *et al.*, 2016 | 24.5% | 15.0% | 1.6 : 1 |
| Dad *et al.*, 2019 | 13.6% | 10.6% | 1.3 : 1 |
| Ullah *et al.*, 2019 | 12.5% | 10.1% | 1.2 : 1 |
| Shan *et al.*, 2024 | 17.7% | 11.4% | 1.5 : 1 |

### 3.3 Age as a Determinant

Differences in the risks of malaria based on age were noticeable across various studies, unlike in the case of sex as shown in Table 3. In particular, in three publications, it was found that children in their early years have the highest risk. Dad *et al.* (2019) [23] showed that the highest level of prevalence occurs within 1-10-year-olds (14.3%), while people older than 60 have the lowest level of risk, with the level of prevalence being 7.3%. Ullah *et al.* (2019) [19] observed that the infection level was the highest among children under ten years old (14.9%). Khan *et al.* (2025) [22] demonstrated that the infection level was the highest among children (it peaked at 9-10 years old with a rate of 83.7%) and increased with age among children. However, other studies showed that the risk was the highest among young and middle-aged adults.
Ahmad *et al.* (2013) [21] demonstrated that 76.7% of malaria cases were in the group of 15-64-year-olds. According to Shah *et al.* (2016) [18] and Zeb *et al.* (2015) [25], the highest risk was found among people aged 21-30 or people aged 11-20. Shan *et al.* (2024) [24] demonstrated that the risk was the highest in the group of 31-40-year-olds (19.7%).

**Table 3. Age group most affected in each study.**

| Study | Highest-risk age group | Prevalence in that group | Lowest-risk age group |
|---|---|---|---|
| Dad *et al.*, 2019 | 1–10 years | 14.3% | 61+ years (7.3%) |
| Khan *et al.*, 2025 (children only) | 9–10 years | 83.7% | 1-4 and 5-8 years (80.9%) |
| Ullah *et al.*, 2019 | <10 years | 14.9% | 11–30 years, female (9.3%) |
| Zeb *et al.*, 2015 | 11–20 years | 12.7% | 51+ years (10.6%) |
| Shah *et al.*, 2016 | 21–30 years | 11.0% | 1–10 years (2.1%) |
| Shan *et al.*, 2024 | 31–40 years | 19.7% | 1–10 years relatively low |
| Ahmad *et al.*, 2013 | 15–64 years | 76.7% of all cases | >65 years (9.5%) |

### 3.4 Seasonality as a Determinant

Seasonal/monthly variation was the second most consistent determinant across the literature (Table 4). Every study that reported month- or season-wise data identified a transmission peak during the warm, humid months roughly spanning June to October, coinciding with the monsoon rains and rising temperatures, and a trough during the cold, dry winter months (December–February). Dad *et al.* (2019) [23]recorded the maximum in August (17.5%) and minimum in March (9.9%); Khan *et al.* (2025) [22] recorded peaks in May–July (85.7%, 84.4%, 86.0%) with the lowest in March (68.6%); Ahmad *et al.* (2013) [21] recorded the peak in June (23.4%) and the lowest in January (8.3%); Zeb *et al.* (2015) [25] found autumn (September–November) had the highest prevalence (16.5%) and winter the lowest (6.6%); Ullah *et al.* (2019) found August highest (21.4%) and January lowest (4.8%); Zaman *et al.* (2022) [20] found summer highest (35.1%) and winter lowest (11.7%); and Shan *et al.* (2024) [24] found September highest (22.4%) and January lowest (5.8%).

**Table 4. Peak and trough transmission months/seasons reported across studies.**

| Study | Peak month/season | Peak positivity | Trough month/season | Trough positivity |
|---|---|---|---|---|
| Ahmad *et al.*, 2013 | June | 23.4% | January | 8.3% |

| Study | Peak month/season | Peak positivity | Trough month/season | Trough positivity |
|---|---|---|---|---|
| Zeb *et al.*, 2015 | Autumn (Sep–Nov) | 16.5% | Winter | 6.6% |
| Shah *et al.*, 2016 | October | 5.0% | January | 1.9% |
| Dad *et al.*, 2019 | August | 17.5% | March | 9.9% |
| Ullah *et al.*, 2019 | August | 21.4% | January | 4.8% |
| Zaman *et al.*, 2022 | Summer | 35.1% | Winter | 11.7% |
| Shan *et al.*, 2024 | September | 22.4% | January | 5.8% |
| Khan *et al.*, 2025 | July | 86.0% | March | 68.6% |

**3.5 Geographic (Tehsil-Level) Distribution**

Six of the nine studies described the prevalence at tehsil level within seven tehsils of Lower Dir (Timargara, Balambat, Lal Qilla, Adenzai, Munda, Khall and Samarbagh). Interestingly, Timargara tehsil was found to be the highest prevalence tehsil in several studies (Dad *et al.*, 2019: [23] 16%; Ullah *et al.*, 2019: [19] 15.2%; Khan *et al.*, 2025: [22] 15.2%; and Shah *et al.*, 2016: [18] 9.3%). However, Samarbagh was the low-prevalence tehsil within four studies (Dad *et al.*, 2019: [23] 7.7%; Ullah *et al.*, 2019: [19] 9.6%; Khan *et al.*, 2025: [22] 9.6%; Shah *et al.*, 2016: [18]). One recent tehsil-focused study (Shan *et al.*, 2024) [24] reported 15.1% prevalence in Samarbagh. Ahmad et al. [21] (2013) reported 17.3%. from Lala Qilla. Zeb *et al.* 2015 [25] reported 13.4% from urban areas of Lower Dir, while 11% from rural areas.

**Table 5. Tehsil-wise prevalence comparison (selected studies reporting all seven tehsils).**

| Tehsil | Shah *et al.* 2016 | Dad *et al.* 2019 | Ullah *et al.* 2019 | Khan *et al.* 2025 | Shan *et al.* 2024 | Ahmad *et al.*2013 |
|---|---|---|---|---|---|---|
| Timargara | 76 (9.3%) | 16.0% | 15.2% | 15.2% | _ | _ |
| Lal Qilla | 45(5.5%) | 15.4% | 14.0% | — | _ | 17.3 |
| Khall | 46(5.6%) | 13.1% | 12.8% | — | _ | _ |
| Munda | 30 (3.7%) | 12.6% | 12.0% | — | _ | _ |
| Balambat | 62(7.6%) | 12.2% | 11.2% | — | _ | _ |
| Adenzai | 37 (4.5%) | 7.9% | 10.8% | — | _ | _ |
| Samarbagh | 28 (3.4%) | 7.7% | 9.6% | 9.6% | 15.1% | _ |

**3.6 Plasmodium Species Distribution**

Species-wise distribution was reported in all eight studies and showed the most uniform pattern of any determinant examined: *P. vivax* was the dominant species in every single study, ranging from 71% (Shan *et al.*, 2024) [24] to 99.5% (Ahmad *et al.*, 2013) [21] of positive cases, with *P. falciparum* consistently secondary (0.5–23.8%) and mixed infections reported only in a minority of studies and always at low frequency (1.7–8%; Table 6). No study identified *P. malariae* or *P. ovale* in the study population. This overwhelming and consistent predominance of *P. vivax* is attributed by multiple authors to the district's subtropical-to-temperate climatic zone, which favours *P. vivax* transmission and relapse (via hypnozoite reactivation) over the more tropically restricted *P. falciparum* [22, 23].

**Table 6. Plasmodium species distribution across studies.**

| Study | *P. vivax* (%) | *P. falciparum* (%) | Mixed infection (%) |
|---|---|---|---|
| Ahmad *et al.*, 2013 | 99.5% | 0.5% | Not detected |
| Zeb *et al.*, 2015 | 94.3% | 3.9% | 1.7% |
| Shah *et al.*, 2016 | 76.2% (of positives) | 23.8% (of positives) | Not detected |
| Dad *et al.*, 2019 | 92.8% | 7.2% | Not detected |
| Ullah *et al.*, 2019 | 90% | 10% | Not applicable |
| Zaman *et al.*, 2022 | 99.1% | 0.9% | Not detected |
| Shan *et al.*, 2024 | 71% | 21% | 8% |
| Khan *et al.*, 2025 | 75.8% | 15.1% | 3.9% |

### 3.7 Other Factors

Other factors such as low education, joint family structure, low income, and lack of modern sanitation were identified as determinants of malaria [49].

## 4 Discussion

Malaria is a vector-borne disease that is sensitive to climate, involving a number of hydroclimatic, biological, socio-economic, and environmental factors [27,28]. Malaria is hard to control and predict owing to the various determinants of malaria [29]. Successful risk factors in relation to malaria need to be identified to come up with effective management strategies [30]. Key factors such as education, poverty, income, and health facilities play a decisive role in the transmission of malaria [31,32]. Achieving success in malaria control is further complicated by the rising resistance of mosquitoes to insecticides used against them and changes in their behavior following control measures, as well as the alteration of the ecosystems by human activities. This shows the need to identify the entire range of factors impacting malaria in order to relieve the malaria-related burden on health care systems [33].

It is hard to control malaria in Pakistan due to the absence of qualified healthcare workers, laboratory facilities, and medications [34]. The application of both passive and active infection methods can greatly help in fighting malaria [35]. Having a reliable database could be used to scale up the malaria control and treatment programs in Pakistan [36]. Within this paper, we perform a broad literature analysis. It was revealed that malaria is significantly associated with the socio-demographic characteristics, including gender, age, season, geography, species of the parasite, size of a family, level of education, availability of sanitation, and income.

The median prevalence is 15%, while some hospital-based studies claim even higher figures, which demonstrates the huge burden for the healthcare system in Lower Dir. Khan *et al.* show that many factors, both environmental and socio-economic, contribute to the malaria prevalence [22]. Male prevalence exceeded female prevalence in Lower Dir. Male-to-female ratios ranged from 1.2:1 to 1.6:1. The possible reason for the higher number of cases in males compared to females may be attributed to greater occupational exposure to the malaria vector, as males are more likely to work outdoors in agricultural fields [21].

In Lower Dir, both adults and children are at risk of malaria. However, children are most prone to the disease as their immune system is not as strong [37,38]. Rural children may also be at a greater risk compared to urban children, as there is a difference in parents' education level and healthcare access [39]. Some other studies from Lower Dir suggest that there is a higher ratio of malaria cases in the adult population. This could be because it is the nature of their occupation and behavior that puts men at a greater risk of the disease [40].

The peak number of cases observed from June to October can be attributed to certain environmental factors affecting malaria transmission, such as temperature, rainfall, humidity, and vegetation. Factors

such as temperature, humidity, and rainfall are known to have a positive correlation with malaria incidents [41,42].

The highest number of cases have been observed in Timargara tehsil, indicating a live potential for ecological transmission in the area, although the exact reason for the clustering remains unknown. It can be assumed that the urbanization status of the tehsil and the presence of irrigation and stagnant water sites could somehow be linked to the rise in cases.

It was determined in all studies that *Plasmodium vivax* was the predominant species with a rate of occurrence between 71–99.5%. *P. falciparum* was second in occurrence (0.5–23.8%), while mixed infections were rare (≤8%). There were no cases of *P. malariae* or *P. ovale* infections. Some other researchers also specified that *P. vivax* was the leading cause of malaria in humans in Pakistan [43-47]. This could be explained by its prevalence in subtropical and temperate zones [48]. A study conducted in Khyber Pakhtunkhwa [49] revealed several additional factors such as poor education, joint family structure, low earnings, absence of modern sanitation facilities, and long distance from homes to hospitals, as other contributing determinants of malaria.

**5 Conclusion**

This comprehensive review brings together nine epidemiological studies carried out in District Lower Dir, Khyber Pakhtunkhwa, Pakistan, and provides an extensive evaluation of malaria prevalence and its determinants. The results indicate that malaria is still a serious public health problem in this area and has an average prevalence of approximately 15% among the residents. The data show that there are a number of interrelated factors that contribute to the prevalence of this disease.

The predominance of males in all studies (male-to-female ratio: 1.2-1.6:1) confirms the significance of the possibility of occupational exposure of workers, as men often participate in outdoor agriculture, experiencing a high degree of contact with Anopheles vectors during times of biting peak. This fact indicates that preventive measures should be taken to protect males of working age, e.g., the distribution of ITNs and personal protective equipment during the agricultural season.

A two-peaked pattern characterizes age susceptibility, with children who are younger than 10 years of age and adults who are younger than 40 years of age most affected by the disease. Children are affected due to their immature immune systems, whereas adults are affected due to their work exposure history. The dual nature of this issue requires distinct approaches: improved treatment methods for children as well as preventive measures for the at-risk working adults.

The behavior of seasonal transmission is very consistent in terms of peak cases during warm and humid months (June-October) and low transmission cases during cold and dry months (Dec-Feb). This seasonal pattern is also correlated with environmental factors such as rainfall, temperature, and humidity. The predictability of this seasonal phenomenon allows for expectations to be fulfilled with respect to pre-monsoon vector control operations and optimal drug distribution.

The geographic diversity is clear, as Timargara tehsil has consistently shown a high prevalence in many studies, suggesting that regionally specific ecological or socio-demographic factors such as irrigation methods, urbanization, and sites with stagnant water may be responsible for transmission. The Samarbagh tehsil appears to be an area with lower levels of risk. Nevertheless, the study carried out in Samarbagh shows that even in low-risk areas, transmission is clinically significant. It is important to understand the mechanisms behind this spatial variation in order to ensure efficient resource allocation.

The consistent result across all studies is that *P. vivax* overwhelmingly dominates in the samples analyzed (71–99.5 against *P. falciparum*), which corresponds to the subtropical and temperate climate in the region of Lower Dir, which promotes the transmission and relapses of vivax malaria through the reactivation of hypnozoites. This fact implies certain treatment procedures, since vivax malaria treatment requires both acute-stage treatment and radical cure to avoid future relapses of the disease. The significant absence of *P. malariae* and *P. ovale* indicates little introduction of those species to the studied territory, but vigilance should be maintained nevertheless.

Apart from biological factors, social and economic determinants like low education, poverty, joint families, poor sanitation, and lack of healthcare were found to contribute to the risk of malaria. This

reveals that controlling malaria does not involve vector control alone, but requires integration of poverty intervention, health literacy, healthcare infrastructure development, and disaster preparedness.

**Recommendations:**

1. Indoor residual spraying and the use of ITNs in hotspot locations like Timargara should be increased during the pre-monsoon period, i.e., April-May.
2. Improve the readiness of health facilities and ensure the stable supply of medicines in anticipation of peaks of Malaria transmission between June and October.
3. Preparation of preventive programs against Malaria for people working in the field, including the provision of ITNs and training of people on health matters.
4. Improving early detection and treatment of children (younger than 10 years) as part of community-based disease management and seasonal chemoprevention programs where applicable.
5. Ensuring the availability of primaquine to achieve radical cure from malaria and conducting tests for G6PD deficiency to avoid complications caused by hemolysis.
6. Involving malaria control in programs on fighting poverty, improving education and sanitation conditions.
7. Creation of early warning systems based on the combination of meteorological forecasts and malaria risk predictions to make prevention possible during floods.
8. Creation of efficient electronic monitoring systems to provide information on disease trends, outbreaks, and effectiveness of control measures.

## REFERENCES:


1. F. E. Cox, "History of the discovery of the malaria parasites and their vectors," Parasite Vectors, vol. 3, no.1, pp.1–9, 2010.
2. WHO. World malaria report 2019; 2019.
3. J. I. Nankabirwa, A. Yeka, E. Arinaitwe *et al.*, "Estimating malaria parasite prevalence from community surveys in Uganda: a comparison of microscopy, rapid diagnostic tests and polymerase chain reaction," Malar Journal, vol. 14, no. 1, p. 528, 2015.
4. Ali, B. and Hashmi, K.Z., 1997. Prevalence of malaria among Karachites. Past Present. Inf. Dis. J. Pak., 4-9.
5. R. W. Snow, C. A. Guerra, A. M. Noor, H. Y. Myint, and S. I. Hay, "(global distribution of clinical episodes of Plasmodium falciparum malaria," Nature, vol. 434, no. 7030, pp. 214–217, 2005.
6. Collins WE. *Plasmodium knowlesi*: a malaria parasite of monkeys and humans. Annu Rev Entomol. 2012; 57:107–21.
7. Gilles H, Warrell D. Diagnostic methods in malaria. Bruce-Chwatt's essential malariology. New York, NY: Oxford University Press; 1985.
8. Chin W, Contacos P.G, Coatney G.R, Kimball H R.A naturally acquired quotidian-type malaria in man transferable to monkeys. Science. 1965;149(3686):865.
9. Nayyar GM, Breman JG, Newton PN, Herrington J. Poor-quality antimalarial drugs in Southeast Asia and sub-Saharan Africa. Lancet Infect Dis. 2012;12(6):488–96.
10. Takken W, Scott TW (Eds.). Ecological aspects for application of genetically modified mosquitoes. vol. 2Springer Science & Business Media; 2003
11. Mohammad J, Rahim F, Ali S. Malaria: causal parasite and clinical features in pediatric patients. J Med Sci. 2014;22(1):39–42.
12. S.M. Malik, H. Awan, N. Khan, Mapping vulnerability to climate change and its repercussions on human health in Pakistan, Glob. Health 8 (1) (2012) 1–10.
13. Ministry of Health Pakistan, Epidemiology of Malaria in Pakistan. Ministry of Health Pakistan, 2010.
14. W.H.O., World Malaria Report, 2021.

15. Elagali A, Shubayr M, Noureldin E, Alene KA, Elagali AJTM, Disease I. Spatiotemporal distribution of malaria in the Kingdom of Saudi Arabia. Trop Med Infect Dis. 2024;9(1):16.
16. Chala B, Hamde FJFiph. Emerging and re-emerging vector-borne infectious diseases and the challenges for control: a review. Front Public Health. 2021; 9:715759.
17. DCR. District Census Report of Lower Dir, Population Census Organisation Statistics Division, Government of Pakistan, Islamabad, Pakistan; Pakistan Bureau of Statistics: Islamabad, Pakistan, 1998.
18. Shah, H., Khan, R., Naz, F., Haseeb, A., Jan, A., & Ullah, R. (2016). Prevalence and distribution of malaria parasites in the general population of district Lower Dir, Khyber Pakhtunkhwa, Pakistan. Journal of Entomology and Zoology Studies, 4(4), 1211–1215. https://www.entomoljournal.com/archives/2016/vol4issue4/PartM/4-4-50-720.pdf
19. Ullah, H., Khan, M. I. U., Suleman, S., Khan, S., Javed, S., Qadeer, A., Nawaz, M., & Mehmood, S. A. (2019). Prevalence of malaria infection in District Lower Dir, Pakistan. *Punjab University Journal of Zoology*, *34*(2). https://doi.org/10.17582/journal.pujz/2019.34.2.137.141
20. Zaman, N., Haq, F. U., Khan, Z., Uallah, W., Ualiyeva, D., Waheed, Y., Rizwan, M., Mahmood, R. T., & Mahmood, M. (2022). Incidence of malarial infection and response to antimalarial drugs in the districts of Lower Dir and Swat of Khyber Pakhtunkhwa, Pakistan. *Dialogues in Health*, *1*, 100035. https://doi.org/10.1016/j.dialog.2022.100035
21. Ahmad, T., Hussain, A., & Ahmad, S. (2013). Epidemiology of Malaria in Lal Qilla. International Journal of Scientific and Technology Research, 2(11), 199–202. https://www.ijstr.org/final-print/nov2013/Epidemiology-Of-Malaria-In-Lal-Qilla.pdf
22. Khan, F., Arifa, N. A., Riaz, S., Shabbir, R., Manzoor, F., Tariq, H., Hassan, A., Tariq, Z., & Khan, A. Q. A. (2025). Clinical spectrum and risk factors influencing pediatric malaria public health concern in District Lower Dir. *Journal of Medical & Health Sciences Review.*, *2*(2). https://doi.org/10.62019/hp9f9k43
23. Omer Dad, Mohammad Attaullah, Haseen Ullah, Rooh Ullah, Ikram Ilahi, Saeed Ahmad, Bashir Ahmad, Liaqat Ali, Sultan Zeb, 2019. Prevalence of malaria and status of Plasmodium spp. in Lower Dir, Pakistan. J. Biodiv. Environ. Sci., 15(2), 83-87. https://innspub.net/prevalence-of-malaria-and-status-of-plasmodium-spp-in-dir-lower-pakis tan/
24. Shan, F., Ullah, K., Khan, A., Rahat, A., Ali, S., & Khan, M. K. (2024). A comprehensive study on prevalence, species distribution, and influencing factors of malaria in Lower Dir, Pakistan. Journal of Health and Rehabilitation Research, 4(1), 1256–1260. https://doi.org/10.61919/jhrr.v4i1.554
25. Zeb, Jehan & Khan, Mian & Ullah, Naseer & Ullah, Hamid & Nabi, Ghulam & Aziz, Tariq. (2015). Epidemiology of Plasmodium Species and Prevalence of Malaria based on Age, Sex, Area, Seasonality, and Clinical Manifestation in the Population of District Lower Dir, Khyber Pakhtunkhwa, Pakistan. 10. 147-152. 10.5829/idosi.wjz.2015.10.2.93158.
26. Khan, M. I., Qureshi, H., Bae, S. J., Khattak, A. A., Anwar, M. S., Ahmad, S., Hassan, F., & Ahmad, S. (2023). Malaria prevalence in Pakistan: A systematic review and meta-analysis (2006-2021). *Heliyon*, *9*(4), e15373. https://doi.org/10.1016/j.heliyon.2023.e15373
27. Ebhuoma O, Gebreslasie M. Remote sensing-driven climatic/environmental variables for modelling malaria transmission in Sub-Saharan Africa. Int J Environ Res Public Health. 2016;13(6). https://doi.org/10.3390/ijerph13060584.
28. Fall P, Diouf I, Deme A, Diouf S, Sene D, Sultan B, Janicot S. Enhancing Understanding of the impact of climate change on malaria in West Africa using the Vector-Borne disease community model of the International Center for Theoretical Physics (VECTRI) and the Bias-Corrected phase 6 Coupled Model Intercomparison Project data (CMIP6). Microbiol Res. 2023;14(4):2148–80. https://doi.org/10.3390/microbiolres14040145.
29. Endo N, Eltahir EAB. Environmental determinants of malaria transmission in African villages. Malar J. 2016;15(1). https://doi.org/10.1186/s12936-016-1633-7.

30. Ouedraogo B, Inoue Y, Kambiré A, Sallah K, Dieng S, Tine R, Rouamba T, Herbreteau V, Sawadogo Y, Ouedraogo LSLW, Yaka P, Ouedraogo EK, Dufour JC, Gaudart J. Spatio-temporal dynamics of malaria in Ouagadougou, Burkina Faso, 2011–2015. Malaria J. 2018;17(1).
31. Labbo R, Fandeur T, Jeanne I, Czeher C, Williams E, Arzika I, Soumana A, Lazou Mar R, Duchemin JB. Ecology of urban malaria vectors in Niamey, Republic of Niger. Malar J. 2016;15(1). https://doi.org/10.1186/s12936-016-1352-0
32. Rouamba T, Nakanabo-Diallo S, Derra K, Rouamba E, Kazienga A, Inoue Y, Ouédraogo EK, Waongo M, Dieng S, Guindo A, Ouédraogo B, Sallah KL, Barro S, Yaka P, Kirakoya-Samadoulougou F, Tinto H, Gaudart J. Socioeconomic and environmental factors associated with malaria hotspots in the Nanoro demographic surveillance area, Burkina Faso. BMC Public Health. 2019;19(1). https://doi.org/10.1186/s12889-019-6565-z.
33. Mattah PAD, Futagbi G, Amekudzi LK, Mattah MM, De Souza DK, Kartey Attipoe WD, Bimi L, Wilson MD. Diversity in breeding sites and distribution of Anopheles mosquitoes in selected urban areas of Southern Ghana. Parasites Vectors. 2017;10(1). https://doi.org/10.1186/s13071-016-1941-3.
34. S. Kurd, M.I. Yasinzai, M. Naseem, *et al.*, Prevalence of human malarial infection in school-going children of district Khuzdar (city), Balochistan. Intern. J. Mosq. Res. 6 (2019) 120–123.
35. S. Zoghi, A.A. Mehrizi, A. Raeisi, *et al.*, Survey for asymptomatic malaria cases in low transmission settings of Iran under elimination programme, Malar. J. 11 (1) (2012) 1–10.
36. M.I. Yasinzai, J.K. Kakarsulemankhel, Incidence of human infection in northern hilly region of Balochistan, adjoining with NWFP, Pakistan: district Zhob, Pakistan. J. Biol. Sci. 11 (12) (2008) 1620–1624.
37. Zuberi UF, Aqeel S, Hashmi F, Khan W. Altered hematological parameters in children with malaria infection, a systematic review and meta-analysis. Diagnostic Microbiology and Infectious Disease. 2024 Apr 1;108(4):116190. https://doi.org/10.1016/j.diagmicrobio.2024.116190.
38. Hussain N, Rayaz S, Akhtar AN, Hanif M, Habib G. Clinical Presentation and Outcome in Children Admitted with Severe Malaria. Indus Journal of Bioscience Research. 2025 Mar 17;3(3):244-8. https://doi.org/10.70749/ijbr.v3i3.845.
39. Diabaté S, Druetz T, Bonnet E, Kouanda S, Ridde V, Haddad S. Insecticide-treated nets ownership and utilization among under-five children following the 2010 mass distribution in Burkina Faso. Malar J. 2014;13(1). https://doi.org/10.1186/1475-2875-13-353.
40. C. Cotter, H.J.W. Sturrock, M.S. Hsiang, *et al.*, The changing epidemiology of malaria elimination: new strategies for new challenges, Lancet 382 (9895) (2013) 900–911.
41. Gbaguidi, G. J., Topanou, N., Filho, W. L., Begedou, K., & Ketoh, G. K. (2025). Environmental and socio-economic determinants of malaria transmission in West Africa: a systematic review. One Health Outlook, 7(1), 47. https://doi.org/10.1186/s42522-025-00158-4
42. M'Bra RK, Kone B, Soro DP, N'Krumah RTAS, Soro N, Ndione JA, Sy I, Ceccato P, Ebi K, Utzinger J, Schindler C, Cisse G. Impact of climate variability on the transmission risk of malaria in Northern Côte d'Ivoire. PLoS ONE. 2018;13(6). https://doi.org/10.1371/journal.pone.0182304.
43. Yasinzai MI, Kakar Suleman Khel JK. Incidence of human malaria infection in desert area of Pakistan: District Kharan. Journal of Agriculture and Social Sciences. 2008; 4:39-41.
44. Ibrahim, Saeed K, Khan S, Akhtar N. Epidemiological findings of malaria in District Buner, Khyber Pakhtunkhwa, Pakistan. World Journal of Medical Sciences. 2014; 11(4):478-482.
45. Khan SN, Ayaz S, Khan S, Attaullah S, Khan MA, Ullah N *et al.* Malaria: still a health problem in the general population of Bannu District, Khyber Pakhtunkhwa, Pakistan. Annual Review and Research in Biology. 2013; 3(4):835-845.
46. Awan ZR, Khan AK, Shahm AH, Suleman M, Khan MA. Assessment of malaria prevalence among school children in rural areas of Bannu District, Khyber Pakhtunkhwa, Pakistan. Pakistan Journal of Zoology. 2012; 44(2):321-326.

47. Majid A, Rehman M, Ahmad T, Ali A, Ali S, Ali S, *et al*. Prevalence of malaria in the human population of District Mardan, Pakistan. World Journal of Zoology. 2016; 11(1):63-66.
48. Wilcock C, Manson Bahr PEC. Manson tropical disease. 17th ed. William and Wilkins Co. Baltimore, USA, 1972
49. Haq, I. U., Mehmood, Z., Muhammad, A., Akhtar, S., Aboagarib, E. A. A., Zaib, A., Ahmed, S. A. M., Huwaikem, M., Khan, G. A., Albugami, H. F., Ahmed, B., & Qu, S. (2026). Determinants of malaria infection across different districts of Khyber Pakhtunkhwa, Pakistan: a cross-sectional study. Malaria journal, 25(1), 102. https://doi.org/10.1186/s12936-025-05731-w