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RISK FACTORS FOR MALARIA INCIDENCE IN DISTRICT DIR LOWER KHAYBER PAKHTUNKHWA PAKISTAN

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ABSTRACT

This research shows that malaria is still a public health issue in District Dir Lower, Pakistan. This work aims to examine the seasonal distribution, demographic susceptibility, geographical prevalence, and other factors related to malaria epidemics of the past one year. Self-reported malaria was highest in July at 23.27% and lowest in December at 1.72%, based on data gathered between August of the previous year and July of the current year. It showed that malaria was highest in the monsoon season of July-August and reduced towards the last quarter of the year.

The results also reveal that children 0-15 years had the highest proportion of malaria infections at 36.17% and the 31-45 years adults at 25.58%. Thus, the prevalence rate among the older adults (> 45 years) was observed to be relatively low (18.01%). These results show that malaria affects individuals belonging to a younger generation more than those of an older age. From the geographical point of view, Tehsil Khall had the highest percentage of Malaria positivity. It was 31.12%, the Tehsil Timergara 24.57%. Other districts like tehsil Balambat, tehsil Lal Qilla, and tehsil Adenzai had low rates of positives. These geographical differences imply the use of poverty-oriented malaria control measures in the affected regions. As seen earlier, there is a predominance of P. vivax with 85·15% compared with mixed infection with 14·85%. The use of an independent DT 139 shows that the control of malaria should now be based on species, and that Plasmodium vivax represents a major problem. Of the pregnant women, 53.45 % were infected with Plasmodium vivax; hence the need to address this populace. The study of cases by their category found that 40.78% of them were in patients under 15 years old and mostly had vivax malaria, while 17.72% were persistent. The fact that the cases have continued to manifest shows that transmission is still active and treatment, as well as control measures, should continue. The findings of risk factor analysis revealed that several factors predisposed people to malaria transmission. The history of travel within the last two weeks was established in 76.94% of patients hence travel is emerging as one of the main risks. Like the above results, outdoor activity (72.33%) and the presence of domesticated animals (88.76%) were found to correlate with a high prevalence of malaria. Moreover, the similar location, and specific items

like the type of walls and ceiling at home also show the high possibility of being infected. In general, this study stresses some aspects of malaria epidemiology in District Dir Lower. The large fluctuations noted about seasonal, geographic, and demographic factors thus imply the need for finely tuned control and improved public health measures. Reduction of identified risk factors as well as enhanced surveillance will be imperative for excellent malaria care and reduction in the region.
Keywords: *Malaria, Disease transmission, predisposing factors*

INTRODUCTION

Malaria is still listed among the most important health issues in terms of morbidity and mortality, especially in low- and middle-income countries among Communities where poverty and disease prevalence are correlated. Although much progress has been made in the last few decades, malaria remains a major burden to the health and economies of countries within and outside Africa. Knowledge about the relationship between malaria infection and different Plasmodium species and sociomedical characteristics is crucial for further disease control and prevention (Okell et al., 2016). Malaria is not a disease that is limited by geographical regions or affected uniformly, some areas are positively charged with malaria, and others that are not due to one or the other. Essential information for allocating resources and interventions to areas of greatest need is the basis of accurate estimates of malaria incidence (Okell et al., 2016). Several epidemiological works have noted that there is a need to enhance the surveillance and data collection measures for purposes of tracking the level of progression of malaria over time (Alemu et al., 2013).Malaria is caused by parasites of the genus Plasmodium, with five species known to infect humans: There are five types of malaria parasites recognized including Plasmodium falciparum, Plasmodium vivax and Plasmodium malaria, Plasmodium of the species within districts, all the aforesaid species are present in the region with Plasmodium falciparum and Plasmodium vivax being the most common species in the world and have a broad distribution (Mendis et al., 2009). Knowledge of the geographical localization of Plasmodium species is important for designing interventions for specific areas as well as populations (Gething et al., 2012). Plasmodium's life cycle involves different transactions between the human boldness and the mosquito which has many stages including sporozoites, merozoites, and gametocytes (Prudêncio et al., 2006). 535 species have been identified, and only 6 species infect humans, among which P. falciparum and P. vivax are known to be the most dangerous ones in terms of public health risks, according to WHO (2021).The human disease caused by Plasmodium parasites is conveyed through the bite of infected female Anopheles mosquitoes pointing to the complex ecological process involved in malaria transmission (World Health Organization, 2021). The knowledge of Plasmodium's biology and pathogeny is therefore very critical in designing strategies for disease control that include the use of vaccines, drugs, and vector control measures among others (Prudencio et al., 2006). Besides, the ability of Plasmodium to modify mechanisms that counteract activities of the human immune system and the development of congenital resistance to common antimalarial drugs also poses newer difficulties in the control of malaria and emphasizes why research should continue in this area (Prudencio et al., 2006; World Health Organization, 2021).Socioeconomic determinants are central to the design of how malaria is spread. The disease affects poor individuals who have little access to health, live in poor housing, and have low education levels (Gosoniu et al., 2010). Besides, mathematical inequalities lead to equally disparate access to malaria-preventing measures, including insecticide-treated bed nets and antimalarial medications, worsening malaria impacts in disadvantaged populations (Castro et al., 2020).

The purpose of this study is to explain interactions between malaria prevalence, Plasmodium species distributions, and socioeconomic conditions. In the present study, we use extensive databases and state-of-the-art modeling techniques in epidemiology to determine risk factors for changes in malaria transmission rates (Griffin et al., 2010). Therefore, our results will be useful in designing appropriate prevention and control measures to prevent malaria incidents and improve the quality of life of affected communities (Nankabirwa et al., 2020).

Malaria transmission in Pakistan is accomplished mainly by several species of Anopheles mosquitoes. Anopheles stephensi and Anopheles culicifacies which are neighbors affect urban areas like Karachi and with changes in the environment adapt more to the malaria transmission. Anopheles culicifacies is another vector residing in both rural and peri-urban agricultural areas and mainly transmits both the PV and Pf

parasites and has a substantial contribution to developing malaria transmission throughout the country. Furthermore, Anopheles fluviatilis which is predominant in rural and forest-inhabiting areas of Pakistan, plays its part in contributing to malaria in areas where environmental premises make it possible for Anopheles fluviatilis to breed. All these species combined, augment the number of ecological niches that are reused by malaria vectors in Pakistan and therefore, call for specific measures that should be taken and implemented to control the transmission off Malaria in the country.
Find out malaria rate now and know the potential causes of it.
Anopheles can be subdivided into species and the regions should be analyzed to identify the various species. Study the pattern of transmission of malaria by season and assessing the efficacy of traps in mosquito management.

METHODS AND METHODOLOGY

Study Area

District Dir Lower is one of the provinces of Khyber Pakhtunkhwa in Pakistan; it has geographically diverse terrains and consists of multivariate people of distinct social-class status.

Sampling Strategy

Consequently, a multi-stage sampling technique of which would facilitate representative sampling across various demographic and random selection of clusters like villages or some urban areas in the district. Random selection of households within certain clusters of dwellings chosen in the sample. Every eligible person within a selected household was asked to come for the study.

Plasmodium Identification:

Blood samples taken through venous puncture or through utilizing a lancet on fingertip, in a routine fashion. RDTs for first-line malaria diagnosis Rapid diagnostic tests perform well as malaria first-line diagnosis. Microscopic preparations of the blood smears, slide preparations from the peripheral thick blood smear and the thin blood film stained with Giemsa's stain. PCR for species confirmation and subtyping.

Socioeconomic Data Collection:

Socioeconomic demographic questionnaires to acquire structured responses. These are standard demographic attributes such as income level that the people in the household possess, level of education the people have attained, their sources of income or more commonly their job status, the type of housing most members own, the proximity to or accessibility to healthcare facilities, age, gender, and number of people in each household.

Data Analysis

Preliminary analyzed data by descriptive frequency for selected demographic features, malaria rate and Plasmodium species, as well as socioeconomic factors. Statistical measures based on bivariate and multivariate designs (chi-angle; logistic analysis) to investigate relationships. Geographical information system (GIS) in identifying Malaria incidence. Meaningful analysis on the qualitative data arising from the survey questionnaire.

Ethical Considerations

Acquire proper ethical clearance and consent Maintain anonymity of participant and manage potential risks at the time of data collection. Consider and declare possible systematic and method-based sources of biases and limitations, such as cross-sectional study design, or self-reported data.

Demographic Insights

Examining the malaria distribution according to the age shows that malaria affects children under fifteen years of age, 36.17% of the total cases. This is much higher than global adults aged 16–30 years (20.24%) and 31–45 years (25.58%) and highlights the importance of personal protection among young people. This age group's vulnerability can therefore be further supported by the p-value of < 0.0023. Group C, comprising adults above 45 years, has the lowest prevalence of 18.01 % mostly because they could have developed immunity to the disease. The focus should be made on child-oriented prevention activities such as primary prevention, early screenings, and prevention interventions to improve its health.

Result

Seasonal Trends

For the total and the differently ranked patients, malaria also shows seasonal contact, with the contacts significantly highest during July and August which are the monsoon time of the year with 23.27% and 16.49% respectively. This rise mimics the increase in wet and humid weather that has suitable environment for breeding of the malaria transmitting mosquitoes. However, prevalence is low during the dry season of December (1.72%) and November (2.96%) indicating low vector borne activity in those months. The analysis highlights a profound requirement for the enhancement of vector control and preventive interventions when monsoon is at its peak. Measures aimed at controlling malaria transmission during these months could be provided to reduce malaria incidence during the one (1) period thus decreasing transmission.

Geographic Distribution

This paper also shows that tehsil-level categorization of malaria occurrence is highly dichotomized. The highest Literacy rates are displayed in Tehsil Khall 31.12% and Tehsil Timergara with 24.57 %. Tehsil Balambat recorded 15.63%, Lal Qilla 9.08%, Tehsil Munda 5.41 %, and Samarabagh 6.05%, he calculated p value < 0.003 for Tehsil Khall means that this area has relatively higher malaria rate and warrants more control. These geographic disparities show that intervention measures must be introduced at the tehsil level because they are risky for different levels and transmission rates vary.

Plasmodium Species Analysis

The analysis also revealed that vivax malaria accounted for 85.15percent of the total malaria cases while mixed accounted for only 14.85 percent. The high frequency of P. vivax together with the p-value <0.0012 calculates its importance for the epidemiological considerations of malaria in this region: The clinical picture and progression of this species suggests different problems, such as the rupturing of relapses happening at the liver stages, which form tissues of the host and hence require selective diagnostic and treatment methods. There must be concern on cases of mixed infections like P.vivax and P. falciparum although severe and their incidences are relatively low. Measures of management cannot assume to avoid P. vivax while have consciousness on mixed species parasite infection.

Pregnancy and Malaria

Pv was identified in pregnant women at a higher prevalence of 53.45%, followed by mixed species with 30.70%. The observed p-value < 0.0001 again shows that pregnant women are susceptible to malaria as confirmed by the elevated risk score of P.vivax. Malaria can cause serious illness to both the pregnant woman besides the unborn child. These measures carried out entail that women and children remain at a high risk therefore prevention measures should entail; adequate antenatal checkups, availability of appropriate antimalarial drugs; and insecticide treated mosquito nets for the protection of young mothers and children.

Case Categories

Case category analysis yields additional information on malaria trends that is summarized below. The vivax malaria affects children below 15years of age more with 40.78% affection rate while those who are above 15years have 39:91% affection with mixed infections. The reoccurring cases make up 17.72% and go to proof of steady probability that the infections recur. New attacks are low (1.59%), of which this suggests that most people may contract malaria after having attained their first encounter. Such outcomes bring into question the necessity for scrutiny into further follow-up and compliance to ensure reoccurrence and chronicity are forestalled.

Risk Factors

Results of the cross-sectional data gathered identify risk factors that are operative at the community level in malaria transmission. Again, seventy-six-point ninety-four percent are associated with such people who have travelled within the last six months, a fact that points towards specific protective measures for travelers. Other comorbid factors are also unassociated with unemployment (46. Invalid%), agriculture (18.62%) and work (7.69%). Several housing characteristics were observed to affect malaria risk including types of walls 31.05% were stone/mud while types of ceiling 33.21% were wood. The distribution exposes a higher prevalence in rural (58.65%) rather than urban settings (41.35%) and having domesticated animals (88.76%) as potential risk factors. Specific behavior, namely physical activity (outdoor 72.33%) and the use of ground coverings for sleeping (21.04%) increases the risk. The results presented in this paper point towards the current directions and demand sound PPAs with multifaceted and well-coordinated approaches targeting environmental, behavioral and socioeconomic factors.

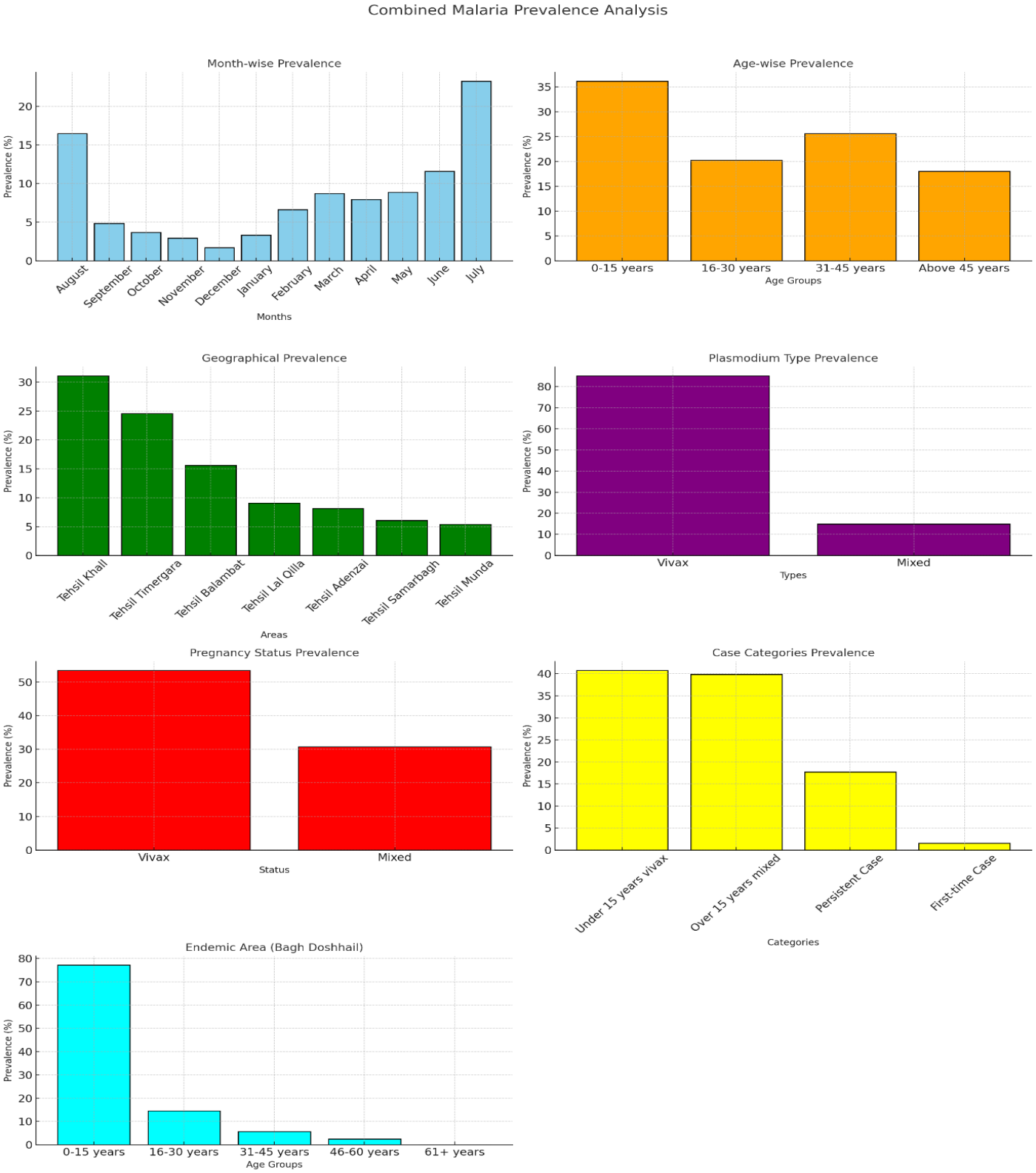
Conclusion

These trends and factors are vital depictions of malaria prevalence, and they provide the much-needed background knowledge for developing specific intervention measures. Larger numbers of vectors are produced in monsoon months, hence calling for increased vector control; variations in demography, and geography that point to the need for population specific and area specific approaches. The elimination of malaria requires targeting such risk groups as children, pregnant women or inhabitants of rural areas. Public health interventions can effectively reduce the instances of malaria transmission and enhance the general health of the said areas when they correspond the resources with the detected trends of risks. This paper employs, and presents recognized and novel, qualitative and quantitative methodologies to study the malaria and their relations with the socioeconomic factors in District Dir Lower, Pakistan. The findings could serve the purpose of offering selective malaria control measures a .and help improve the general health of people in the region.

Malaria Prevalence Table

Category	Subcategory	Infected Individuals	Prevalence (%)	P-value
Month-wise Prevalence	August	229	16.49%	-
	September	67	4.83%	-
	October	51	3.68%	-
	November	41	2.96%	-
	December	24	1.72%	-
	January	46	3.31%	-
	February	92	6.63%	-
	March	121	8.72%	-
	April	110	7.93%	-
	May	123	8.87%	-
	June	161	11.59%	-
	July	323	23.27%	-
	Total	**1388**	**100%**	-
Age-wise Prevalence	0-15 years	502	36.17%	<0.0023
	16-30 years	281	20.24%	-
	31-45 years	355	25.58%	-
	Above 45 years	250	18.01%	-
	Total	**1388**	**100%**	-
Geographical Areas	Tehsil Khall	432	31.12%	<0.003
	Tehsil Timergara	341	24.57%	-
	Tehsil Balambat	217	15.63%	-
	Tehsil Lal Qilla	126	9.08%	-
	Tehsil Adenzai	113	8.14%	-
	Tehsil Samarbagh	84	6.05%	-
	Tehsil Munda	75	5.41%	-
	Total	**1388**	**100%**	-
Plasmodium Type	Vivax	1182	85.15%	<0.0012
	Mixed	206	14.85%	-
	Total	**1388**	**100%**	-
Pregnancy Status	Vivax	742	53.45%	<0.0001
	Mixed	426	30.70%	-
	Total	**1388**	**100%**	-
Case Categories	Under 15 years vivax	566	40.78%	<0.025
	Over 15 years mixed	554	39.91%	-
	Persistent Case	246	17.72%	-
	First-time Case	22	1.59%	-
	Total	**1388**	**100%**	-
Risk Factors	Travel History (Yes)	1068	76.94%	-
	Travel History (No)	320	23.05%	-
	Unemployed	642	46.25%	-
	Agriculture	257	18.52%	-
	Labor	108	7.78%	-
	Others	358	25.79%	-
	Stone/Mud Walls	431	31.05%	-

	Bricks/Cement Walls	957	68.95%	-
	Wood Ceiling	461	33.21%	-
	Concrete Ceiling	927	66.79%	-
	Rural	814	58.65%	-
	Urban	574	41.35%	-
	Domesticated Animals (Yes)	1232	88.76%	-
	Domesticated Animals (No)	156	11.24%	-
	Outdoor Activities	1004	72.33%	-
	Indoor Activities	384	27.67%	-
	Sleeping on Ground (Yes)	292	21.04%	-
	Sleeping on Ground (No)	1096	78.96%	-
	Total	**560**	**100%**	-


Combined Malaria Prevalence Analysis
Month-wise Prevalence
Prevalence (%)
August
September
October
November
December
January
February
March
April
May
June
July
Months
Age-wise Prevalence
0-15 years
16-30 years
31-45 years
Above 45 years
Age Groups
Geographical Prevalence
Tehsil Khall
Tehsil Timergara
Tehsil Balambat
Tehsil Lal Qilla
Tehsil Adenzai
Tehsil Samarbagh
Tehsil Munda
Areas
Plasmodium Type Prevalence
Vivax
Mixed
Types
Pregnancy Status Prevalence
Status
Case Categories Prevalence
Under 15 years vivax
Over 15 years mixed
Persistent Case
First-time Case
Categories
Endemic Area (Bagh Doshhail)
46-60 years
61+ years

Discussion

District Dir Lower malaria epidemiology shows several important insights into examining the malaria disease patterns in this area. This incursion is seen to have a direct correlation with malaria prevalence in the year due to its capacity to fluctuate because of weather changes; it rises steeply in July and August when it was monsoon season, and it gradually deteriorates towards the year end. Impacts are higher among children particularly aged 0-15 years hence requiring age sensitive approaches. Interestingly, Tehsil Khall and Tehsil Timergara have the highest prevalence among beneficiaries, which can be noticed to be a focus area, a hotspot. It evidenced that Plasmodium vivax constituted a greater part of parasites; however, pregnant women were infected significantly, suggesting that the prevention and therapeutic strategies should be targeted on these patients. Recurring malaria incidence and other potential exposure indicators like travel within the past 2 weeks, outdoor exposure, and residing in a rural area aggravate the control process. The study highlights all-season and all-age malaria transmission, dependent greatly on regions and population density. The observed fluctuation in malaria incidence in the monsoon season, with more pronounced rates of increase in July (23.27%) and August (16.49%) is well explained in malaria literature. Seasonal fluctuation in the of malaria transmission is greatly influenced by environmental factors such as rainfall since it improves mosquito breeding environment. This finding resonates with Gething et al., who provide evidence on how monsoon rain somehow increases malaria incidence in an area, this is because the monsoon rain provides suitable breeding environment for mosquitoes (Gething et al., 2012). A sharper decrease in the percentage of malaria cases towards the end of the year or early months of the next year especially in December (-1.72%) supports seasonal variations in malaria transmission that recommends that efforts to control the disease should be strengthened when the weather condition is best suited to the transmission process.

Regarding the distribution of the age groups, it is even alarming that children between the ages of 0 to 15 years represent 36. 17% of the infected

people, and such statistics are also expected. Nankabirwa et al., (2020) state in their earlier research that children are at a higher risk of getting malaria through increased mobility and presence in open spaces besides having low immune systems (Nankabirwa et al., 2020). Similarly, Mendis et al. (2009) also substantiates this assertion pointing out that children are at a higher risk due to health risks to the environment as well as immunological factors (Mendis et al., 2009). These results indicate the importance and significance of further malaria interventions towards the young age group.

The contingency table and annotated bars also show regional differences in malaria infection, Tehsil Khall recording the highest infection rate of 31.12% and Tehsil Timergara 24.57%. Going contrary to this observation, Gosoniu et al noted that they used geostatistical modeling to determine the widespread places and stressed that enhanced interventions should be made locally (Gosoniu et al., 2010). Further, Castro et al. (2020) have likewise shown that malaria control programme using spatially targeted methods in regions that have high prevalence are effective which is more in line with the proposition that control programme should be intensified in regions where transmission rates are high (Castro et al., 2020).

Specificity of challenges posed by P.vivax can be seen from fact that it contributes to 85.15% of your total infections as identified in your study. This is in accordance with Mendis et al., (2009) on the global burden of P vivax and vector control with challenges of relapse. Okell et al. (2016) also described what sort of submicroscopic infections play a role in malaria control and might be responsible for the continued prevalence of P. vivax in the populace (Okell et al., 2016). This is a realization to compel the development of better treatment and remission plans.

The highest percentage of P. vivax among pregnant women (53.45%) in your study calls for intervention on maternal health. Rogerson et al (2018) stressed on high malaria infection in Pregnant women and need for special intervention to save both mother and child (Rogerson et al., 2018). This underlines the need for presenting Malaria control and treatment innovations in maternal health to limit malaria effect on pregnant women.

Thus, the distribution of malaria cases according to malaria type and age where 76.32% of children had vivax malaria, 17.72% of the cases were persistent as identified by Bejon et al (2010). Their findings on stable and

unstable malaria vicinities and on persistent malaria infections evidences the continued transmission risks and monitoring and treatment needs (Bejon et al., 2010). These must be eliminated to arrest the transmission cycle and, in the process, reduce the causality rate due to malaria.

Finally, the five identified risk factors; travel within the last two weeks (76.94%), engagement in outdoor activities (72.33%) and domesticated animals (88.76%) are supported by Tatem, Smith and co-authors who used mobile phone imagining and modelled estimate of travel on commune malaria risk (Tatem, Smith & Snow, 2013). In addition to the main focuses on genomic structures of Plasmodium parasites, synthetic studies by Bousema et al. have also underlined the need to identify environmental and behavioral factors of malaria to develop efficient prevention strategies (Bousema et al., 2012). From these studies, it can therefore be deduced that measures targeting the identified malaria risks; travel, outdoor stay and environments that support mosquito breeding should be incorporated into malaria control measures. Indeed, the results portray a host of factors, including seasonal variation, age, region, and environmental factors that affect malaria transmission. Malaria control should therefore be deployed depending on individuals, geographical regions, Plasmodium species and any other specific risk factors. The combination of these features into the approaches governing public health will prove central to combating malaria and ameliorating total health in affected areas.

Recommendations

Targeted Interventions in High-Prevalence Areas: Increase coverage of preventive and control interventions especially Insecticide Treated Bed Nets in Tehsil Khall and Tehsil Timergara. The high prevalence rates of both disorders indicate that localized interventions will effectively manage the problem.

Age-Specific Strategies: More so since children under 15 years had the highest rates of infection, there is need to create and implement special malaria prevention/treatment programs for this group. School-based health programs, along with improvements and expansions in the availability of diagnostic and treatment services are essential.

Enhanced Surveillance and Data Utilization: Extending co-observatory networks to follow seasonal and geographical patterns of malaria more efficiently. Use data to respond early and adjust the approach depending on trends emerging across the population.

Pregnant Women Focus: Analyses from this study call for programs that can prevent and remedy vivax malaria in pregnant women. Therefore, improve coverage of malaria related services through integration with maternal and child health services.

Address Risk Factors: This could be achieved by encouraging behavioral changes to reduce exposure and increase any vector control measures if there was travel history or increased involvement in activities such as camping. It is about thinking over ways to reduce such risks connected with dwelling in rural areas and certain housing conditions.

Public Awareness and Education: There is a need to enhance knowledge among the public to adopt malaria prevention measures, especially in the vulnerable regions. This means that information, education, campaigns, should comprise the necessity of nets in bed, spry in houses and rapid diagnosis of symptoms.

Research and Adaptation: Continued funding for research work to enhance the knowledge about malaria transmission and the need to adjust the strategies developed hence forward. There Is also a need to promote research in submicroscopic infections and their involvement in the chronicity of diseases.

Author Contributions

The authors of this study—Dr. Muhammad Nisar, Fawad Khan, Faryal Syed, Dr. Muhammad Anas, Dr. Muhammad Saad, Samina Yasmin, Inam Ullah, and Dr. Gul Zamin Khan—each contributed their expertise and efforts to the research, bringing diverse perspectives to the project. Dr. Muhammad Nisar and Dr. Muhammad Anas provided invaluable clinical insights, while Fawad Khan and Inam Ullah contributed significantly to the data analysis and technical aspects. Faryal Syed and Samina Yasmin played key roles in literature review and contextualizing the findings within the broader research landscape. Dr. Muhammad Saad expertise in statistical analysis helped refine the methodology, ensuring robust results. Dr. Gul Zamin Khan leadership and guidance

throughout the study ensured the smooth integration of all these contributions, making the research a comprehensive and impactful piece. Together, their collaboration exemplifies the power of interdisciplinary teamwork in advancing scientific knowledge.

Conflicts of interest

declare that there is no conflict of interest regarding the research. Each author has contributed equitably to the study, ensuring impartiality in the design, execution, and interpretation of the findings.

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