An Exploratory Case study of the effect of Ecology on Malaria Risk Factors in Northern Pakistan

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Abstract

Malaria vector mosquito population and its ability to transmit the disease is greatly influenced by the ecology of an area, which provide suitable breeding habitats for increasing its population. Areas having similar climatic conditions may differ in ecological conditions which can affect the malaria transmission factors, thus leading to different vector control strategy to control malaria transmission in an area. Present study is conducted by using a cross-sectional approach to investigate various malaria risk factors in two ecologically dissimilar districts of Khyber Pakhtunkhwa, Pakistan. Closed-ended question is employed to collect data from 2854 and 1944 randomly selected individuals of District Charsadda and Swabi respectively from December to August. Association between various possible malaria risk factors and history of malaria infection is measured by a univariate logistic regression analysis. Plasmodium vivax *is found to be the dominant species causing infection in the local population. Factors like gender, marital status, sleeping habits, irrigated fields, windows mesh, house material made of and animals in home showed a significant relationship ($P<0.05$) to malaria transmission in district Swabi, while parameters like previous infection, sleeping habits, family history, outdoor night roaming, use of bed nets, use of repellents, use of residual sprays, irrigated fields, animals in home, house material made of and windows mesh are found significant ($P<0.05$) to malaria transmission in district Charsadda. Current study provides some basic guidelines by identifying the potential risk factors in the two districts having diverse ecology to plan an effective and comprehensive strategy for reducing malaria disease burden in these districts.*

***Keywords**:* Charsadda; Swabi; Ecology; Malaria Transmission; Risk Factors.

Introduction

Malaria is endemic in approximately 130 countries around the world. The disease results in mortality and severe disability among the afflicted communities, particularly in Africa. In 2001, the World Health Organization (WHO) ranked malaria as the eight highest contributors to the global disease burden as reflected in disability-adjusted life years (DALYs), and the second highest in Africa. There

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are about 300 to 500 million malarial infections and one million malaria attributed deaths worldwide each year. About 90% of these deaths occur in Sub-Saharan Africa, and majority of them include women and children (Sahar et al., 2015; WHO, 2017).

Among more than 200 million population of Pakistan approximately Ninety-five million people making roughly 60% of the country population, live in malaria-endemic areas of the country. Floods affecting a significant population of the country has been among the major causes of an increase in malaria cases in the endemic areas. Despite of well-established malaria control programme, annually 500,000 malaria cases with 50,000 deaths has been attributed to this deathly disease in Pakistan with approximately 1/3rd of the cases been estimated to occur in regions bordering Iran and Afghanistan (WHO, 2017).

Majority of malaria infection accounting for approximately 80% of total infections in this part of the world are caused by *Plasmodium vivax* while approximately 1/5th of the infections are accounted for *Plasmodium falciparum*; the two prevalent *Plasmodium* species in Pakistan (Javid, 2015). A bimodal presentation of malaria infection due to *Plasmodium vivax* has been observed in Pakistan peaking in April and May and then again in August to October, while relapses of the infection transmitted in previous seasons are observed during the off season. On the contrary the peak transmission period for *P. falciparum* is from August to December (Khattak, 2013).

In Pakistan *P. vivax* has been attributed to majority of malaria infections, however a shift in trend has been observed during past few decades where a rise in *P. falciparum* infection has been observed accounting for approximately 31% of the total malaria infections (Kakar, 2010). This rise in *P. falciparum* cases reported from various parts of Pakistan might be partially attributed to development of drug resistance in this species. As changes occur both in parasite as well as human population, therefore monitoring the disease burden and distribution of malaria parasite species in Pakistan is necessary to ensure proper treatment particularly in those situations where appropriate diagnostic techniques are not available (Khattak, 2013).

In Pakistan out of 23 species of *Anopheles* (Aslam khan, 1971), only few species act as vector of *Plasmodium* and can transfer this protozoan parasite from one human to another. *An. stephensi* has been considered as major vector of malaria in urban whereas *An. culicifacies* act as vector of this disease in rural areas (Ali and Rasheed, 2009). Other species like *An. maculatus, An. nigerimus, An. superpictus* and *An. subpictus* act as a vector in Baluchistan (Anonymous, 2014), while *An. fluviatilus, An. splendidus, An. stephensi* and *An. culicifacies* have been regarded as vector of malaria in Charsadda district of Khyber Pakhtunkhwa through serological tests and systematic operational research (Ali et al., 2015). In Swabi both

An. stephensi and *An. culicifacies* had been reported from malaria endemic area of the district (Yousafzai, 1994) but no study has been conducted to date regarding incriminating the vector of malaria in the district.

Keeping in view the ecological differences between the districts of Charsadda and Swabi, present study is designed to determine the period prevalence of malaria in these two malaria endemic areas of KP along with identifying the risk factors associated with the transmission of diseases in the study area.

Methods

Study Area

Khyber Pakhtunkhwa (KP) is one of the four administrative provinces of Pakistan located in the north west of Pakistan. Administratively it is divided into 27 districts but after the merger of Federally Administered Tribal Areas (FATA) in Khyber Pakhtunkhwa the number of districts increased to 34. Both KP and FATA have malaria endemic regions. Two Districts of KP: Charsadda and Swabi (Figure 1) are selected for malaria risk factor analysis. District Swabi has an area of 1,543 sq. km having a population of 18,94,600 while District Charsadda has an area of 996 sq. km having a population of 18,35,504. Both districts have extreme climate with hot summers and cold winters. There are two spells of rainy season in a year, the winter rain due to western disturbance and summer rains due to monsoon, that persist from July to September when the temperature is hot and humid, thus resulting in maximum transmission of malaria in the region.

Charsadda and Swabi are two agricultural districts of Khyber Pakhtunkhwa (KP). Though not located far away from each other and separated by district Mardan only. Both have similar climatic conditions, but they are ecologically distinct. Charsadda known as land of rivers has River Swat, River Kabul, Jindi and Landai rivers, upper and lower Swat canals, Michini Dalazak canal and Doaba feeder canal, which are the main source of irrigation in the area. Due to these water bodies the land of Charsadda is water logged (Anonymous, 2000a).

On the contrary Swabi is also an agricultural area. River Indus flows along the southern boundary of the district and small streams like Badrai, Narranji, Shagai and Pehur high level canal are used to irrigate fields of the district but there are some areas (arid areas) of the district where irrigation is not feasible and are used for dry farming of crops or tube wells are used for irrigation (Anonymous, 2000b). Comparatively dry nature of Swabi and water logging of Charsadda may be playing an important role in differentiation of the factors for transmission of malaria.

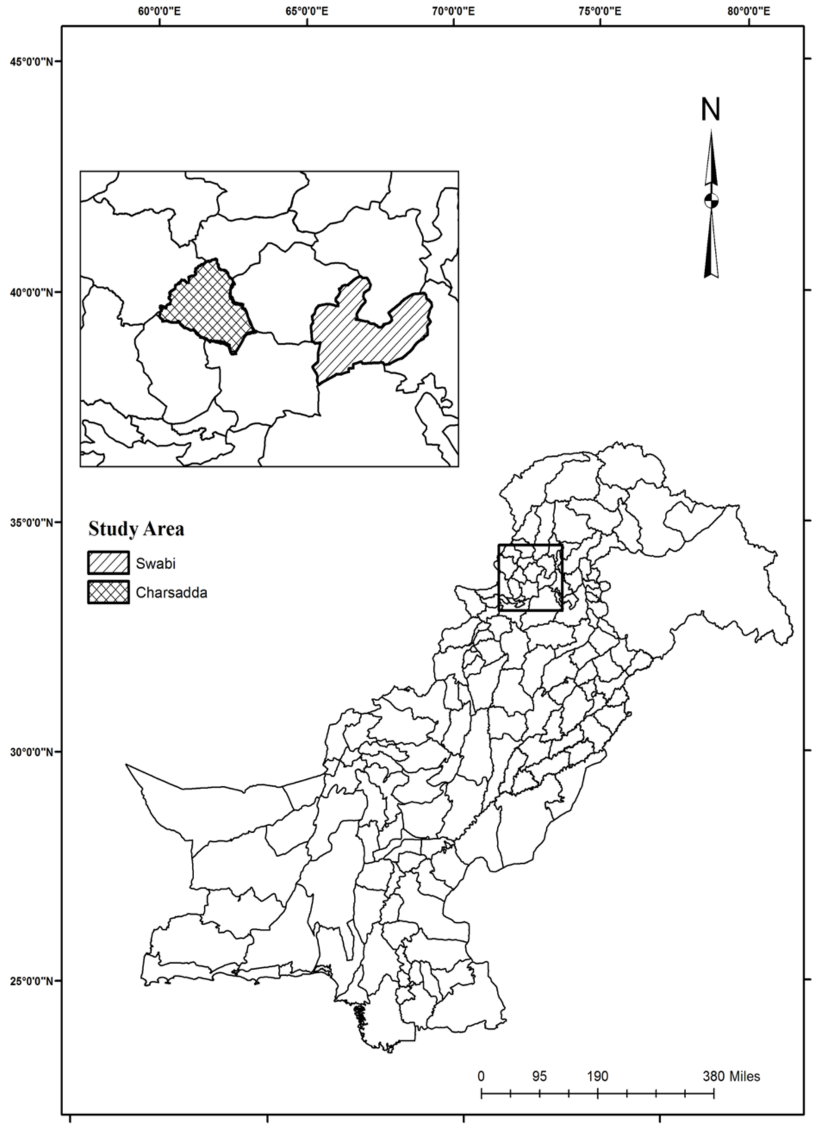

Figure 1. Map showing study area in Pakistan.

Questionnaire Design

A questionnaire is designed to assess the associated risk factors in both districts. The questionnaire has three main parts: first part is regarding sociodemographic characters such as age, gender, education level, occupation, and employment status. Second part focused on exposure of human population to the vector mosquitoes like presence of animals in house, water storage activities, outdoor roaming late night, type of house building material, presence of agricultural fields near the houses and sleeping habits while the last part described the prevention activities like use of bed nets, windows mesh, repellents, and insecticides to prevent interaction with mosquitoes. Information regarding malaria family history and previous infection is also gathered through the questionnaire. Objectives of the study are clearly explained and consent on the questionnaire is obtained from each participant with the assurance that the privacy of the data obtained through questionnaire will be maintained. To enquire about the case history of malaria in the district, each participant is asked whether they had suffered from malaria during last one year.

Data analysis

Statistical analysis is performed using SPSS version 20. For determining the association between malaria prevalence and potential risk factors, a multivariate analysis is performed using logistic regression together with their 95% confidence interval. Map showing the study area is prepared using ArcGIS version 10.2.2.

Results

A total of 2854 individuals from Charsadda and 1944 individuals from Swabi are included in the survey. Characteristics of the individuals from both districts included in the survey are given in Table 1. In district Charsadda 1073 out of 2854 (37.6%) individuals showed malaria case history while in Swabi 905 out of 1944 (46.5%) individuals are having history of malaria disease. Not all the respondents are having information regarding the species of *Plasmodium* causing the disease. Among the positive cases having the test reports, *Plasmodium vivax* is found to be the dominant species with 81.4% cases while *P. falciparum* is represented by 18.6% cases.

Regarding various factors related to chance of getting malaria infection in district Swabi, being male, married, having water tanks and tube wells as water source, working in irrigated fields and sleeping outside during night significantly increase the risk of having malaria. On the other hand, living in households with meshed windows seemed protective and significantly lower the malaria risk (Table 2). In district Charsadda, the univariable analyses revealed that working in irrigated fields, living in mud walled houses, sleeping outdoor, presence of animals in houses, and roaming at night results in significantly higher odds of acquiring malaria. Similarly, having history of malaria infection, or living with family members having disease history, has been associated with increased risk of malaria. Ownership of meshed windows and use of protective means such as bed nets, repellents and residual sprays apparently reduce malaria risk (Table 2). In Charsadda sleeping habits (OR=4.05), irrigated fields (OR = 3.37), mud house type (OR = 1.53), late night roaming (OR = 1.52) and family malaria history (OR = 1.27), while in Swabi drinking water source (OR =

1.77), irrigated fields (OR = 1.7) and sleeping habits (OR = 1.29) are playing more important role in malaria transmission.

Table 1: Distribution of characteristics of population in the study area.

Characteristics		Charsadda (n=2854)		Swabi (n=1944)	
		Frequency	Proportion	Frequency	Proportion
Gender	Male	1552	54.4	1107	56.9
	Female	1302	45.6	837	43.1
Marital Status	Married	1263	44.3	765	39.4
	Unmarried	1591	55.7	1179	61.6
Age	<5	184	6.4	99	5.1
	5-14	896	31.4	876	45.1
	15-24	1038	36.4	499	25.7
	25-34	336	11.8	202	10.4
	35-44	213	7.5	138	7.1
	>45	187	6.5	130	6.7
Occupation Status	Public service	196	6.9	73	3.8
	Self-employment	498	17.4	455	23.4
	Private sector	542	19.0	134	6.9
	Farmer	546	19.1	540	27.8
	Students	596	20.9	465	23.9
	House wife	292	10.2	178	9.1
	Children	184	6.4	99	5.1

Discussion

In this study, prevalence rate of malaria and risk factors associated with malaria transmission are studied in two ecologically distinct districts: Charsadda and Swabi, of Khyber Pakhtunkhwa, Pakistan. Ecology of an area greatly influence the mosquito density due to availability of breeding habitats and ultimately transmission of malaria. In Charsadda as well as in Swabi majority of the cases are caused by Plasmodium *vivax*. *Plasmodium vivax* and *Plasmodium falciparum* are transmitted by *Anopheles* species, but *Plasmodium falciparum* has been deemed responsible for 99% of the deaths due to malaria (WHO, 2017; Gunda et al., 2015; Mace et al. 2018). Current study revealed that the causative agent in majority of malaria cases is reported to be *Plasmodium vivax*, this is like the findings of Javed et al who reported that 80% of the cases in the country belongs to *Plasmodium vivax* while 20% are caused by *Plasmodium falciparum* (Javid et al., 2015).

Current study showed that proper use of barriers like windows screening, housing types and bed nets significantly reduces the incidence of malaria. Window screening though a simple method but offered a formidable barrier to the vectors of malaria and indoor sleeping has been considered beneficial in minimizing the transmission of malaria (Kirby et al., 2008; Ogoma et al., 2010). Studies have shown 50% reduction in indoor vector density and ultimately reduction in malaria due to screening of doors and windows (Kirby et al., 2009). Present study showed that in both districts; Charsadda and Swabi, a significant reduction in malaria cases (143 and

365 cases having windows mesh as compared to 930 and 520 cases having no windows mesh) have been observed due to use of window screening, though this factor has little contribution to the malaria transmission in both districts (OR = 0.144 and 0.379 for Charsadda and Swabi, respectively). Majority of positive malaria cases have been observed among households not having windows mesh. Thus, presence of windows mesh plays an important role in reducing malaria case burden in malaria endemic areas.

Table 1: Distribution of characteristics of population in the study area.

Variable		Charsadda (n=2854)				Swabi (n=1944)			
		Positive	Negative	Odd Ratio (95% CI)	*P value*	Positive	Negative	95% CI	*P value*
Gender	Male	570	982	0.922	0.259	469	638	0.676	0.000
	Female	503	799	(0.79-1.08)		436	401	(0.56-0.81)	
Marital Status	Married	453	810	0.876	0.089	317	448	0.711	0.000
	Unmarried	620	971	(0.75-1.02)		588	591	(0.59-0.86)	
Windows Mesh	Yes	143	919	0.144	0.000	365	725	0.379	0.000
	No	930	862	(0.12-0.18)		520	384	(0.32-0.46)	
House Made	Mud Wall	764	1101	1.527	0.000	372	405	0.915	0.340
	Brick Houses	309	680	(1.29-1.80)		533	634	(0.76-1.10)	
Animals in Home	Yes	857	744	0.181	0.000	411	434	1.160	0.106
	No	216	1037	(0.15-0.22)		494	605	(0.96-1.39)	
Drinking Water	Own Source	944	1525	1.219	0.087	810	860	1.774	0.000
	Piped	130	255	(0.97-1.54)		95	179	(1.35-2.34)	
Irrigated Fields	Yes	776	778	3.368	0.000	570	531	1.694	0.000
	No	297	1003	(2.85-3.98)		327	516	(1.41-2.04)	
Use of Repellents	Yes	139	1001	0.116	0.000	353	393	1.055	0.569
	No	934	780	(0.09-0.14)		551	647	(0.87-1.27)	
Use of IRS	Yes	59	859	0.062	0.000	292	340	0.997	0.979
	No	1014	922	(0.05-0.08)		607	705	(0.82-1.21)	
Use of Bed Nets	Yes	103	688	0.166	0.000	268	314	0.971	0.770
	No	968	1095	(0.13-0.21)		637	725	(0.80-1.19)	
Outdoor Night Roaming	Yes	201	235	1.516	0.000	177	186	1.115	0.350
	No	872	1546	(1.23-1.87)		728	853	(0.88-1.41)	
Family History	Yes	356	501	1.269	0.004	278	354	0.858	0.115
	No	717	1280	(1.07-1.50)		627	685	(0.71-1.04)	
Previous Infection	Yes	288	675	0.601	0.000	318	365	0.985	0.870
	No	785	1106	(0.51-0.71)		592	669	(0.81-1.19)	
Sleeping Habits	Outdoor	719	595	4.048	0.000	397	392	1.290	0.006
	Indoor	354	1186	(3.44-4.77)		508	647	(1.07-1.55)	

Along with screening windows and doors, modifying the building architecture (Bradley et al., 2013) and good house construction (Wanzirah, 2015) may help in minimizing risks of malaria infection in disease endemic areas. These strategies could also minimize human-vector interaction, thus resulting in reduction of the disease burden in the endemic areas. In our study, malaria cases are also found to be significantly associated with house type. The odds of malaria infection are found to be twice as high among houses made of mud (OR = 1.53) in Charsadda, while no association have been observed in Swabi. Houses having good construction (brick made) are having significantly low malaria cases as compared to houses having mud walls and thatched roofs. Mud walled and thatched roof houses provide favourable conditions to vector mosquitoes for resting and taking refuge in the cracks, crevices, and thatched roofs. Living in towns and in indoor setting significantly reduce the malaria transmission (Snyman et al., 2015). House construct plays an important role in determining the frequency of mosquito bites as their vectoral potential because such houses provide less resting and refuge places for the vector (Charlwood et al., 2003). People in rural settlements and peripheral populations of towns have been found more vulnerable to malaria due to inadequate house construct and improper sanitation (Castil-Salgado, 1992). Both our study districts have more rural settlements, but district Charsadda is almost all rural except the town of Charsadda. This may be the reason that houses having mud wall construction play a significant role in malaria transmission in Charsadda.

Using insect repellents, indoor residual spray (IRS) and insecticide treated bed nets reduce the chances of getting infected with malaria (Dawaki et al., 2016). In Pakistan Deltamethrin wettable powder is used for IRS and temephos is used as larvicide as per WHO guidelines while Mosphel (Diethyltoluamide) (Abbott laboratories Pakistan) is the only insect repellent available by. However, the use of these insecticides is variable in both districts. In Charsadda the odds of getting malaria infection is low but significant for those who use repellents, IRS and bed nets (OR = 0.116, 0.062 and 0.166 respectively). Charsadda being waterlogged provide abundant sites for mosquito breeding resulting in high abundance of mosquitoes, therefore using insect repellents, bed nets and IRS is a common practice in the area, which helps in reducing mosquito densities thus resulting in low transmission of the disease in households using these strategies. On the contrary, Swabi has canal irrigation and dry areas, not providing abundant breeding sites like Charsadda, so insecticide use in various form is found infrequent in the people of the study area and no association has been observed between them and malaria occurrence. In addition, national and international organization like roll back malaria program and international organizations like global fund carry out IRS programs and distribute bed nets among the locals in Charsadda (Munir et al., 2014) this may contribute towards the reduction in disease burden. On the other hand, no such organized activity either by government or NGOs took place in Swabi and locals carry out their own IRS activity, which may be the reason of these factors not playing any significant role in malaria transmission in Swabi.

Ecology of an area effects the vector abundance by providing breeding habitat for the mosquitoes (Ferraguti et al., 2016). Water storage activity has been associated with malaria occurrence (Idowu,

2014) and has been found significant in Swabi only. The odds of malaria infection are found to be twice as high (OR = 1.8) for those households using water storage containers in Swabi. Charsadda being water logged provide enough breeding sites for mosquitoes, so presence of water storage container does not have significant effect on the occurrence of malaria in the study area. Contrarily, lack of abundant breeding sites due to arid area and canal system does not provide enough egg laying opportunities around the year for mosquitoes, diverting them to breed in water storage containers (Nison et al., 2018).

Irrigated fields also played an important role in breeding of the mosquitoes and has been observed to increase the odds of getting malaria thrice in Charsadda (OR = 3.37) and twice in Swabi (OR = 1.7). It has been reported that stream bed pools used for irrigation act as an important source of *Anopheles culicifacies* breeding during dry period resulting in seasonal peak of malaria cases (Amerasinghe et al., 1997). Charsadda and Swabi being agricultural districts depends upon canals and streams for irrigation, which can provide breeding grounds for vector mosquitoes thus playing significant role in malaria transmission in both districts. Sleeping outside has been observed to play a major role in malaria transmission in Charsadda by getting the odd ratio of malaria four times (OR = 4.05) higher for sleeping outside at night as compared to Swabi (OR = 1.3). Sleeping habits is also found significantly associated with malaria incidence in the study area. Outdoor sleeping increases the incidence of malaria due to exposure to vector mosquitoes as use of window mesh can prohibit mosquito entrance into the rooms thus decreasing mosquito-human interaction.

Since domestic animals offer an alternative host for the mosquito vector to meet its blood meal demand, they may reduce the spread of disease. This evidence is supported by a study conducted in Keerom, Indonesia, where majority of people keep their animals close to their homes (Sandjaja et al., 2014). In Swabi presence of domestic animals has not been significantly associated with malaria risk but significant association has been observed in Charsadda where presence of domestic animals increases the occurrence of malaria. As it has been discussed afore that domestic animals attract vector mosquitoes and house construction type provide refuge to indoor resting mosquitoes, both these conditions have been found associated with malaria in Charsadda only, thus house type and domestic animals combine effect increase the risk of malaria in the district.

Conclusion

Vector borne diseases like malaria can be controlled by minimizing the human-vector interaction through reducing the vector densities. Our study identified the risk factors responsible for the incidence of malaria in the studied area. Using this information in formulating a strategy to control vector population and decreasing malaria occurrence in the study area can help in saving lives. Controlling the vector population by physically destroying the breeding habitats along with wise use of insecticide and convincing people to change their behaviour like sleeping habits, late outdoor roaming, use of windows mesh and bed nets can help in decreasing disease burden in the study area.

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