Original Article

Epidemiology of malaria in saravan city and its suburbs from 2018 to 2023, Southeast Iran

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Background: Malaria, transmitted by *Plasmodium* parasites and anopheline mosquitoes, continues to be a leading cause of global disease and death. This retrospective investigation from 2018 to 2023 examines the epidemiological attributes of malaria in Saravan, southeastern Iran. It seeks to evaluate the prevalence, transmission causes, local population impact, and health system effects. **Materials and Methods:** Blood samples from suspected malaria cases in Saravan health centers were collected for this analysis. Each positive case was detailed with demographic data in a questionnaire. The SPSS 26 statistical program scrutinized data with *t*-tests comparing the variables. **Results:** The study indicated fluctuating malaria cases peaking in 2023, with an annual parasite incidence. (API) of 17.27. *Plasmodium vivax* was the predominant species ($P < 0.001$), with the majority of cases in individuals over 15, notably males. A significant number of cases were reported in September (20.7%). **Conclusion:** The findings emphasize the persistent malaria challenges in Saravan, accentuating the urgent need to strengthen prevention and control strategies. Reducing disease burden demands focused approaches, including improving prevention and treatment programs, enhancing surveillance systems, developing health infrastructures, and implementing localized therapies, especially considering recent climatic and rainfall patterns.

Key words: Epidemiology, Iran, malaria, Saravan, weather situation

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INTRODUCTION

Amidst the COVID-19 pandemic's widespread impact, several nations successfully maintained crucial measures against malaria, including prevention, identification, and therapy. Annually, malaria claims over 600,000 lives, predominantly affecting children. The World Health Organization's 2019 report noted a marginal rise in cases, from 227 million in 2018-229 million.[1]

Plasmodium parasites cause malaria transmitted by infected mosquitoes.[2] Four nations–Afghanistan, Somalia, Sudan, and Yemen–are the epicenters of malaria prevalence, comprising 95% of the global 14 million annual cases.[3] Iran reports endemicity in Sistan and Balochistan, Hormozgan, and Kerman. However, recent years have marked a remarkably low incidence, with *Plasmodium vivax* and *Plasmodium falciparum* being predominant and *Plasmodium malariae* a rarity.[4]

Most cases of malaria diagnosed in the nation arise from imported cases, primarily from Iran's neighboring countries.[5] National health strategies entailing vector control, case management, and widespread education have been enacted as a countermeasure. These strategies have been augmented by using insecticide-treated nets, intradomestic residual spraying, and vigilance in curbing mosquito proliferation.[6]

The WHO has stipulated a surveillance gold standard, detailing case definitions, data capture protocols, and

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systems for surveillance encompassed by drug and vector resistance monitoring.[7]

Anopheles species variability is vast, with over 460 identified, yet few are consequential in malaria transmission–weather patterns profoundly influencing their populations.[8,9] The primary vector in Iran's s, particularly Sistan‑Baluchistan, *Anopheles stephensi* exhibits a variety of seasonal activities.[10]

However, in Iran's endemic precincts, challenges like *P. falciparum*'s resistance to chloroquine and vector pesticide resistance still exist.[8]

The influx of people from countries where malaria is endemic illustrates the disease's resurgence.[10,11] Immigration has been identified as a significant contributor to the increased imported malaria cases in Iran.[11] Additionally, migratory movements within disease‑dense localities potently circulate malaria and other pathogen risks like CRF35_AD and CCHF remarkably.[12,13]

The influx of people from countries where malaria is endemic illustrates the disease's resurgence.[14] with *P. vivax* endemicity posing control quandaries G6PD and thalassemia are more frequently observed in southeastern Iran and are associated with malaria resistance.[15,16]

Malaria cases increased in 2018 and 2023 despite a decline but suddenly surged in 2022, attributed to climate change, foreign nationals, and COVID‑19 coexistence.[17] Malaria symptoms range from mild to severe, classified as severe or uncomplicated. Standard diagnostic tests exist, but accurate reporting due to COVID‑19 overlapping symptoms is crucial.[18]

Temperature and humidity can increase malaria prevalence, increasing mosquitoes carrying the disease, and potentially causing transmission in previously unreported areas.[19] Studies have shown that temperature is positively associated with malaria incidence.[19] Lower humidity negatively impacts malaria cases, while higher temperatures and lower rainfall increase cases.[20] Relative humidity significantly influences the interannual variability of urban malaria in Indian cities, particularly during the pretransmission season.[21]

Societal obstacles include historical and emerging malaria foci, demanding focused control strategies andan in‑depth understanding of their characteristics and dynamics of transmission.[22] To effectively handle this widespread health risk, it is necessary to engage in both passive and active malaria surveillance that is proactive and precise. Our research specifically examines the urban and rural areas of Saravan and tracks a 5‑year epidemiological progression from 2018 to 2023 to understand the disease's epidemiological impact clearly.

MATERIALS AND METHODS

Study areas

The study area, Saravan County in Iran's Sistan and Baluchistan Province, is recognized as a pivotal region for malaria transmission. Situated in a warm climate zone with minimal rainfall, it reports temperatures ranging from 7°C to 45.3°C. A comprehensive study conducted in this area, with 19 health centers and 100 health houses, analyzed malaria cases from April 2018 to October 2023. The incidence fluctuated between 2002 and 2010, influenced by regional epidemics and climate factors. Saravan's geographic and climatic conditions heighten the risk of malaria, underscoring the need for focused disease management strategies in this arid region.[23,24]

Data collection

Data for this retrospective study was collected using the informatics system in Saravan City and Suburban Health Network. It covered urban and rural areas [Figure 1], including distant villages and suburbs. Diagnosis of malaria relied on rapid diagnostic tests in areas with difficult access to health centers.[25] Microscopic detection, based on the examination of blood smears, has been used as a diagnostic method in health treatment centers in more accessible regions. Using both RDTs and microscopic detection enabled comprehensive coverage of malaria diagnoses in the study area. The data collected by the informatics system, together with the results of the diagnostic tests, provided a comprehensive data set for the epidemiological analysis of malaria in Saravan and its suburbs.

The relationship between different foci of new active (previously unknown site), transient, and old active malaria and their probabilities is a complex phenomenon that requires a thorough understanding of the epidemiology of the disease. The spatial distribution of malaria cases is not always uniform, and different foci of malaria activity, including new active, transient, and old active foci, play an important role in shaping the likelihood of disease transmission and its impact on the population.[26] However, understanding the complex dating between these herds and the possibility of malaria prevalence is a multifaceted project stimulated by several factors.[27]

When we calculate how many patients become reinfected with malaria, we are trying to distinguish between relapse and reinfection. Relapse refers to the reactivation of dormant liver‑stage parasites, while reinfection refers to a new infection with a different strain of the *Plasmodium* parasite.[28]

To confirm malaria cases, either the microscopy or RDT kit (pLDH/HRP2) was employed. A complete malaria diagnosis was carried out in a total of nine laboratories in Saravan and the surrounding suburbs. Data were collected by a computerized system and analysis based on patient characteristics and *Plasmodium* species.

Statistical analysis

The study utilized the Statistical Package for the Social Sciences (SPSS), version 26.0 (IBM., Corp., New York, NY, USA), for data analysis to assess associations between parasitic type and variables including month, average temperature, and humidity. The analytical methodology employed an analysis of variance (ANOVA) and a Tukey HSD *post hoc* test. Outcomes were expressed as means ± standard deviations, with seroprevalence compared using Chi-square and Fisher's exact tests. Statistical significance was determined at a P value threshold below 0.05.

RESULTS

In 2023, we witnessed a spike in infections with 1060 reported cases. It was a challenging time for all of us, but we managed to pull through it together. A comprehensive overview of our investigation can be found in Table 1. The predominant species in 5 years of our study was *P. vivax* with significant association (P < 0/001).

The incidence of malaria was higher in men than in women, (80.9%) of cases were identified as men, while (19.1%) of women were diagnosed, and there was a significant relationship between them [Figure 2].

According to the information in Figure 3, October and September, had the highest infection prevalence. Malaria shows a significantly higher incidence in some months.

The highest incidence of *P. falciparum* was observed in April at 24.7%, while *P. vivax* reached its peak in September at 20.7%. For *P. vivax*, the trend shows an initial low prevalence in February, March, and December, with a gradual increase from May to July, culminating in a significant surge in September, indicating a potential outbreak. For *P. falciparum*, only the months of April and May saw a substantial rise in cases, with 24.7% and 13.9%, respectively. Additionally, there were mixed cases involving both *P. falciparum* and *P. vivax*, reaching a high of 24.4% in April, with the dominant transmission mechanism being through importation.

The Annual Parasite Incidence (API/1000) showed a notable increase in overall malaria cases from 2018, peaking in 2019, followed by a subsequent decline in 2020, and a more significant reduction in 2021. A resurgence was noted in 2022, with a reduction afterward. However, 2023 experienced a dramatic spike in cases, recording an unprecedented API of 1060 as shown in Table 1 of the article.

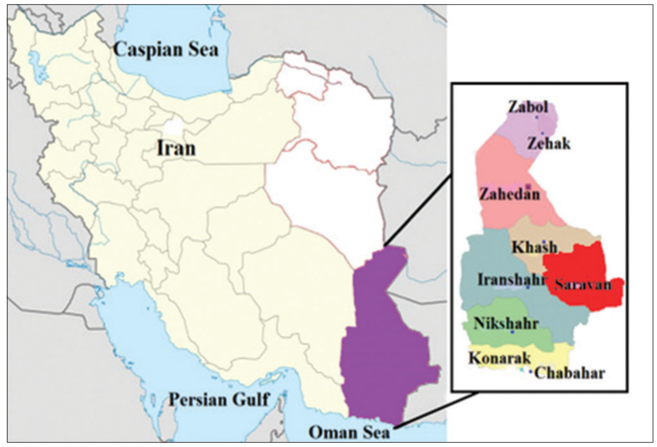

Figure 1: The geographical location of Saravan City in Sistan and Baluchistan province in the southeast of Iran. (Saravan City and suburbs on the map are seen in red), Aerial view of Saravan City, Captured using Google Earth, (Google Earth,2024). Retrieved from https://www.google.com/about

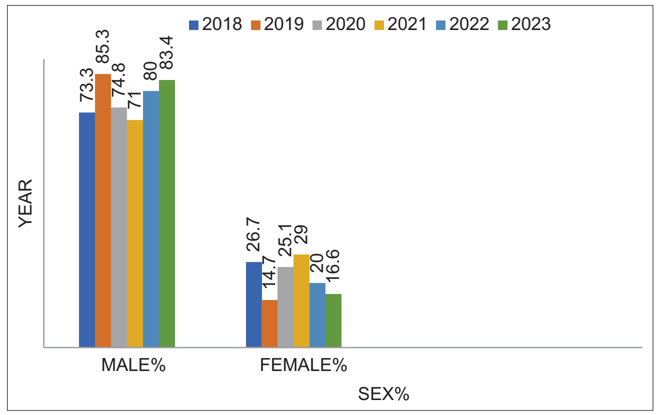

Figure 2: Frequency of malaria cases by sex and year in Saravan City (2018–2023)

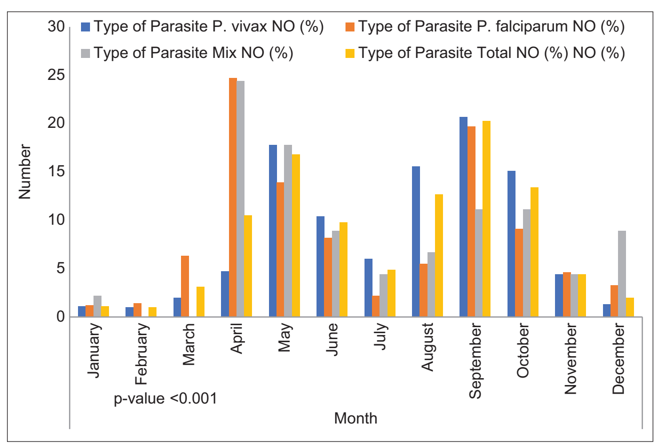

Figure 3: Monthly Prevalence of Malaria Cases by Species in Saravan City, Southeast Iran (2018–2023)*. Malaria cases show a significant monthly variation (P < 0.001): P value calculated using Chi-square test. The expression of a significant relationship between the type of parasite that led to a person's disease and the month of the disease

Table 2 shows the number of imported cases from a neighboring country as well as the transfer between these imported cases and domestic cases. The $P = 0.005$ suggests that there may be a statistically significant association between the variables "Epidemiological transmission" and "Nationality." Overall, this table provides information on the distribution of malaria cases between different countries and transmission groups, allowing analysis of the relationship between nationality and epidemiological transmission.

The effects of our job calculations have been all at once brilliant when it came to the statistics accumulated on malaria through research [Figure 4].

Figure 4 provides information about the distribution of occupational categories among people who tested positive for malaria. The total number of cases was 424. Males represent 23.2% of all males and females in this category, while females represent 2.9%. The highest percentage of positive cases was found among Kids and teenagers (28.7%), followed by drivers (22.6%) and self-employed people (19.4%). The lowest percentage of positive cases were found among people off duty (1.90%) and farmers and ranchers (2.6%).

The relationship between temperature, humidity, and incidence of malaria was evaluated according to months of year [Tables 3 and 4]. In our study in general, according to the Tukey HS *post hoc* ANOVA test, there was a significant difference between the months of the year and the air temperature, for example with an increased number of parasites in May, according to the statistical average, it was higher than January, February, April, October, and December, and significantly shows an increase.

September is the month when the incidence of this disease increases significantly, second only to June, July, and August. It is worth noting that the air temperature during

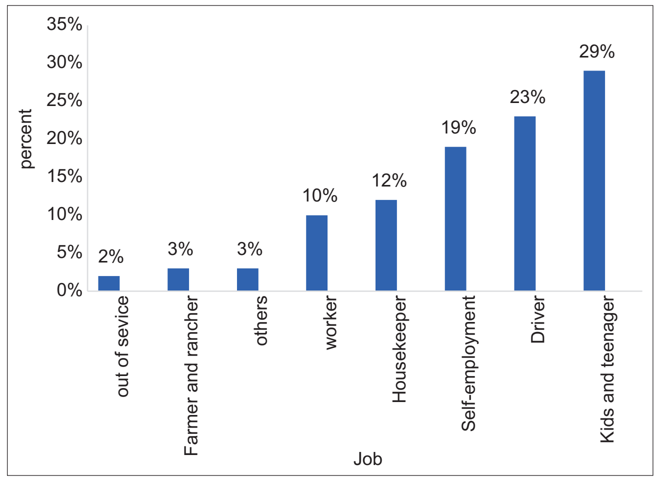

Figure 4: Frequency of Malaria Cases by Occupation Type in Saravan City, Southeast Iran (2018–2023)

Table 1: Epidemiologic indices of malaria cases in Saravan City, Southeast Iran (2018–2023)

Year	2018	2019	2020	2021	2022	2023	Total	P
Number of malaria cases	30	34	159	93	815	1060	2191	
Total population	60,155	60,317	60,423	60,571	61,012	61,374		
API (×1000)	0.51	0.74	2.49	1.46	13.35	17.27		
Malaria species, *n* (%)								
Plasmodium vivax	20 (1.3)	25 (1.6)	97 (6.2)	90 (5.8)	642 (41.1)	688 (44.0)	1562 (71.3)	<0.001
Plasmodium falciparum	9 (1.5)	9 (1.5)	57 (9.8)	2 (0.3)	159 (27.2)	348 (59.6)	584 (26.7)	
Mixed	1 (2.2)	0	5 (11.1)	1 (2.2)	14 (31.1)	24 (53.3)	45 (2.1)	

API stands for API, which is a commonly used indicator in malaria epidemiology. It represents the number of new malaria cases per 1000 people annually. It is calculated by dividing the total number of new malaria cases by the total population at risk in a given year, then multiplying by 1000. API is an essential metric in malaria surveillance and control programs because it helps track the transmission intensity and disease burden in a given area. By monitoring API, public health authorities can evaluate the effectiveness of malaria interventions and allocate resources strategically to target high-risk populations and areas. High API values (above 10–30, depending on the region) may indicate areas with ongoing malaria transmission, necessitating targeted control measures to reduce the disease burden. API=Annual parasite incidence (per 1000 population)

Table 2: Frequency of malaria cases by nationality and source of infection in Saravan City, Southeast Iran

Nationality	Source of infection			Total, *n* (%)
	Imported, *n* (%)	Transmission from, *n* (%)	Indigenous, *n* (%)	
Imported case				
Iranian	1137 (85.6)	185 (13.5)	24 (1.7)	1446 (100.0)
Pakistani	537 (81.1)	112 (16.9)	13 (2.0)	662 (100.0)
Afghan	53 (63.9)	28 (34.1)	2 (2.4)	83 (100.0)
Total	1727 (78.8)	325 (14.9)	40 (1.8)	2191 (100

P=0.005, a Chi-square test or a Fisher's exact test was conducted and the P value remains the same (P=0.005), indicating a statistically significant difference in the distribution of malaria cases among nationalities and sources of infection. A P=0.005 is less than the commonly used significance level of 0.05, which suggests that the observed differences in the distribution of malaria cases among nationalities and sources of infection are statistically significant. In other words, the P value indicates that the likelihood of observing such differences by chance is very small (only 0.5%). Therefore, it is reasonable to conclude that the differences in the distribution of malaria cases among nationalities and sources of infection are not due to random variation but rather reflect real differences these 3 months is 2°–4.6° higher than in September. This temperature difference has affected September due to the parasite cycle and incubation period.

It indicates how much variability or dispersion exists in the temperature data for each month. For example, the mean temperature in January is 11.38°C, and the standard deviation is 1.56°C. This means that the actual temperature values in January are likely to vary within a range of approximately 11.38°C ± 1.56°C, or between 9.82°C and 12.94°C, for most of the observations. By providing the standard deviation values in parentheses, the table shows not only the mean temperatures for each month but also the variability or spread of the temperature data around the mean, which can help understand the temperature patterns and trends in the dataset.

Table 4 shows the relationship between humidity and the incidence of malaria based on the season of the year. It suggests that humidity levels vary across seasons, with the highest average humidity observed in winter and the lowest in autumn [refer to *post hoc* Table 4]. The relative humidity, which is one of the causes of the disease, and the occurrence of malaria, in September, show the causes of high humidity in June, July, and August.In our study, the probability between parasite species and disease foci as well as the possibility of disease transmission is significant [$P = 0.001$, Figure 5].

Percent within the type of parasite: This represents the percentage of each kind of foci category within each type of parasite category. The table presents measures of association for types of relationships: Interval by interval and ordinal by ordinal. Here is an analysis of the symmetric measures provided:

Interval by Interval: Pearson's R coefficient is 0.104, indicating a weak positive correlation between the variables. The approximate $t = 4.915$, indicating that the correlation is statistically significant. The approximate significance is 0.000c, implying a highly significant relationship. Ordinal by Ordinal: Spearman's correlation coefficient is 0.098, indicating a weak positive correlation between the variables. The approximate significance is 0.000c, implying a highly significant relationship.

Both measures of association suggest a weak positive correlation between the variables in their respective categories. However, it's important to note that these measures only provide information about the strength and significance of the relationship and not the direction or causality.

DISCUSSION

Global efforts to reduce malaria morbidity and mortality

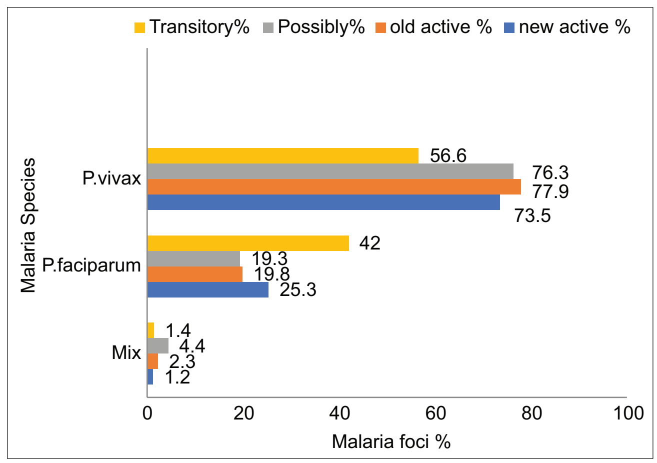

Figure 5: Association between parasite species and different malaria foci and the probability of transmission, in terms of percentage, $P < 0.001$ based on the Chi-square test, New active: Represents newly active disease foci. Old active: Represents previously active disease foci. Possibly: Represents disease foci that have the potential for activity. Transitory: Represents transitory disease foci

Table 3: Association between temperature and incidence of malaria in different months according to the statistical index

Month	Number of malaria cases	Temperature (mean±SD)	*Post hoc*	
January	25	11.38±1.56	May > January (16.32)	September > January (16.87)
February	23	13.71±0.27	May > February (13.99)	September > February (14.54)
March	68	18.62±3.6	May > March (9.08)	September > March (9.63)
April	229	22.33±1.18	May > April (5.36)	September > April (5.91)
May	367	27.70±0.870	-	September > May (0.55)
June	214	32.88±0.85	May < June (−5.17)	September < June (−4.62)
July	108	32.66±0.55	May < July (−4.96)	September < July (−4.41)
August	278	31.24±0.80	May < August (−3.54)	September < August (−2.99)
September	444	28.25±0.81	May < September (−0.55)	-
October	294	23.86±2.04	May > October (3.84)	September > October (4.39)
November	97	20.89±1.88	May > November (6.81)	September > November (7.36)
December	44	14.46±0.30	May > December (13.24)	September > December (13.79)
Total	2191	26.75±4.94		

The numbers in parentheses in this table represent the SD of the mean temperature values. The SD is a measure of the spread or dispersion of a set of data points around the mean. SD=Standard deviation

Table 4: Association between humidity and incidence of malaria in different seasons

Season	Number of malaria incidence	Humidity (mean±SD)*	*Post hoc*
Spring	664	30.80±6.17	Autumn < spring (−9.28)
Summer	600	32.79±7.56	Autumn < summer (−11.26)
Autumn	879	21.52±6.97	Autumn < winter (−19.26)
Winter	48	40.79±9.92	
Total	2191	27.84±8.82	

*The mean difference is significant at the 0.05 level. Average humidity $P<0.001$. SD=Standard deviation

by 90% by 2030 and remove malaria in 35 countries face major challenges due to factors such as mosquito resistance to pesticides and parasite resistance to drugs.[29]

Malaria is a dynamic disease, particularly in the northern temperate zone, whose local incidence and geographic distribution change over time.[30] Understanding the epidemiology of malaria requires a detailed understanding of the complex relationship between the various foci of new activity, transient, and old active cases of malaria. In this study, *P. vivax* was found to be the predominant species, suggesting alternative routes of transmission and opening new avenues for research into its interactions with the environment and its effects on human health.[31] The emergence of previously unknown malaria outbreaks can be attributed to various factors, including human mobility, forest degradation, climate change, and the implementation of effective malaria control measures.[32]

Climatic conditions such as increased rainfall have been identified as a risk factor for malaria outbreaks in Iran, differentiating them from malaria patterns in Africa and other countries.[33] A study conducted by Wangdi *et al*. in 2010 and, in Bhutan's endemic regions found that the average maximum temperature, with a one-month lag, was a strong and positive predictor for malaria incidence. Another study by Peng *et al*. in 2003 in Shuchen reported that the monthly minimum tempera-ture, with a one-month lag, had the highest positive correlation with the monthly malaria incidence. A study conducted by Zhang *et al*. in a temperate region of China in 2010 revealed that there is a signifi-cant positive correlation between the incidence of monthly cases and both maximum and minimum temperatures. This correlation was observed even with a one-month lag. The study also found that a 1°C increase in minimum temperature resulted in a 12-16% increase in incidence. Interestingly, the minimum temperature hada greater impact on incidence than the maximum temperature.[34] With an increase in April temperatures, malaria incidence rose in May, July, and August, then declined in September; this trend was observed in line with other studies.

There is a significant relationship between humidity and the incidence of malaria. Humidity has a critical role to play in the spread of malaria. Studies have found that relative humidity is a crucial factor that affects the yearly variation of urban malaria in Indian cities. It has a strong and significant impact on the burden of malaria during the pretransmission season.[21]

In Iran, the 1st month of autumn aligns with the last month of summer in the solar year. This period is characterized by high temperatures and humidity, which can contribute to the spread of various diseases. Malaria outbreaks in this region can be attributed to the elevated humidity levels observed in June, July, and August. The combination of hot weather, seasonal floods, and the proximity to the Oman Sea creates favorable conditions for mosquito populations to thrive, subsequently leading to an increased incidence of malaria in the following season [Table 4].

On the other hand, many people who were experiencing symptoms of malaria were hesitant to seek medical attention due to their fear of being diagnosed with COVID-19 or contracting the virus while at the healthcare facility. Additionally, individuals who were suspected of having COVID-19 and had been instructed to self-quarantine may have further decreased the number of people getting tested and diagnosed with malaria. The strain on the healthcare system due to COVID-19 has adversely impacted the global malaria elimination program.[18]

The effect of the coronavirus disease 2019 affects multiple organs in the human body,[18] and modulation of immunity consequences must be evaluated. Individuals who have previously been exposed to the *P. falciparum* parasite may have developed immunity against the SARS-CoV-2 virus. This could be due to the presence of conserved immunologic regions within the dominant proteins of both the parasite and the virus. As a result, this may be one of the reasons for the lower incidence of COVID-19 in malaria-endemic zones.[18] The province of Sistan-Baluchistan registered the apex in case counts from 2011 to 2014, and now in this study, proposing a focal point for epidemiological scrutiny. The movement of people from malaria-endemic countries in the east has been identified as a significant factor. A study conducted in southern Iran revealed that the presence of foreign immigrants could lead to a malaria outbreak.[10] Additionally, migratory movements within disease-dense localities potently circulate malaria and other pathogen risks like CRF35_AD and CCHF remarkably.[9,10]

Accurate evaluation of the probabilities requires detailed surveillance systems, advanced diagnostics, and effective vector control strategies, and requires collaboration between health authorities, researchers, and policymakers.[35]

In numerous investigations to deal with malaria, they are concerned with the recognition of new and old foci and the possibility of disease and transient cases, which are also mentioned in Figure 4 in this research.

Thailand has successfully reduced its malaria burden by using the 1-3-7 method, which is an efficient strategy applied to the surveillance system. This strategy is based on rapid case notification within 1 day, case investigation within 3 days, and targeted foci response within 7 days. It helps to reduce the spread of *Plasmodium* spp. and has been a key factor in Thailand's success in the fight against malaria.[36] Historical infection data analysis helps select appropriate prevention methods, set early warning systems, and adapt evidence-based strategies for malaria control.[37]

In this study, we observed a higher proportion and significance of malaria cases in men compared to women, which may have been due to occupational and behavioral factors that led to increased exposure to infected vectors.[10,38]

Also, topographic parameters such as slope can affect mosquito larval habitat near large dams in Africa and influence the frequency and suitability of mosquito breeding ponds.[39] Climate change is a major concern because it is expected to increase the risk of vector-borne diseases like malaria. While the presence of water reservoirs and underwater agriculture in cities used to contribute to the transmission of malaria, improved water pipes have partially solved the problem.[40] Yet, recent rains and climate change can still pose a risk of disease outbreaks.

CONCLUSION

The study concludes that understanding the complex epidemiology of malaria is crucial for control efforts, which should involve multi-stakeholder collaboration, adaptive surveillance, and intervention strategies, along with a reassessment of goals for malaria elimination. It highlights the historical and ongoing challenges posed by malaria in Sarvan, emphasizing the need for improved healthcare strategies, surveillance enhancement, and targeted preventive measures to effectively address and mitigate the disease's impact.

Ethics ID approval

All procedures followed relevant institutional ethical standards and Commission versions of Human Trials since the 1964, Declaration of Helsinki. Informed consent was obtained from all patients in the study. After receiving the required approval number, approve the ethics code with ethics ID IR.ZBMU.REC.1402.150 and consent, samples were collected and centrifuged for serum separation.

Authors' contribution

All authors have read and approved the final version of the manuscript. Shaghayegh Dabirzadeh, assisted in interpreting the epidemiological data and discussing the findings about regional health policies. He also contributed to the writing and revision of the manuscript, with an emphasis on the study's methodology conducted field research in Saravan City, She drafted the introduction and results sections of the manuscript and provided final approval for publication. Hamidaldin Bayegan coordinated the field study and contributed to the research design and data collection methodologies. He assisted in interpreting the epidemiological data, and collecting crucial epidemiological data. She analyzed the data using statistical tools to identify patterns in malaria incidence. Mehdi Rezaei Kahkhazhaleh oversaw the laboratory analysis of field samples to confirm malaria diagnoses. He ensured the integrity and validation of analytical methods and participated in drafting and revising the manuscript, focusing on methods and discussion sections. Mansour Dabirzadeh led the project and played a key role in study conceptualization and theoretical framework development. He synthesized the research findings, provided critical insight, wrote the manuscript, and incorporated contributions from co-authors. He also acted as the guarantor of the work and endorsed the final draft of the manuscript.

Limitations

Data limitations and potential sampling bias were some of the study's limitations. Its location in Saravan City, Iran, and its dependence on diagnostic methods also limit generalizability. Additionally, the study did not explicitly consider external factors such as socioeconomic conditions, climate change, or vector control measures on malaria transmission.

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Conflicts of interest

There are no conflicts of interest.

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