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Malaria Prevalence and Associated Risk Factors in Al Managil city, Aljazeera state, Sudan

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ABSTRACT

Introduction: Malaria remains a significant public health challenge in Aljazeera State, Sudan, substantially contributing to morbidity, particularly in areas like Al Managil City. This study aimed to determine malaria prevalence and associated risk factors in Al Managil City to inform targeted interventions. **Methods:** A cross-sectional study was conducted in Al Managil City between August 2022 and April 2023. A random sample of 385 individuals presenting at four healthcare facilities was enrolled. Data on demographics and potential risk factors were collected using a standardized questionnaire. Malaria infection was diagnosed by microscopic examination of thick and thin blood films. **Results:** The overall malaria prevalence was 63.9% (246/385), with *Plasmodium falciparum* identified in 98.8% of positive cases. The study population was 54.5% male, and 89.9% resided in rural areas. Age was significantly associated with malaria infection (P = 0.003), with the highest prevalence in those over 15 years (76.2%) and the lowest in children under five years (57.4%). No significant associations were found with gender (P = 0.915) or residency (P = 0.295). Fever was reported in 74.8% of all participants (288/385), with a higher prevalence among malaria-positive cases. Proximity to irrigated agricultue was significantly associated with malaria infection (P = 0.009). **Conclusion:** This study demonstrates high malaria prevalence in Al Managil City, with *P. falciparum* predominant in 98.8% of cases. The disproportionately high prevalence in individuals over 15 years (76.2%) highlights the need for targeted interventions in this age group, alongside broader vector control strategies. Proximity to irrigated agriculture is a significant risk factor, emphasizing the need for environmental management. These findings support integrated malaria control strategies, including targeted interventions for at-risk groups, to reduce the malaria burden.

INTRODUCTION

Malaria persists as a substantial public health challenge in Sudan, contributing significantly to the overall infectious disease burden in sub-Saharan Africa. In 2022, the World Health Organization (WHO) estimated 249 million malaria cases and over 608,000 deaths globally, underscoring the enduring global impact of this parasitic disease [1, 2]. Notably, within the WHO African Region in 2022, approximately 94% of global malaria cases and 95% of malaria-related deaths were reported [1]. Therefore, a thorough understanding of local malaria epidemiology is essential for the development and implementation of effective and targeted control strategies.

Sudan bears a disproportionately high burden of malaria in Africa. In 2020, Sudan accounted for approximately 56% of reported malaria cases and 61% of malaria-related deaths in the WHO Eastern Mediterranean Region [3], a region with a relatively low overall malaria burden compared to sub-Saharan Africa. Malaria transmission in Sudan is characterized as unstable [4], exhibiting substantial interannual variations in incidence and localized outbreaks. These fluctuations are influenced by seasonal rainfall patterns and geographical factors [4]. The fluctuating transmission patterns, characterized by periods of low endemicity interspersed with unpredictable outbreaks, present a complex public health challenge and elevate the potential for widespread malaria epidemics in Sudan. Aljazeera State experiences a significant burden of malaria, with severe malaria constituting a major cause of hospital admissions [5]. This state contributes to 20% of Sudan's total severe malaria cases, thereby emphasizing the urgent requirement for targeted interventions [5].

Malaria transmission in Aljazeera State demonstrates a distinct seasonal pattern, typically reaching its peak between October and December [6]. This peak is attributable to increased rainfall and humidity, which establish optimal breeding conditions for *Anopheles* mosquitoes. Children under five years of age and pregnant women represent particularly vulnerable populations with respect to malaria [7], experiencing elevated rates of infection compared to the general population. This heightened vulnerability is attributed to underdeveloped immunity in young children and physiological changes associated with pregnancy [7].

Despite ongoing malaria control efforts, malaria continues to pose a significant public health challenge in Al Managil City. Limited recent data on malaria prevalence in Al Managil since 2013 hinders the development of effective, evidence-based control strategies. Therefore, ascertaining current malaria prevalence and its associated risk factors is crucial for designing and implementing effective, targeted interventions [8].

A multitude of environmental and behavioral factors are determinants of malaria risk [8, 9], encompassing proximity to mosquito breeding sites, the utilization of long-lasting insecticidal nets (LLINs), housing conditions, and individual awareness and adoption of malaria prevention practices. Notably, a substantial proportion of residents in Al Managil live in close proximity to potential mosquito breeding sites, prominently including the Al Managil irrigated agricultural schemes [10], consequently elevating their risk of exposure. Despite this elevated risk, suboptimal LLIN utilization is evident, with only 45.3% of households reporting their utilization [11], thereby indicating a necessity for enhanced LLIN promotion and uptake strategies. A comprehensive understanding of the complex interplay of these factors in Al Managil City is critical for optimizing malaria control strategies and maximizing their effectiveness. National malaria control strategies in Sudan have predominantly emphasized vector control, particularly through the mass distribution of LLINs and, with indoor residual spraying (IRS) implemented to a lesser extent [12]. An investigation conducted in Aljazeera State established the cost-effectiveness of both IRS and LLINs as malaria control interventions, further indicating that LLINs were more cost-effective than IRS in averting malaria cases [8]. Notably, IRS provided a substantial return on investment with respect to the reduction of severe malaria [13].

Vulnerability to malaria is frequently age-dependent, with children under five years of age typically experiencing the greatest infection rates [14]. Socioeconomic factors, such as lower income [15] and lower levels of education [16], may exacerbate malaria risk by limiting access to preventive measures, such as LLINs, and timely and appropriate healthcare, and by impeding the adoption of effective malaria prevention practices. Agricultural practices and associated environmental modifications, including deforestation [17] and proximity to *Anopheles* mosquito breeding sites within the Al Managil agricultural scheme [18, 19], significantly influence malaria transmission dynamics. Studies from Ethiopia further demonstrate that irrigation schemes exacerbate malaria transmission by enhancing mosquito breeding opportunities [19].

The ongoing conflict and displacement crisis in Sudan has profoundly impacted malaria control efforts in Aljazeera State. Interruptions to healthcare access, reduced availability of LLINs, and overcrowding in displacement settings have likely contributed to heightened vulnerability to infection [20].

The ongoing conflict in Sudan has profoundly disrupted healthcare services in Aljazeera State. Data suggest that over 70% of health facilities in conflict-affected states are non-functional, resulting in severely compromised, or entirely absent, access to healthcare for millions within conflict-affected populations [21]. This disruption has likely significantly constrained malaria diagnosis, treatment, and prevention efforts in the region [22].

The ongoing conflict in Sudan has severely compromised supply chains and healthcare provision, substantially impeding malaria control efforts. This situation has been compounded by medicine shortages resulting from disrupted supply chains, notwithstanding resource provision by health partners, including the WHO. Moreover, healthcare workers across Sudan have experienced salary disruptions for four months, precipitating industrial action and further exacerbating the strain on healthcare delivery [20-22].

This study endeavors to address the exigent need for contemporary data on malaria prevalence and its associated risk factors in Al Managil City, particularly in light of the ongoing conflict and its deleterious effects on healthcare infrastructure.

MATERIAL AND METHODS

Study design and setting. This cross-sectional study was conducted in Al Managil City, Aljazeera State, Sudan, between August 2022 and April 2023. Al Managil, the capital of the Al Managil District, is situated approximately 153 kilometers south of Khartoum and has a population of 128,297 [23]. The city lies within an irrigated agricultural region and experiences a tropical climate that favors mosquito breeding.

Study participants and sampling. The study population included individuals presenting with fever or suspected malaria at designated healthcare facilities in Al Managil City. To ensure representativeness of the city's healthcare-seeking population, four healthcare facilities – Al Shaiq Health Center, Wladalbor Health Center, Al Nasr Health Center, and El Managil Hospital – were selected using simple random sampling from a comprehensive list of all health facilities in the city. The sample size was calculated as 385 participants using the formula: $n = z^2 * p * q / d^2$, where:

- n = sample size
- z = Z-score corresponding to a 95% confidence interval (1.96)
- p = estimated prevalence rate (0.5; this conservative estimate was used in the absence of reliable prior data on malaria prevalence within the specific study area)
- $q = 1 - p$ (0.5)
- d = margin of error (0.05)

This calculation yielded a required sample size of 385 participants. A systematic random sampling technique was utilized to select participants from the daily attendance registers at each healthcare facility. Individuals who declined participation or were unable to provide informed consent were excluded from the study. Non-response rates were monitored at each facility to evaluate potential for bias.

Microscopy procedures. Thick and thin blood films were prepared from capillary blood samples obtained from participants, adhering to standard operating procedures for malaria microscopy [24]. These procedures included cleansing the fingertip with alcohol, puncturing the skin with a sterile lancet, and collecting a droplet of blood. Thick blood films were utilized for the detection of malaria parasites, while thin blood films were employed for parasite species identification. Thin blood films were fixed with absolute methanol, and both thick and thin films were subsequently stained with a 10% Giemsa solution (pH 7.2) for 10 minutes. Following staining, slides were rinsed with distilled water, allowed to air dry, and then examined by optical microscopy under oil immersion at 1000x magnification. Microscopic examination involved reviewing at least 100 fields before determining a negative result.

Data collection and statistical analysis. Following the acquisition of written informed consent, a structured questionnaire, pre-tested in a pilot study, was administered to each participant to collect data on demographic characteristics and potential malaria risk factors. These factors included, but were not limited to, gender, residence (urban/rural), age group, bed net utilization, prior malaria history, and proximity to irrigated agriculture, among others. The collected data were entered into a digital database and analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed for all variables. Associations between categorical variables and malaria infection status were assessed using Pearson's chi-square tests. Statistical significance was defined as a p-value of less than 0.05. Ninety-five percent confidence intervals (CIs) were calculated for malaria prevalence estimates.

Ethical considerations. Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine at the University of Kassala (approval number NKS/UK/C/122). Written informed consent was secured from all participants following a detailed explanation of the study's purpose, procedures, risks, benefits, and their right to withdraw at any time without consequence, as described in the data collection process. All procedures adhered to the Declaration of Helsinki and national ethical guidelines. Participant data were anonymized and stored securely, with access limited to authorized personnel.

RESULTS

Participant characteristics. Participants ranged in age from 5 months to 65 years and were categorized into three groups: under 5 years, 5–15 years, and over 15 years. Regarding gender distribution, 54.5% were male and 45.5% were female. The majority of participants (89.9%) resided in rural areas, with the remaining 10.1% residing in urban areas.

Malaria prevalence and species distribution. The overall malaria prevalence in Al Managil City was 63.9% (246/385), with 246 individuals testing positive for malaria and 139 testing negative. Among the confirmed cases, 243 (98.8%) were attributed to *P. falciparum*, while 3 (1.2%) were due to *Plasmodium vivax* (Table 1).

Association between socio-demographic characteristics and malaria infection. The association between socio-demographic characteristics (gender, residency, and age group) and malaria infection status was evaluated using Pearson's chi-square tests. No statistically significant association was found between gender and malaria infection (P = 0.915). Specifically, 135 out of 210 males (64.3%) tested positive for malaria, while 75 males (35.7%) tested negative. Similarly, 111 out of 175 females (63.4%) tested positive, and 64 females (36.6%) tested negative.

Table 1. Demographic characteristics and malaria infection status of study participants

Characteristics	Frequency (*n*)	Percentage (%)
Gender		
Male	210	54.5
Female	175	45.5
Residency		
Urban	39	10.1
Rural	346	89.9
Age group (years)		
<5	237	61.6
5–15	85	22.1
>15	63	16.4
Malaria infection status		
Positive	246	63.9
Negative	139	36.1
***Plasmodium* species**		
P. falciparum	243	98.8
P. vivax	3	1.2

No statistically significant association was found between residency and malaria infection (*P* = 0.298). Among urban residents, 28 out of 39 (71.8%) tested positive for malaria, while 11 urban residents (28.2%) tested negative. Conversely, 218 out of 346 rural residents (63.0%) tested positive, and 128 rural residents (37.0%) tested negative.

However, age group was significantly associated with malaria infection (*P* = 0.003). Within the < 5 years age group, 136 out of 237 participants (57.4%) tested positive for malaria, while 101 participants (42.6%) tested negative. Among individuals aged 5–15 years, 62 out of 85 (72.9%) were malaria-positive, with 23 individuals (27.1%) testing negative. For those above 15 years of age, 48 out of 63 (76.2%) were malaria-positive, while 15 individuals (23.8%) were malaria-negative. These findings underscore age as a significant factor associated with malaria infection (Table 2).

Table 2. Association between socio-demographic characteristics and malaria infection in Al Managil City, Sudan

Characteristics	Malaria positive *n* (%)	95% CI	Malaria negative *n* (%)	95% CI	*P*-value
Gender					
Male	135 (64.3)	57.4–70.8	75 (35.7)	29.2–42.6	0.915
Female	111 (63.4)	55.8–70.6	64 (36.6)	29.4–44.2	
Residency					
Urban	28 (71.8)	55.1–85.0	11 (28.2)	15.0–44.9	0.298
Rural	218 (63.0)	57.7–68.1	128 (37.0)	31.9–42.3	
Age group (Years)					
<5	136 (57.4)	50.8–63.8	101 (42.6)	36.2–49.2	0.003
5–15	62 (72.9)	62.2–82.0	23 (27.1)	18.0–37.8	
>15	48 (76.2)	63.8–86.0	15 (23.8)	14.0–36.2	

Association between symptoms and malaria infection. The association between reported symptoms and malaria infection status was evaluated using Pearson's chi-square tests. Statistically significant associations were observed between malaria infection and several reported symptoms (Table 3), including fever (*P* < 0.001), headache (*P* < 0.001), malaise (*P* = 0.019), chills (*P* = 0.006), joint pain (*P* = 0.008), fatigue (*P* = 0.020), and abdominal pain (*P* = 0.020). Fever was the most common symptom, reported by 81.3% of participants, with a significant association with malaria infection (Table 3). In contrast, no statistically significant associations were found between malaria infection and nausea/vomiting (*P* = 0.525) or diarrhea (*P* = 0.507). The significant association observed for abdominal pain is consistent with the overall findings.

Table 3. Association between reported symptoms and malaria infection

Symptom	Malaria positive (n=246)	Malaria negative (n=139)	*P*-value
	Present n (%)	**Absent n (%)**	
Fever	200 (81.3)	88 (63.3)	0.000
Headache	99 (40.2)	26 (18.7)	0.000
Malaise	97 (39.4)	38 (27.3)	0.019
Chills	76 (30.9)	25 (17.19)	0.006
Nausea/Vomiting	75 (30.5)	42 (30.2)	0.525
Diarrhea	46 (18.7)	30 (21.6)	0.507
Joint Pain	77 (31.3)	26 (18.7)	0.008
Abdominal Pain	71 (28.9)	25 (17.19)	0.020
Fatigue	126 (51.2)	40 (28.8)	0.020

Environmental risk factors associated with malaria infection. The association between environmental risk factors and malaria infection status was evaluated. Proximity to vegetation within irrigated or cultivated agricultural schemes was significantly associated with malaria infection (*P* = 0.009). Specifically, among those residing near such vegetation, 107 out of 246 (43.5%) tested positive for malaria, compared to 41 out of 139 (29.5%) of those who did not reside near such vegetation. Other environmental risk factors evaluated, including the use of insect repellent cream, closing windows and doors, the use of smoke as an insect repellent, wearing protective clothing, the presence of stagnant water, the use of insecticide spray, and the utilization of insecticide-treated mosquito nets, did not exhibit statistically significant associations with malaria infection (Table 4).

Table 4. Association between risk factors and malaria infection

Risk factor	Malaria positive *n* (%)	Malaria negative *n* (%)	*P*-value
Use of insect repellent cream	16 (6.5)	6 (4.3)	0.495
Closing windows and doors	205 (83.3)	123 (88.5)	0.182
Use of smoke as an insect repellent	108 (43.9)	50 (35.9)	0.133
Proximity to vegetation within irrigated/cultivated agricultural schemes	107 (43.5)	41 (29.5)	0.009
Wearing protective clothing	19 (7.7)	9 (6.4)	0.838
Presence of stagnant water	101 (41.0)	46 (33.1)	0.128
Use of insecticide spray	97 (39.4)	54 (38.8)	0.499
Utilization of insecticide-treated mosquito nets	142 (57.7)	81 (58.3)	0.502

DISCUSSION

The observed malaria prevalence of 63.9% in Al Managil City is consistent with the prevalence reported in Al Geneina City, Sudan (61%) [25]. However, this finding is markedly higher than the prevalence reported in North West Ethiopia (29%) [26], and also exceeds the national average for Sudan. This variation likely reflects differences in several factors, including rainfall patterns, the implementation and effectiveness of insecticide-treated net programs, access to diagnostic testing and antimalarial treatment, and the impact of the ongoing conflict on healthcare infrastructure.

Our study confirmed *P. falciparum* as the predominant malaria species in Al Managil City, accounting for 98.8% of confirmed cases. This finding is consistent with reports of *P. falciparum* dominance in Sudan [25], South Sudan [27], Ethiopia [28], Chad [29], and other regions of sub-Saharan Africa [30], thereby reinforcing the established high prevalence of this species in the region. This dominance has significant implications for malaria control strategies, influencing treatment guidelines, the selection of diagnostic tools, and the design of vector control interventions. *P. falciparum* is associated with more severe disease manifestations, higher mortality rates, and an increased propensity for developing resistance to antimalarial drugs compared to other malaria species.

Notably, individuals over 15 years exhibited the highest prevalence (76.2%), despite comprising only 16.4% of participants, contrasting with typical patterns of childhood vulnerability seen in Tanzania [31] and Rwanda [32]. This may reflect increased occupational exposure in agricultural settings or lower bed net use among adults, though age-specific utilization data were not collected. The predominance of under-5 participants (61.6%) in our sample, likely due to higher healthcare-seeking for young children, may underrepresent adult prevalence, suggesting a need for broader population-based studies.

Studies conducted in Tanzania [31] and Rwanda [32] have demonstrated that younger age groups are frequently at higher risk of malaria. This discrepancy underscores the potential for varying age-related malaria prevalence patterns depending on the specific epidemiological context.

While increasing evidence underscores the complex interplay between sex and gender roles in influencing health outcomes [33], our study did not reveal a significant association between gender and malaria infection. This contrasts with a prior study conducted in Sudan [25], which reported a higher prevalence of malaria among males compared to females and a statistically significant association between gender and malaria infection. The aforementioned study [25] focused on a displaced population in Al-Geneina City, western Sudan, whereas our investigation was conducted in Al Managil City. The observed discrepancy may be attributable to differences in population characteristics such as occupational profiles (*e.g*., a higher proportion of males engaged in outdoor agricultural work leading to increased exposure), environmental factors including proximity to mosquito breeding sites, and differential access to healthcare services encompassing preventive measures like insecticide-treated nets. Furthermore, the temporal context of data collection may also contribute to the observed differences, as malaria transmission patterns exhibit seasonal variability. Further research investigating gender-specific behaviors related to malaria prevention (*e.g*., bed net utilization, healthcare-seeking practices) and access to healthcare resources within the Al Managil City context is warranted. A nuanced understanding of these factors is crucial for developing effective and equitable malaria control strategies, such as targeted health education campaigns or enhanced access to preventive measures for specific subpopulations.

While some studies have reported a reduction in infectious disease risk associated with increasing urbanization [34], our findings did not reveal a significant association between residency (urban *versus* rural) and malaria infection in Al Managil City. This lack of association may be attributable to several factors. Similarities in environmental conditions, such as the presence of irrigated agricultural schemes and a tropical climate conducive to mosquito breeding, across both urban and rural areas of Al Managil City likely contribute to a consistent risk of malaria transmission across these settings. Furthermore, the increasing *ruralization* of urban areas in Sudan, driven by unplanned migration from rural to urban areas, may also contribute to the observed lack of association [35]. This migration can lead to the introduction of rural lifestyles and practices, including agricultural activities and potentially lower rates of utilization of preventive measures like bed nets, into urban environments, potentially obscuring the distinction between urban and rural risk profiles for malaria. Further research investigating the specific environmental and behavioral factors contributing to malaria risk in both urban and rural settings within Al Managil City is warranted. This research should focus on factors such as access to and utilization of bed nets, proximity to breeding sites, and the prevalence of *Anopheles* mosquitoes in different residential areas. A nuanced understanding of these factors is crucial for developing tailored interventions, such as targeted vector control or community-based health education programs, which address the specific challenges of each setting.

Our findings contrast with some studies conducted in other regions, such as Malaysia, where a higher prevalence of malaria was observed in rural compared to urban areas [36]. However, comparisons between such geographically and socioeconomically disparate regions should be interpreted with caution. More pertinent comparisons would involve studies conducted in similar settings within Africa; however, such data may be limited for this specific research question. This underscores the context-specific nature of malaria epidemiology.

Our study demonstrated a statistically significant association between malaria infection and several key clinical manifestations, including fever, headache, malaise, chills, arthralgia**,** abdominal pain, and fatigue. This finding is consistent with prior research; for instance, Quaresima *et al***.** (2021) similarly reported fever as the most frequently reported symptom of malaria [37].

Our study demonstrated a statistically significant positive association between malaria infection and proximity to vegetation within irrigated agricultural schemes (P = 0.009), consistent with findings from Malaysia linking forested areas to elevated malaria risk [18]. Such vegetation likely enhances *Anopheles* mosquito breeding by providing shade, humidity, and aquatic sites, increasing transmission risk.

Secondly, this study was undertaken during a period of prevailing political instability and economic hardship, which could have influenced healthcare-seeking behaviors and potentially compromised the representativeness of our sample. While laboratory analyses and medications were provided to study participants without charge to mitigate the impact of economic constraints, the overarching context of instability may still have influenced participation rates and timely access to healthcare services.

Thirdly, data regarding occupation and educational attainment, which are recognized as potential risk factors for malaria, were not collected in this study. Future investigations incorporating these variables would facilitate a more comprehensive analysis of the determinants of malaria risk within this specific setting.

This study unequivocally demonstrates a high prevalence of malaria (63.9%) in Al Managil City, with *P. falciparum* identified as the predominant causative agent. Crucially, individuals over 15 years of age were found to be disproportionately affected, thereby highlighting the critical need for targeted interventions aimed at this vulnerable population. These interventions require a multifaceted approach, including sustained ITN distribution and use, IRS, and targeted health education campaigns for adults over 15, alongside environmental management to reduce vector breeding sites.

Furthermore, the statistically significant association observed between malaria infection and proximity to agricultural schemes strongly indicates that these areas serve as significant determinants of malaria risk within this setting. This finding underscores the critical importance of integrating comprehensive environmental management strategies into malaria control programs in Al Managil City. Such strategies should encompass the systematic elimination of stagnant water sources, implementation of effective waste management practices, improvement of drainage infrastructure to prevent water accumulation, careful water management within agricultural practices to minimize mosquito breeding sites, active community engagement and education initiatives to promote environmental sanitation, and targeted larval control measures implemented around potential breeding habitats.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest associated with this manuscript.

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