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Original article

A case-control study of a malaria outbreak in Nensebo District, West Arsi Zone, Southeast Ethiopia

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Abstract

Background: Malaria-related morbidity and mortality are 94% concentrated in Africa. Ethiopia is one of ten African countries affected by malaria, with 60% of the population living in malaria-risk areas. Recently, seasonal outbreaks have been reported in all regions, including previously malaria-free areas. Nationally, the Nensebo district of the west Arsi zone is classified as having very low transmission. During the 21st WHO week of 2021, Melka Denbi kebele reported an unusually high number of malaria cases to this district. The purpose of this study was to look into the magnitude of the malaria outbreak and the factors that contributed to it.

Methods: A descriptive study was followed by an unmatched case-control study on 86 cases and 172 controls who were chosen at random. Malaria cases were those who were confirmed positive by rapid diagnostic test (RDT) and were line-listed at a health facility, while controls were those who lived nearby and were confirmed negative by RDT. At a p-value of 0.05 and a 95% confidence interval, logistic regression was used to identify malaria contracting factors.

Results: With a mean age of 22 (± 12.31SD), the overall attack rate was 20.2/1000. Plasmodium vivax (PV) 105 (52.8%) was the most common. Staying out at night (AOR=3.94; 95%CI: 2.18-7.37) and stagnant water/intermittent river within one km of the vicinity were risk factors. Screened houses were protective (AOR=0.49; 95%CI: 0.27-0.89), as was knowledge of malaria transmission (AOR=0.51; 95%CI: 0.28-0.93) and prevention and control methods (AOR=0.50; 95%CI: 0.27-0.93).

Conclusion: The illness was caused primarily by PV species known for their relapsing characteristics. Risk factors included stagnant water near homes and sleeping outside at night. Malaria screening centers and increased public awareness reduce the risk of contracting the disease. Our recommendations included regular environmental monitoring, behavioral change communication, ensuring radical cure, and further research with a detailed entomological survey and climate variables.

Keywords: Malaria outbreak, Investigation, Nensebo distict, Kebele, Melka Denbi, Ethiopia

Introduction

An outbreak of malaria occurs when there are more cases than would be expected at a specific location and time (1). Malaria is still a major cause of morbidity and mortality among children and adults in endemic areas around the world (2). The world's poorest tropical and subtropical regions are the most commonly affected. In 2019, approximately 229 million malaria cases were reported, with an estimated 409,000 deaths worldwide. In 2019, the WHO Africa region accounted for 94% of malaria cases and deaths (3).

Emerging resistance to anti-malaria drugs and insecticides used against vectors, misconceptions about malaria, insufficient routine surveillance data to determine trends and variation in malaria incidence, a lack of comparable historical data, and insufficient health care coverage in many epidemic-prone areas all hampered progress in controlling the global malaria epidemic (4–6). Other difficult factors included mosquito biting patterns in the evening, people's behavior, and occupation activities (7,8).

In relation to these, the re-emergence of malaria after its eradication caused enormous damage to a country's economy and people's lives. Malaria outbreaks were among the complex public health challenges attributed to both natural and man-made causes in Sub-Saharan Africa (9). The outbreak was attributed to a breakdown in surveillance, consistently low annual parasite incidence (API), villages not covered by indoor residual spray (IRS), favorable weather conditions for vectors to grow rapidly, abnormal and sudden climatic change, unusual rain, and population migration in the majority of low transmission or non-endemic areas (10).

Malaria threatened 75% of Ethiopia's landmass, with 60% of the Ethiopian population living in this area's 565 districts (11,12). As a result, Ethiopia is among the world countries responsible for 94% of malaria morbidity and mortality in 2019. (3). Malaria transmission rates are highest in Ethiopia during the two seasons of September to December and April to May, which coincide with the main planting seasons (13) (14). In Ethiopia, the coexistence of the common species Plasmodium falciparum (which accounts for 70% of cases) and Plasmodium vivax complicates malaria prevention and control efforts (15).

Long-lasting insecticide bed nets (LLIN) and IRS have been the primary preventive and control methods in Ethiopia for many years. However, LLIN coverage remained low at 62%, with IRS coverage at 23%. (15). Another concerning issue concerning the efficacy of preventive efforts was the recent increase in malaria incidence, which increased from 15/1000 cases in 2019 to 28/1000 cases in 2020, with 1,509,182 total malaria cases and 0.39/100,000 deaths (16). Furthermore, numerous malaria outbreaks have been reported in various low-transmission and malaria-free regions of the country (17). According to studies, having a mosquito breeding site near home, staying outside overnight, not wearing protective clothing, a lack of knowledge about malaria, not using insecticide-treated bed nets, the presence of breeding sites near home, and a lack of environmental control were all factors that contributed to the outbreaks (18,19).

By 2020 national stratification, Nensebo district is among the very low malaria transmission districts, having lagged behind malaria-free areas prior to this stratification (13,20). The district public health emergency management (PHEM) case team received a report of an unusually high number of malaria cases from one of the peripheral kebeles called Melka Denbi during the early 21st WHO week of 2021. This was an unusual occurrence in comparison to the district's malaria transmission patterns over the previous ten years. As a result, understanding the causes of malaria outbreaks in such low transmission areas is critical to preventing the re-emergence of competent anopheles and ensuring an elimination target by 2030. As a result, the purpose of this study was to look into the magnitude and risk factors associated with a malaria outbreak in the low-transmission area of the west Arsi zone in southeast Ethiopia.

Methods

The study setting and period

On August 15-30, 2021, the research was carried out in Melka Denbi of Nensebo Woreda, West Arsi zone, Oromia Region, Southeast Ethiopia. The district's elevation ranges from 1500 to 3700 meters above sea level (a.s.l), with a bimodal rainfall pattern of 900 to 1100 mm and temperatures ranging from 15 to 22 degrees Celsius. The district's population is currently served by five health centers and twenty health pots. By the 2017 national malaria transmission stratification, the district was malaria-free, but by the 2020 stratification, it had reverted to a very low transmission area. The district was not included in the Insecticide Treated Bed Nets (ITNS) and Indoor Residual Spray (IRS) programs due to this transmission pattern. The district public health emergency (PHEM) data revealed previously unknown malaria cases reported from the kebele (the smallest administrative unit) of Melka Denbi between the 24th and 28th WHO weeks of 2020, which went uninvestigated and were repeated during the early 21st WHO week high case load (Figure 1).

Study design

To identify risk factors for malaria, we performed a descriptive analysis followed by a case-control study. The confirmed malaria case for the descriptive study was an acute febrile illness with a rapid diagnostic test positive for malaria line listed at Melka Denbi health post. Because the district was no-endemic prior to 2019, the malaria epidemic threshold level was set using doubled data from 2020's weekly malaria cases report. The outbreak was described using a line list obtained from Melka Denbi's health post by age, gender, week, slide positivity rate, attack rate, and case fatality rate. We conducted an unmatched case-control study in 1:2 ratios for the analytical study to identify risk factors associated with contracting illness from August 15 to 30, 2021.

Study population and variables

Confirmed malaria cases were defined as malaria confirmed by Rapid Diagnostic Test (RDT) in an individual living in the study area between the 21st and 34th WHO World Malaria Day in 2021. (outbreak period). Any person with fever or fever with headache, back pain, chills, rigor, sweating, muscle pain, nausea, and vomiting who was clinically diagnosed with malaria was considered a suspect. Controls were healthy neighbors of cases who were RDT-negative for malaria during the outbreak period. To collect data from cases and controls, we used a standardized questionnaire from the literature. A trained interviewer administered the questionnaire to collect data on patient age, gender, residence, family size, the intermittent river within 1 km, overnight sleeping location (outdoor or indoor), the presence of mosquito breeding sites at home, and respondents' knowledge of malaria transmission. We also carried out an environmental assessment.

Sample size and Sampling

A total of 234 sample sizes were calculated using the EPI-Info statistical package, assuming 76.9% and 57.6% case and control exposure at a 1:2 ratio, based on Afar's (21) study, with a 95% CI, power of 80%, and level of significance of 5%. Adding a 10% non-response rate, the final sample size generated was 258. (86 for the case and 172 for the control). Cases were chosen at random from a line list using the number assigned to each case, and controls were chosen from the vicinity of the chosen case. Community health workers were used to track down cases in each village or residence.

Operational definitions

Malaria outbreak: An unusual increase in malaria cases in specific weeks when compared to the doubled cases in similar weeks the previous year.

Wearing Protective cloth: Respondents who wear clothing that covers their extremities at night (18).

Stagnant water near home: Standing/immobile water within a one-kilometer radius of the home respondent (18).

Staying outdoor overnight: - A person who spends more than six hours outside during the night (18).

Good knowledge: Individuals who performed better than the average on knowledge questions (18).

Screened house: A home with a window screen and closed eaves to prevent mosquito entry at night (22).

Data collection tool and procedure

To collect descriptive data, a standard line list formatted according to national guidelines is used. An interviewer-administered structured questionnaire adapted from previous relevant studies was used to interview cases and controls. The questionnaire collects information from both cases and controls on socio-demographic characteristics, clinical presentation (for cases only), potential risk factors, and knowledge of malaria transmission, prevention, and control (18,22). The data is gathered directly from cases and controls, regardless of their age, gender, educational background, or ethnicity.

Environmental assessment

A one-kilometer radius around the resident was surveyed for the presence of larvae positive breeding sites, including any artificial breeding sites. Larvae from positive breeding sites were collected for an entomological survey.

Quality control

Data collectors received a one-day orientation on the components of the data collection tool, how to recruit cases and controls, and interview ethics. The completeness of the collected data was checked prior to data analysis.

Table 1. Sex and age-specific attack rate per 1000 population in Melka Denbi Kebele of Nensebo Woreda, Southeast Ethiopia, 21 to 34 epidemic weeks, 2021.

Variables	Total population	Number of cases	Species			Attack rate per 1000 pop.
Sex			PV	PF	Mixed	
Male	4,800	113(57%)	56(49.6%)	48(42.4%)	9(7.9%)	24
Female	4,996	85(43%)	50(58.8%)	30(35.3%)	5(5.9%)	17
Age group						
<5	1609	20	8(40%)	12(60%)	0(0%)	12.4
5-15	3057	43	15(35%)	25(58%)	3(7%)	14.06
>15	5130	135	55((40.7)	69(51.1%)	11(8.2%)	26.3

PV: Plasmodium vivax, PF: Plasmodium falciparum

Table 2. Demographic characteristics of malaria outbreak study participants, Melka Denbi kebele of Nensebo Woreda, West Arsi, Southeast Ethiopia, 2021

Variables	**Category**	**Respondent category**		**COR**	**95% CI**	**P-Value**
		Case (N=86(%))	Control (N=172(%))			
Sex	Female	39(45.3%)	82(47.7%)	0.91	0.51-1.53	0.96
	Male	47(54.7%	90(52.3%)	1		
Age category	0-4	4(4.7%)	6(3.5%)	4	0.68-23.2	0.122
	5-14	20(23.3%)	25(14.5%)	3.6	0.94-13.9	0.059
	15-44	59(68.6%)	123(71.5%)	3.1	0.87-10.8	0.081
	>=45	3(3.4%)	18(10.5%)	1		
Marital status	NA	25(29.10%)	35(20.3%)	1.264	0.69-2.31	0.447
	Single	14(16.3%)	32(23.3%)	1.127	0.54-2.34	0.749
	Widowed / Separated	1(1.20%)	2(1.2%)	1.087	0.09-12.2	0.946
	Married	46(53.5%)	103(59.9%)	1		
	No formal	10(11.6%)	31(18.0%)	0.392	0.14-1.02	0.057
	Primary	49(57.0%)	108(62.80)	0.519	0.25-1.07	0.078
	Secondary	17(19.80%)	23(13.40%)	1		
Family size	Small	12(14.0%)	22(12.8%)	1		
	Large	74(86.0%)	150(87.2%)	0.904	0.42-1.92	0.795

Table 3. Factors associated with contracting malaria in Melka Denbi Kebele of Nensebo Woreda, Oromia, Southeast Ethiopia, 2021

Factors	Respondent category		COR 95% CI		AOR	95% CI	P-value
	Case	Control					
Staying outdoor over night							
Yes	56(65.1%)	69(40.1%)	3.07	(1.79, 5.27)*	3.11	(1.70, 5.68)**	**0**
No®	30(34.9%)	103(59.9%)	1				
Wearing full extremity covering clothe in evening							
Yes	28(32.6%)	97(56.4%)	0.4	(0.23,0.69)*	0.57	(0.31,1.04)	0.07
No®	58(67.4%)	74(43.0%)	1				
Screened house							
Yes	28(32.6%)	97(56.4%)	0.52	(0.31,0.88)*	0.49	(0.27,0.89)**	**0.02**
No®	58(67.4%)	74(43.0%)	1				
Having waste collection							
Yes	38(44.2%)	102(59.3%)	0.54	(0.32,0.92)*	0.63	(0.35,1.14)	0.13
No®	48(55.8%)	70(40.7%)	1				
Breeding site / intermittent river with in 1KM of vicinity							
Yes	78 (90.7%)	121(70.3%)	4.2	(2.36,7.48)*	4.28	(1.79,10.27)**	**0**
No®	8 (9.3%)	51 (29.7%)	1				
Good knowledge on malaria prevention methods							
Yes	29(33.7%)	95(55.2%)	0.41	(0.24,0.71)*	0.51	(0.28,0.93)**	**0.03**
No®	57(66.3)	77(44.8%)	1				
Good knowledge on transmission ways							
Yes	34(39.5%)	97(56.4%)	0.51	(0.30,0.86)*	0.5	(0.27,0.93)**	**0.03**
No®	52(60.5%)	75(43.6%)	1				

* Significant variables in bivariate analysis, ** Significant variables in multivariable analysis

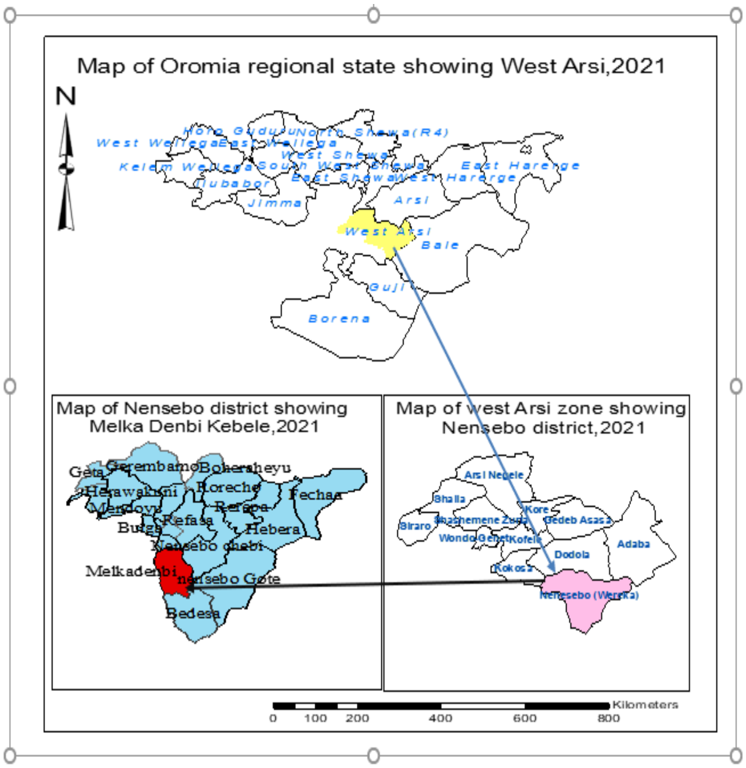

Figure 1. Map of investigation area, Melka Denbi kebele of Nensebo Woreda, West Arsi Zone, southeast Ethiopia, 2021

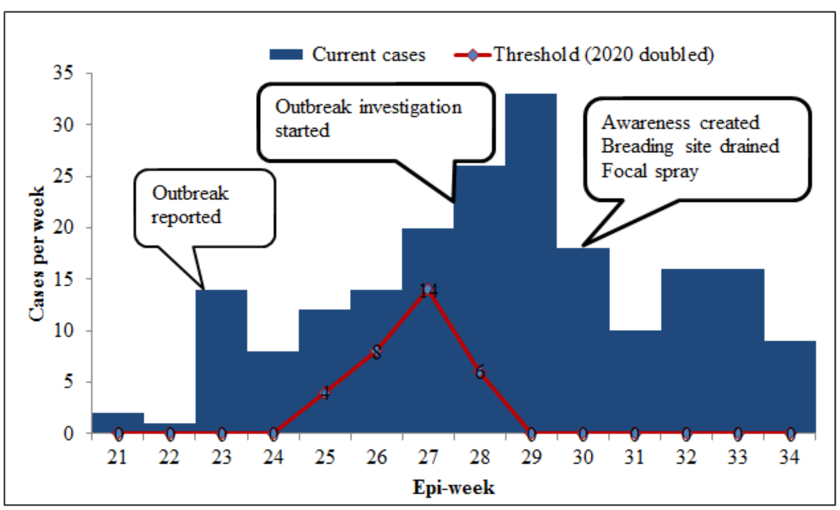

Figure 2. Epidemic curve showing malaria outbreak in Melka Denbi kebele of Nensebo district, West Arsi zone, Oromia, Ethiopia, 2021

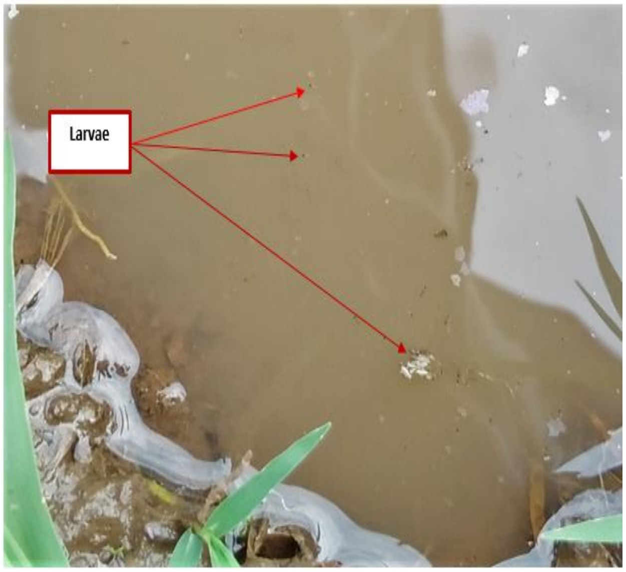

Figure 3. Larvae positive breeding site in Melka Denbi Kebele, Nensebo district, Southeast Ethiopia, 2021

Data processing and analysis

Both collected and line-list data were checked for completeness, coded, entered into Epidata version 4.6, cleaned, and transferred to the Statistical Package for Social Science (SPSS) version 25 for analysis. The magnitude of this epidemic was described using descriptive statistics such as frequency, percentage, ratio, and proportion for descriptive epidemiology. To identify candidate variables for multivariable logistic regression with a P-value less than 0.25, a bivariable logistic regression was performed. Finally, at a P-value less than 0.05, a multivariable logistic regression model with an adjusted odds ratio (AOR) and a 95% confidence interval was used to identify factors associated with malaria. The final model's goodness of fit was evaluated using Hosmer and Lemeshow's goodness of fit.

Ethical consideration

Jimma University and the West Arsi zonal health department both wrote letters of support for the study. The Nensebo district health office provided us with a permission letter. The participants were informed of the study's objectives and their willingness to participate. All study participants/caregivers provided written informed consent after being clearly informed of the study's objectives, and confidentiality was assured.

Results

Epidemic confirmation, preparedness and response

The presence of an outbreak was confirmed by an unusual increase in malaria cases during the early 21st epidemic weeks of 2021, compared to the doubled cases during the same weeks the previous year. The district health team's assessment of the district's readiness for an epidemic and measures taken were ineffective due to the district's characteristics of a very low malaria transmission pattern. In addition, the district lacked sufficient essential drugs for case management, as well as an epidemic planning and response plan.

Description of the outbreak by person

Between the 21st and 34th epidemic weeks, 322 presumptive malaria cases were reported, with an overall positivity rate of 198 (61.5%) and no deaths. There were 113 (57.1%) males and 85 (42.9%) females among the 198 confirmed malaria cases. The overall attack rate of the outbreak when aggregated to the population of kebeles was 20.2/1000. The age group 15-44 years had the highest attack rate, accounting for 63.6% of total cases. The affected people were 22(12.31SD) years old on average (Table 1).

Descriptive epidemiology by place, time and clinical characteristics

During the investigation period, 198 cases were registered with no history of travel to other endemic areas. The villages of Hibiso, Hawi, and Denbi were the most affected, with attack rates of 15.19, 8.8, and 7.71 per 100 people, respectively. The epidemic curve for this outbreak was created on a weekly basis by considering the Plasmodium parasite's average incubation period. Figure 2 shows that the outbreak was a propagated (progressive) type, which lasts longer than the common source with multiple successive peaks. The epidemic investigation was launched late, six weeks after there were cases reported and a decrease in cases seen after the intervention. As a result, the case load peaked during epidemic weeks 28 and 29. Plasmodium vivax was the most common species in this outbreak, accounting for 105 (52.8%) of the total, followed by Plasmodium falciparum (79(39.7%)).

Environmental assessment

During the early stages of the epidemic, an environmental assessment revealed the identification of numerous breeding sites that were positive for larvae, owing to heavy rain and river breaks that spanned the kebele (Figure 3). Anopheles gambiae was discovered in larvae collected from various kebele breeding sites, according to an entomological larvae investigation. Because the district was not a part of the program, none of the visiting families had ever used a bed net or had their home sprayed.

Analytical study

Socio-demographic characteristics of the participants

There were 137 (53.1%) males and 121 (46.9%) females among the 258 study participants. The vast majority, 182 (70.5%), were between the ages of 15 and 44. Cases and controls had median ages of 22.6211.18SD and 24.9912.11SD, respectively (Table 2).

Risk factors analysis

Staying outdoors overnight, having a breeding site/intermittent river within 1 km of the vicinity, having unprotected irrigation, wearing protective clothing, screening house, waste collection, and having good knowledge of malaria transmission and prevention methods were factors significantly associated with contracting malaria in a bivariable logistic regression analysis. Five of the eight candidate independent variables that were entered into multivariate logistic regression analysis and were adjusted to other variables using forward stepwise selection were factors in either contracting or protecting against illness (Table 3). Accordingly, those who live near a breeding site or an intermittent river within 1 km of their home were 4.28 times more likely to become ill than those who did not (AOR=4.28, 95%CI: 1.8-10.27); those who stayed outside at night were 3.11 times more likely to become ill than their counterparts (AOR=3.11, 95%CI: 1.70-5.68). Those who lived in screened-in houses were 51% safer than those who did not (AOR=0.49, 95%CI: 0.27-0.89). Knowing how malaria spreads (AOR=0.51, 95%CI: 0.28-0.93) and how to prevent infection (AOR=0.50, 95%CI: 0.27-0.93) reduces the risk of infection by 51% and 50%, respectively, when compared to the opposite group.

Public health intervention

An emergency order was used to obtain emergency drugs. Residents were given information on malaria prevention and environmental control. Draining and steering of breeding sites were carried out with community participation. The focal spray was also applied to known breeding sites.

Discussion

The outbreak in this study lasted from the 21st to the 34th WHO week, which corresponded to the expected vector months in Ethiopia (13). Males (57.1%) and people aged 15 to 44 years (63.6%) were the most affected during this outbreak, accounting for the majority of cases. Plasmodium vivax species were responsible for nearly 60% of the morbidity during the outbreak. Following the outbreak's onset in the early 21st WHO week, the high load of cases progressively increased from week 24th to week 29th, owing to a delay in epidemic response. Unlike the national malaria elimination effort, which aims to limit the spread of malaria in low transmission areas by 2020, this outbreak had a high attack rate (23).

During this outbreak, the most affected age group was 15-44, with many of them being males (63%), which was consistent with the outbreak in Colombia (24). Furthermore, this finding was supported by malaria outbreaks in India's non-endemic district (10) and other malaria outbreaks in Ethiopia's Afar region, where reproductive age groups older than 15 years were mostly affected (21). Adults may be more vulnerable to attack than children because of activities such as staying out late at night, which has been strongly linked to this outbreak. Plasmodium vivax was responsible for 52% of malaria illnesses, followed by Plasmodium falciparum (40%). This finding was consistent with the findings of the Indian investigation and the report of the malaria pattern investigation in the highland fringe of southern Ethiopia (25,26). This resemblance could be attributed to the high land features of this study area, where Plasmodium vivax species are thought to be the most common due to the species' relapsing characteristics. Malaria illness was caused by increased breeding sites formed as a result of heavy rainfall and inadequate malaria prevention measures (27). In line with this reality, our study's findings revealed that residents who had access to stagnant water or intermittent rivers within 1 km of their home had a 4.28 times higher risk of contracting malaria than those who did not. This finding was consistent with the findings of a Zimbabwean malaria outbreak investigation (28, 29). Similarly, the findings of this investigation were consistent with those of the Simada district, Northwest, and other studies in east and north Ethiopia (19, 21, and 22). This highlighted the importance of focusing on larvae source management in high land fringe areas with low transmission rates to prevent competent anopheles re-emergence (30).

Supported by evidence that malaria mosquitoes are active at night and that people's occupation factors during the night contribute to the persistence of malaria transmission (11, 12), the findings of our study revealed that those who stayed outside at night were three times more likely to contract malaria than their counterparts. This finding is consistent with a malaria outbreak investigation conducted in India's Bengal region, as well as another study conducted in rural south Zimbabwe (25, 31). This finding was also consistent with other malaria outbreak investigations conducted in Ethiopia (18, 21, and 22).

Our research found that living in a screened-in house (windows and doors) reduces the risk of contracting malaria by 51%. This is comparable to the findings of the malaria outbreak investigation from Northern Uganda and Ethiopia's Tigray region (22, 27). Malaria awareness and perception were important factors in reducing the risk of contracting the disease (32). Similarly, our findings indicate that understanding malaria transmission and prevention mechanisms reduces the risk of contracting malaria by 50% and 49%, respectively. This finding was consistent with the findings of Ethiopian studies (18, 19).

RDT, which was not the gold standard, was used to recruit all participants. Climate variables that may be important considerations in areas with low transmission patterns were not investigated in our study. Furthermore, due to financial constraints, detailed entomological surveys of mosquitoes were not carried out.

Conclusion and recommendation

In this outbreak, males were attacked more than females. In this outbreak, people over the age of fifteen were the most affected. Plasmodium vivax species were the most common culprits in this outbreak. During the outbreak, an entomological survey revealed an Anopheles gambiae emergency from collected larvae. Staying outside in the evening and having stagnant water or an intermittent river nearby were risk factors. In this study, screened houses, as well as knowledge of malaria transmission and prevention, were found to be protective against malaria illness.

Regular environmental monitoring to ensure effective larvae source management, strengthening the malaria surveillance system along with active case search is required for early warning and to capture early unfamiliar cases before they cause high risk, behavioral change communication, ensuring radical cure, species-based case management, preventive measures like ITNS, IRS, and focal spray, and additional research with detailed entomological survey and climate variables were our findings.

Abbreviations

API: Annual parasite incidence, AOR: Adjusted Odd Ratio, AR: Attack Rate FMOH: Federal Ministry of Health, IRS: Insecticide Residual Spray, LLIN: Long lasting insecticide net NMSP: National Malaria Strategic Plan

Availability of data and material

The datasets used in this study are available from the corresponding author upon request.

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This research received no funding.

Authors' contributions

AN: Conceptualization, data analysis, first draft writing, and manuscript preparation. FAM was involved in protocol development, data collection, and analysis; DHG and KM were involved in drafting, data analysis, and manuscript review; and JAA and GCF were involved in drafting and manuscript review. The final manuscript was read and approved by all authors.

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