

## Risk factors for *Plasmodium falciparum* recurrence in artemetherlumefantrine treated population from Bushenyi district, Uganda

### Abstract

**Background:** Malaria remains a major vector borne diseases globally. In 2019, it was reported that Uganda accounts for 5 % of the total global cases of malaria related deaths after Nigeria and Democratic Republic of Congo. Various risk factors may be responsible for poor treatment outcomes which has necessitated the current study

**Methods:** A descriptive cross-sectional study was conducted in four selected health centers of Bushenyi district, Uganda by using questionnaire, direct observations and laboratory based studies. Data analysis was done using statistical package for social sciences (SPSS version 23 windows) for descriptive statistics. Logistic regression analysis was done to evaluate the association between *Plasmodium falciparum* recurrence and associated risk factors.

**Results:** Statistically independent predictor risk factors for *Plasmodium falciparum* recurrence at  $p < 0.05$  were; Previous Diagnosis used before the current artemetherlumefantrine (AL) treatment (OR=11.864; 95% CI: 1.477-95.280;  $p=0.020$ ), Sleeping with animals (OR=0.193; 95% CI: 0.075-0.894;  $P=0.032$ ), Age (OR=1.435; 95% CI: 0.0825-0.975;  $p=0.040$ ), Travelling outside the study area (OR=2.324; 95% CI: 0.050-0.699;  $p=0.012$ ), Weight (OR =1.543; 95% CI: 0.085-0.987;  $p=0.002$ ), Gametocytes on day 0 (OR =0.284; 95% CI: 0.0625-0.735;  $p=0.032$ )

**Conclusions:** Monitoring of transmission potentiality after Artemisinin combined therapies (ACTs) treatment is vital in the fight against malaria infection.

**Keywords:** Risk factors, *Plasmodium falciparum*, recurrence, Uganda.

### Introduction

Malaria remains the major parasitic infection in the world especially in pediatrics and pregnant women. According to World Health Organization (WHO) (2019), 216 million cases of malaria were registered worldwide in 2018. According to the World malaria report, approximately 3.4 billion of the world population reside in the geographical regions which are vulnerable to malaria transmission (malaria report, 2019). Mortality resulting from malaria has been majorly reduced through the use of artemisinin based combination therapies (ACTs). Reduced *P. falciparum* sensitivity to ACTs has been reported in South East Asia and this scenario may also affect the African continent where majority of the countries have adopted the use of ACTs in the treatment of uncomplicated malaria.

The association between parasite clearances after treatment is not clear and parasite transmissibility is also unknown and it's regarded as the major question behind the successful prevention of evolution and spread of drug resistance. Uganda has made some positive progress in combating the burden of malaria; however, it has still remained high. Recurrence after

treatment may influence the occurrence of new clinical infections with a risk of complications on the patient (WHO, 2015). Thus, understanding on the factors making malaria to remain a persistent crisis even after employing treatment is vital for developing elimination tools in sub-Saharan Africa and Uganda inclusive. The distribution and transmission mechanism is multifaceted in nature affected by environmental factors, parasitic factors, vector factors, and host factors. Thus determining the association between malaria infections and host factors is vital in developing standard interventions in malaria endemic areas.

Biological factors have been implicated in influencing the clinical outcomes of malaria infections. Major biological factors include, but not limited to Age, immunity and health status of human host (Protopopoff et al., 2009). Previous studies have reported that acquired immunity reduced the severity of malaria infections. Consequently Health status of human population has been implicated as one of the vital factor influencing the outcomes of malaria infection coupled with malnutrition increased the mortalities and morbidities due to malaria infections. Consequently immunosuppression of the population can increase malaria incidences (Carrasco-Escobar et al., 2017).

A previous meta-analysis has indicated that drug usage, parasitic factors, transmission intensity and host factors were the major factors influencing drug responses by malaria parasites (Woodrow & White, 2017). These factors basically increases the ability of bulky numbers of parasites to be exposed to drug concentration that are inadequate to eradicate the parasites, hence increasing the multiplication and survival of the parasites. Human behavior has also been reported as a major factor influencing the evolution of poor drug responses. A previous report from Southeast Asia has indicated that treatment failure is majorly concentrated to forested places which are close to migration borders which harbors mostly immigrants of young age who are more prone to malaria. Moreover self-medication without proper diagnosis and using substandard drugs coupled with poor dosage admiration are some of the factors implicated in increasing chances of poor drug responses in South East Asia, an epicenter of drug resistance (Kumar et al., 2019).

Despite the fact that ACTs drugs are recommended as the first line drugs for the treatment of uncomplicated malaria in Uganda, different treatment outcomes have been reported which might be influenced by both intrinsic such as age, sex, weight and extrinsic factors such as drug use. Robust information about risk factors influencing the treatment outcomes in Uganda is insufficient. Previous ACTs therapeutic efficacy studies have reported occurrences of malaria parasites in patients treated and followed for 28 days despite lack of molecular markers for resistance. A study conducted in Brazil showed that relapse episodes mostly occurred between the day 28 and 90 after initiating treatment (Simoes, 2014). However, such studies have not evaluated the possible risk factors influencing the treatment outcomes. This study forms part of a broader study in the same area having used the same study participants who reported poor responses to ACTs (Maniga et al., 2018), despite lacking sufficient resistant molecular markers in circulation (Maniga et al., 2021, Unpublished data). Uganda has not developed a standard health operating protocols to be followed by malaria patients after undergoing treatment. This can be achieved by first identifying the risk factors which might be influencing the treatment outcomes. Therefore, this study was conducted to establish the risk factors which might be influencing the ACTs treatment outcomes among patients with uncomplicated malaria. The

findings from this study are significant to a proposal by the Ministry of Health of Uganda in eliminating malaria infection by the year 2030.

## **Materials and methods**

### **Study area description**

This study was carried out in Bushenyi District, which is located in South Western of Uganda. The District is composed of eleven sub-counties namely; Bushenyi-ishaka, Ibaare, Kyamuhunga, Bitooma, Bumbaire, Kyabugimbi, Nyabubare, Nyakabirizi, Kyeizoba, Kakanju, Ruhumuro, 76 parishes, and 529 villages. The total population stands at 235,621 as in the latest census carried out in 2014. The district covers an area of 905 km<sup>2</sup> with the population Density of 274.3/km<sup>2</sup>. The district is located approximately 380 kilometers from the capital city, Kampala. It lies on latitude: 0° 28' 22.8" (0.473°) South, longitude: 30° 16' 8.4" (30.269°) East. The average elevation is about 1,649 meters (5,410 feet). The district is a cosmopolitan in nature with majority of the inhabitants being the local Ankole ethnic group. The district experiences seasonal movement of people from other countries such as Rwanda and Democratic Republic of Congo (DRC) who may be a source of imported malaria parasites. Moreover, the district is a hub of many foreign students and foreign health workers who may also be a source of imported malaria. The economic activities of the district include daily farming, fish farming, banana farming and tea farming. The district houses the third largest referral hospital in the country (KIUTRH), but is also served by several government and private health facilities. In the rural setting, the district has local village health heads that coordinate public health issues at the community level. The map showing study area is indicated in figure 1 below.

Figure 1; map of Bushenyi district showing the study area (Uganda Bureau of Statistics, UBOS, 2015). Copyright © 1998-2018: Copyrights reserved to United Nations Office for the Coordination of Humanitarian Affairs, based on OCHA/relief web

### **Study Design**

The study employed the usage of laboratory based procedures and questionnaires.

### **Laboratory protocols**

The recruitment of study participants from the health facility was conducted irrespective of their individual ages. These consisted of out-patients presenting with signs of uncomplicated malaria to the responsible medical practitioner. Informed consents were obtained from all participants as adult patients willingly tendered their signatures on the informed consent forms while minors below 18 years, gave their consents through their parents or guardians. Therapy was given using AL for 28 days and the patients were followed throughout the treatment period to determine the presence of parasites using Rapid Diagnostic Test (RDT) and microscopy technique. Blood sample was collected by obtaining 1 ml of venous blood for the adult participants. In the case of children who were under 2 years of age, 100  $\mu$ L finger prick blood sample was collected. This procedure was repeated during the subsequent follow up visits. Rapid Diagnostic Test (RDT) analysis was done by using HRP-II (HRP2 (Pf) (Access Bio, Inc, USA), and for the positive samples was subjected to microscopy studies for *P. falciparum* confirmation. For microscopy, thick and thin blood smears were prepared by following standard procedures. Thick and thin blood smears were stained with 10% Giemsa stain for 10 min. Slides were considered negative if after examination of thick smears, there was no parasite detected in 100 high power fields. For thin smears, they were fixed in methanol solution (Maniga et al., 2018).

### **Questionnaire administration**

The demographic health survey (UDHS, 2015), served as a guide in developing the questionnaires used for this study. This approach was necessary as it availed the researchers with the correct and accurate information regarding the health complications associated with malaria in the Ugandan population. There were three subsections in the questionnaire. Section 1 consisted of socio-demographic characteristics such as marital status, Educational level, Age, Gender, Annual income, Employment status and Agricultural practices. Section 2 contained various modes of exposure to bites by the vector such as nocturnal activities, having extremely close contacts with animals, visits to areas other than the study sites, extreme closeness to mosquito breeding areas. Section 3 involved a study carried out on the final follow up day that observed housing and other environmental factors.

### Data Analysis

Filled questionnaires were serially coded. Data was entered and cross checked for errors using Microsoft Excel version 2013 prior to analysis. Data analysis was done by descriptive statistics and regression using IBM SPSS version 23. Descriptive statistics was used to obtain the 28 day parasitemia frequency and the mean age. Bivariate regression analysis between human related variables and 28 day parasitological outcome as well as bivariate analysis between health and patient practices in relation to parasitological outcome was carried out and all the variables with a  $p$  value of 0.005 or less were entered into stepwise forward multiple logistic regression model. Interaction and confounding were assessed and values of  $P \leq 0.05$  were regarded as statistically significant relationships. Chi-Square test was used to determine possible associations between categorical variables.

### Ethical Considerations

The ethical approval of the study was sought from Mbarara University of Science and Technology (MUST), Institutional Research and Ethics Committee (IREC) on Human Research (Approval no 06/01-17) and Uganda National Council for Science and Technology (Approval no HS2241). All research protocols were performed in accordance with the ethical standards of the committees on human experimentation laid down in the Helsinki declaration of 1975 as revised in 2000. Permission was sought from the community leadership. Written consent was obtained from the participants after clearly explaining the purpose and procedures behind the study. Moreover, privacy and confidentiality of the participants was highly maintained during the entire period of the study.

## RESULTS

### 28 days follow up parasitemia recurrence

After a 28 days follow up, 194 participants attending different health facilities in Bushenyi district for malaria treatment were considered for this study. Low parasitemia after day 28 follow up was observed in 17/194 (8.7%). The prevalence of parasitemia was highest in age group 20-29 with 8/17 (53.3%) as compared to the lowest value of 0/17 (0%) in the 50-59 and 60 and above age groups respectively (Table 1).

**Table 1: Age-specific parasitemia after day 28 follow up**

AGE RANGE	PARASITOLOGICAL OUTCOME		TOTAL, N (%)
	Positive, n (%)	Negative, n (%)	
1-9	1 (6.7)	16 (9.0)	17 (8.9)
10-19	4 (13.3)	64 (36.2)	68 (34.4)
20-29	8 (53.3)	31 (17.5)	39 (20.3)
30-39	3 (20.0)	31 (17.5)	34 (17.7)
40-49	1 (6.7)	21 (11.9)	22 (11.5)
50-59	0 (0.0)	9 (5.1)	9 (4.7)
60 AND ABOVE	0 (0.0)	5 (2.8)	5 (2.6)
TOTAL	17 (100)	177 (100)	194 (100)

**Comment [D1]:** Why did you section your age brackets from 10 to 10? I think you would do better to section 5 by 5 because it is well known and confirmed by the WHO that it is in children from 1 to 5 years old that malaria is much more frequent and serious.

### Biological factors associated 28 days follow up occurrence of parasitemia.

Weight and level of parasitemia before treatment was statistically significant at influencing the reoccurrence of the parasites after treatment at  $p=0.001$ . However gender was not found to be influencing the treatment outcomes (Table 2).

**Table 2: Analysis of biological characteristics and 28 day parasitemia recurrence**

Variables	Hospital				P value
	Kyamuhunga HC III n (%) (n=42)	KIUTH n (%) (n=71)	Kyeizooba HC III n (%) (n=71)	Ishaka Adventist Hospital n (%) (n=10)	
<b>Weight (kg), mean (SD)</b>	54.8±6.1	49.9±10.5	56.4±8.7	48.4±9.5	0.002*
<b>Gender (male), n (%)</b>	18 (42.8)	42 (59.1)	47 (66.1)	6 (60.0)	0.38
<b>Gender (female), n (%)</b>	24 (57.2)	29 (40.9)	24 (33.9)	4 (40.0)	0.51
<b>Body temperature on day 0, °C, mean (SD)</b>	37.7 °C ± 1.1	37.5 °C ± 1.1	37.9 °C ± 1.1	37.4 °C ± 1.1	0.42
<b>Gametocytes (µl) on day 0* (95% CI)</b>	10,4801 (8,257–11,785)	13,623 (9,242–14,570)	13,540 (9,300–16,620)	9,221 (7,308–11,252)	0.032*
<b>Median age in years (males)</b>	31.5	28.5	32.5	31.5	0.153
<b>Age range in years (males)</b>	(5–72)	(3–82)	(6–69)	(2–65)	0.245
<b>Median age in years (females)</b>	21.5	38.5	31.5	30.5	0.85
<b>Age range in years (females)</b>	(4–63)	(2–65)	(4–70)	(3–62)	0.235

°C: degree Celsius; Temperature of  $\geq 37.5^{\circ}\text{C}$  or history of fever during the previous 24 hours. Parasitemia\*: geometric mean parasite density (asexual parasites/ $\mu\text{l}$ ); n: number of patients; SD: standard deviation; 95% CI: 95% confidence interval; \* $p < 0.05$ , the mean was significantly different.

#### Human related Factors associated 28 days follow up occurrence of parasitemia

When the predictor variables for occurrence of parasitemia were subjected to bivariate analysis, they had the following logistic regression values: Utilization of mosquito nets (OR=0.253; 95% CI: 0.083-0.774;  $p < 0.05$ ), sleeping with animals (OR=0.420; 95% CI: 0.053-3.337;  $p < 0.05$ ), outdoor activities (OR=0.249; 95% CI: 0.092-0.678;  $p < 0.05$ ), travelling outside the study area (OR=0.342; 95% CI: 0.042-2.534;  $p < 0.05$ ). Whereas, presence of stagnant water near the homestead, type of house owned and presence of vegetation in homestead were found to have no significant association with occurrence of parasitemia after 28 days follow up (Table 3)

**Table 3: Bivariate regression analysis between Human related variables and 28 day parasitemia**

Variables	Categories	Unadjusted Odds ratio	95% CI	<i>p</i> -value	χ <sup>2</sup> value
Presence of stagnant water near the homestead	Present	0.926	0.322-2.668	0.887	0.9
	Absent	1			
Type of house owned	Permanent	0.535	0.182-1.568	0.254	0.3
	Local	1			
Sleeping with animals	Yes	0.420	0.053-3.337	0.0412*	4.1
	No	1			
Presence of vegetation in homesteads	Present	1.543	0.332-7.7.172	0.580	0.4
	Absent	1			
Materials for house roof	Iron sheets	0.398	0.050-3.161	0.384	0.3
	Grass	1			
Outdoor activities	Yes	0.249	0.092-0.678	0.018*	3.8
	No	1			
Travelling outside the study area	Yes	0.342	0.042-2.534	0.012*	3.2
	No	1			

Footnote: CI= confidence interval, *p*= probability, \*statistically significant factors (*p* <0.05) under logistic regression

**Health and patient practices associated 28 days follow up occurrence of parasitemia**

When the predictor variables for occurrence of parasitemia were subjected to bivariate analysis, they had the following logistic regression values: Previous Diagnosis used (OR=13.213; 95% CI: 1.7-102.697; *p*<0.05), frequency of infection (OR=3.519; 95% CI: 1.141-10.847; *p*<0.05), indiscriminate use of drugs (OR=0.090; 95% CI: 0.011-0.738; *p*<0.05) (Table 4 and Table 5)

**Table 4: Bivariate analysis between health and patient practices in relation to parasitological outcome**

Variables	Categories	Unadjusted Odds ratio	95% CI	<i>p</i> -value	χ <sup>2</sup> value
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<b>Fever at admission</b>	Present	4.031	1.362-11.928	<b>0.012*</b>	6.1
	Absent	1			
<b>Previous Diagnosis used</b>	Standard diagnosis	13.213	1.7-102.697	0.014*	5.3
	Presumptive treatment	1			
<b>Frequency of infection</b>	Once in a year	3.519	1.141-10.847	0.029*	4.0
	More than once	1			
<b>Indiscriminate use of drugs</b>	Yes	0.090	0.011-0.738	0.025*	3.7
	No	1			

Footnote: CI= confidence interval,  $p$ = probability,  $p \leq 0.05$  value is \* statistically significant under logistic regression

#### **Risk factors associated with 28 days parasitological outcome using stepwise forward multiple logistic regression analysis**

When the predictor risk factors were subjected to stepwise multiple logistic regression analysis, they had the following regressions values: Previous Diagnosis used (OR=11.864; 95% CI: 1.477-95.280;  $p < 0.05$ ), sleeping with animals (OR= 0.193; 95% CI: 0.075-0.894;  $p < 0.05$ ), Age (OR=1.435; 95% CI: 0.0825-0.975;  $p < 0.05$ ), travelling outside the study area (OR=2.32495% CI: 0.050-0.699;  $p < 0.05$ ) (Table 5)

Table 5: Stepwise forward multiple logistic regression analysis

<b>Variables</b>	<b>Categories</b>	<b>Adjusted Odds ratio</b>	<b>95% CI</b>	<b>p-value</b>	<b><math>\chi^2</math> value</b>
<b>Previous Diagnosis used</b>	Standard diagnosis	11.864	1.477-95.280	0.020*	1.5
	Presumptive treatment	1			

<b>Sleeping with animals</b>	Yes	0.193	0.075-0.894	0.032*	1.3
	No	1			
<b>Age</b>	Less than 18 years	1.435	0.0825-0.975	0.040*	1.4
	More than 18 years	1			
<b>Travelling outside the study area</b>	Yes	2.324	0.050-0.699	0.012*	1.2
	No	1			
<b>Weight</b>	Less than 10 Kg	1.543	0.085-0.987	0.002*	1.8
	More than 10 Kg	1			
<b>Gametocytes on day 0</b>	Yes	0.284	0.0625-0.735	0.032*	1.7
	No	1			

Footnote: CI= confidence interval,  $p$ = probability,  $p \leq 0.05$  value is \* statistically significant under stepwise forward multiple logistic regression analysis

### Discussions

Malaria infection has been documented as the major killer disease, in the East African country of Uganda. More than 90% of the population is at risk of the infection. Currently, Uganda is ranked fourth in the countries with malaria burden, accounting for 50% of outpatient visits, 20% of mortalities and up to 15–20% of admissions (Global malaria programme, W.HO, 2019). Among all control measures that are used against the spread of malaria, chemotherapeutic agents seem to contribute largely to the strategy of combating malaria mortality in the world. However, different treatment outcomes have been reported all over the world (Ocan et al., 2016;; (Balikagala et al., 2017; Ouji et al., 2018; Siddiqui et al., 2020; Kassaza et al., 2021), thus raising the question of therapeutic efficacy of different chemotherapeutic drugs used against malaria. A previous study on the same study area of Bushenyi district using the same human participants reported early treatment failure (ETF) among 75 (38.7%) participants (Maniga et al., 2018). Moreover, a follow

up molecular study which was evaluating the presence of ACTs resistant markers in the study area did not find sufficient evidence of resistance emergence in the study area (unpublished data). Several studies have evaluated different risk factors associated with occurrence and transmission of malaria in Uganda and the rest of the world; however, there are insufficient reports in relation to risk factors influencing the occurrences of parasites after treatment of patients with drugs. Different factors have been implicated previously in eliminating parasites after treatment from the bloodstream, hence determining the treatment outcomes (Kone et al., 2020). Recurrent malaria parasites may occur as a result of relapses, recrudescence or new infections. Malaria is generally influenced by intrinsic factors such as parasite, human, mosquito and extrinsic factors such as environmental, social, behavioral, political, economic conditions and malaria intervention strategies (Bremner, 2001). Therefore, this study was aimed to establishing the risk factors which might be influencing the ACTs treatment outcomes among patients treated for uncomplicated malaria in the study area.

The association between slow parasite clearance and gametocyte carriage reported in our study may be attributed to the ongoing gametocyte production by persisting asexual parasites after treatment. This is because parasite clearance dynamics shortly after initiation of ACTs influences malaria transmission potentiality after 1 week treatment (Adjalley et al., 2011). Our results is in agreement with previous studies which postulated that elevated gametocyte production is associated with slow clearance of parasites after treatment with ACTs (Krishna et al., 2013; Fairhurst et al., 2012; Das et al., 2013). Moreover our results are in agreements with reports from Thailand– Myanmar border, an epicenter of drug resistance, where slow parasite clearance was related with a higher period of gametocyte carriage after mefloquine-artesunate treatment (Carrara et al., 2009). Parasitaemia is associated with the degree of malaria severity, thus serving as a vital indicator of decision making in relation to the type of treatment. Additionally it serves as epidemiological indicator since it can give a clue on the level of transmission intensity.

Our results reported a high parasitemia of 53.3% after 28 day follow up in the age group of 20-29 years. This may be attributed to the social practices which allow most people aged between 20-29 years of the Ugandan population to stay outside in the night hence being exposed to mosquito bites after treatment. Thus, our findings are in contrast with a previous study conducted in Nigeria which reported a high parasitemia recurrence after day 28 treatment in the age group of less than 2 years (Contoh et al., 2019). Moreover, a study conducted over a period of more than 10 years at Thai-Myanmar border, an epicenter of antimalarial resistance also reported that the age group of less than 2 years had more risk of parasitemia recurrence after treatment (Vugt et al., 2011). Consequently, a study conducted in Nigeria reported a contrasting findings by indicating that poor treatment outcomes increased with the decrease in the age of the participants, with the children of less than 12 months having poor treatment outcomes (Sangowawa et al., 2014). Moreover, a recent study conducted in Kenya also reported that age was not a predictor risk factor among the children participants (Beshir et al., 2013)

Proper malaria diagnosis stands out as one of the pillar in malaria elimination. Accurate diagnosis leads to appropriate treatment. Malaria is a febrile disease having clinical symptoms resembling other microorganisms, thus specific diagnostic methods are necessary for differentiation. Moreover, early diagnosis and treatment may halt further progression of the disease. Febrile illness in Africa are commonly treated with drugs which are not properly

**Comment [D2]:** You risk missing the diagnosis of severe malaria if you limit yourself to parasitaemia only. Another important parameter used for this purpose by the WHO is the hemoglobin level. If this rate is less than or equal to 6 g/dl, especially in children under 5, malaria is serious even if the parasitaemia is low.

prescribed by health workers. Our study is in agreement and in contrast with previous study conducted in Gambia, Zaire and Burkina Faso. In Gambia it was reported that previous presumptive diagnosis increased parasite incidence after treatment. This might be correlated with drug resistance which had been reported in Gambia prior to this report. However, in Zaire and Burkina Faso, they recorded reduction of parasite incidences on those patients who had undergone presumptive diagnosis (Hopkins et al., 2007). Use of antimalarial drugs unnecessary without proper diagnosis may promote drug resistance and may lead to development of severe malaria (Mahittikorn et al., 2021).

Despite the high prevalence of malaria in Uganda, no much reports have implicated human movement as a risk factor for recurrence of parasitemia after treatment. Our current study has clearly indicated that travelling outside the study area after treatment was an independent risk factor for *P. falciparum* recurrence. However, the relationship between travelling and malaria risk is likely to be as a result of many factors other than travelling such as malaria vector abundance and vector protection methods. Interestingly, as far as travelling may be indicated as a risk factor, it is a complicated variable which is retrospectively difficult to measure since the patients may not remember exactly the date of travelling. Our study however is in agreement with a previous study conducted in Ethiopia which reported that, travelling was a major risk factor for *P. falciparum* incidences (Yukich et al., 2013). Furthermore, our study also corroborates with a recent study conducted in Thailand-Myanmar border, a geographical location considered an epicenter of antimalarial resistance (Lawpoolsri et al., 2019)

Integration of zoo prophylaxis which is the usage of animals to prevent the occurrence of malaria parasites in the community has been suggested as the future option, with some studies reporting conflicting protective values. Our study used the relationship between domestic animal possession and occurrence of malaria parasites, however the study did not record the specific domestic animal used. This study, reported that, sleeping with animals was a risk factor for occurrence of malaria after treatment. Our study is in agreement with a recent meta-analysis which has indicated that, staying together or next to animals served as risk factors for malaria incidences (Asale et al., 2017). Previous studies conducted in Uganda and outside Uganda reported that presence of animals around the residential areas reduced high malaria parasitemia (Bogh, 2002; Saul, 2003; Donnely et al., 2016).

Our present study reported lack of association of presence of stagnant water near the homesteads, type of house owned, materials for house roof and presence of vegetation in homestead with recurrence of malaria infection. This is in contrast with other studies conducted globally. A recent study conducted in Equatorial Guinea reported that environmental factors such as altitude and distance to rivers and forests served as risk factors of malaria infections (Gomez et al., 2017). Moreover a recent study conducted Thailand-Myanmar border, an epicenter of drug resistance, reported poor housing condition as a predictor of malaria episode after treatment. Additionally, the study reported that malaria episodes increased with staying with other malaria infected individuals in the same house, age, male sex, young age, forest-related occupation (Lawpoolsri et al., 2019).

In contrast with our study, other previous studies have reported other factors which have significant influence on malarial recurrence in patients with uncomplicated malaria. They

reported that, the recurrence of malaria after treatment of *Plasmodium* parasites was as a result of many factors such as drug resistance, substandard drugs and poor malarial immunity (Mahittikorn et al., 2021). Such factors were not considered in our study, thus serving as a major study limitations.

### Conclusions

A thorough understanding of the risk factors influencing the treatment outcomes is vital in setting up policy guidelines which may help to eliminate malaria in Uganda. This may be attained by putting in place robust regulations by the Uganda Ministry of Health. Moreover, increased vigilance during and after treatment needs to be strengthened. Consequently, more researches needs to be conducted to gain better understanding on the parasite recurrence after treatment. Despite the fact that causes of *P. falciparum* malaria was not genetically identified, drug resistance and effective drug management needs to be extensively monitored.

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