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Knowledge, attitudes, and practices regarding malaria control among communities living in the south Cameroon forest region

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ABSTRACT

Objective: This study assessed knowledge, attitudes, and practices (KAP) regarding malaria among communities living in the equatorial forest region of south Cameroon.
Methods: The study was conducted in Olama and Nyabessan. Interviews were undertaken using a semi-structured questionnaire for data collection on KAP, while malaria rapid diagnostic testing, using SD BIOLINE kits, was employed for malaria parasite detection.
Results: In total, 186 heads of households (HoH), comprising 105 (56.45%) males and 81 (43.45%) females, were interviewed. The majority of HoH demonstrated good knowledge of malaria (86.56%; $n = 161$) and control measures, with a high proportion of long-lasting insecticidal net (LLIN) ownership (96.8%; $n = 180$). More than two-thirds (81.1%; $n = 151$) of households owned at least one LLIN for two people. The majority of HoH (85.40%) declared visiting hospitals or clinics in cases of suspected malaria. Malaria parasite prevalence was high in the two study sites (63.9% in Nyabessan and 48.65% in Olama), and varied according to age, house type, and sleeping time.
Conclusion: The study indicated that despite good knowledge of malaria, high possession and utilization of control measures by population, transmission of malaria still persist in the area. The study stress the need for implementing additional control measures to improve the fight against malaria in the area.

Introduction

Malaria remains the most dangerous vector-borne disease in the world, causing high mortality among young children and pregnant women. It is estimated that 229 million new malaria cases were recorded across the world in 2019, leading to 409,000 deaths. Sub-Saharan African countries are the most affected, with 93% of cases and 67% of associated deaths (WHO, 2020). In Cameroon, malaria accounts for over 30% of outpatient visits and is classified as the third-highest cause of mortality in healthcare centres after HIV/AIDS and neonatal infections (PNLP, 2019).

Malaria prevention relies on chemoprevention and vector control, with the mass distribution of bed nets and indoor residual spraying as the primary control measures (Bhatt et al., 2015; Keiser et al., 2005).

Abbreviations: HoH, head of household; LLIN, long-lasting insecticidal net; IRS, indoor residual spraying; WHO, World Health Organization; MoH, Ministry of Health. PBO, piperonyl butoxide; mRDT, malaria rapid diagnostic test; KAP, knowledge, attitude, and practice; NMCP, National Malaria Control Program.

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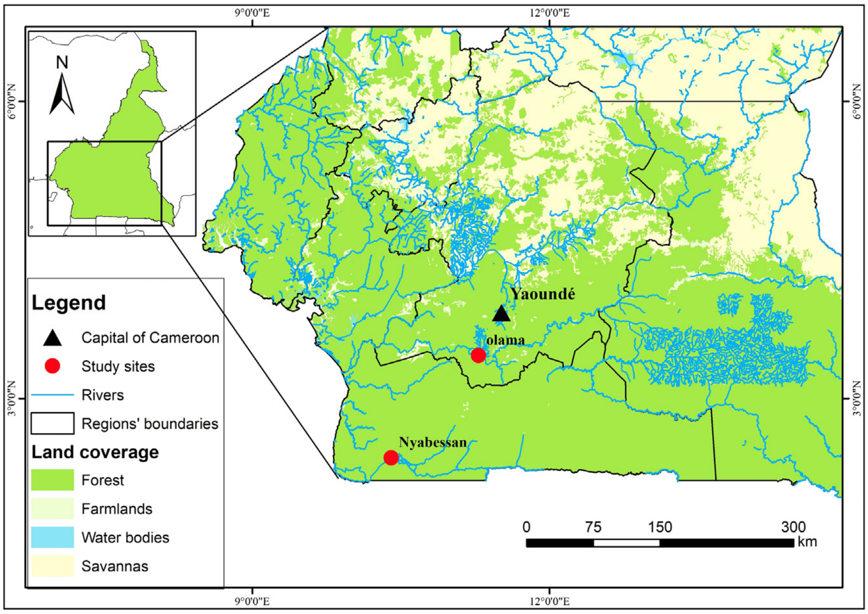

Figure 1. Map of the southern part of Cameroon, showing both study sites.

The deployment of these tools during the last decade has led to a significant reduction in malaria morbidity and mortality across the world (Bayoh et al., 2010; Bhatt et al., 2015; Cook et al., 2018; Finda et al., 2018; Meyers et al., 2016; Meyrowitsch et al., 2011; Mwangangi et al., 2013).

Between 2000 and 2016, Cameroon recorded reductions in the prevalence and mortality of malaria of around 29% and 57%, respectively (WHO, 2015). The regular scaling up of LLINs was the mainstay of this reduction. Between 2014 and 2017, around 20 million nets were distributed in Cameroon (WHO, 2017), increasing the ownership and usership rate in the population. The latest LLIN mass distribution campaign in the country took place in 2019, leading to the distribution of over 15 million pyrethroid-only and pyrethroid + PBO (piperonyl butoxide) bed nets (PNLP, 2021).

Despite progress in the scaling up of LLINs in the country, no significant reduction of malaria mortality and morbidity has been recorded since 2015 (WHO, 2017; WHO, 2018). Several factors, including the rapid expansion of insecticide resistance (Antonio-Nkondjio et al., 2019; Piameu et al., 2021) and changes in vector composition and in the feeding and resting behaviour of *Anopheles* mosquitoes (Bamou et al., 2018; Moiroux et al., 2012; Mwangangi et al., 2013; Sherrard-Smith et al., 2018) are considered to affect the efficacy of control measures. In addition to human-related factors, such as sleeping time, night-time activities, and time spent outdoors at night, factors such as the state or integrity of LLINs, socioeconomic status, and house type could also influence transmission risk, but the effects of these factors have not been fully assessed (Durnez et al., 2013; Finda et al., 2018; Gryseels et al., 2015; Rodríguez-Rodríguez et al., 2021).

Data on household characteristics and human behaviour could be useful for mapping malaria transmission risk and for improving vector control interventions and malaria control programmes. In the south Cameroon forest region, previous studies have indicated a high diversity of anopheline species, along with high levels of insecticide resistance and different behavioural patterns among mosquito species (Antonio-Nkondjio et al., 2005; Awono-Ambene et al., 2004; Bamou et al., 2021, 2018; Mbakop et al., 2019). However, there is not enough information on the influence of human, household, or house-related factors on exposure to malaria transmission risk. Our study assessed the influence of house characteristics and human-related factors on malaria transmission risk.

Methodology

Ethical considerations

This study received approval from the WHO Ethics Review Committee (WHO ERC), protocol ID ERC.0002666, and from the Cameroon National Ethics Committee for Research on Human Health (CNERSH), under ethical clearance number 2016/01/685/CE/CNERSH/SP. Written informed consent was obtained from the parents/guardians of children during the malaria prevalence surveys, while assent was obtained for participants under 18 years. The Helsinki Declaration's guidance on ethical principles regarding human subjects was followed in this study.

Study sites

The study was conducted in two villages, Olama and Nyabessan, in the equatorial forest region of south Cameroon. Olama (3°24′ N; 11°18' E) and Nyabessan (2°80′ N; 10°25′ E) are located 65 km and 220 km from Yaoundé, respectively (Figure 1). Olama village is surrounded by the Nyong river and is characterized by high forest cover. It consists of a cluster of traditional houses built with mud. Nyabessan is bordered by the Ntem river and is located near the recently constructed Menve'ele dam. Houses in Nyabessan are constructed in wood and mud. The main activities in both villages are farming and fishing. Malaria is endemic in both localities, with an entomological inoculation rate of about 252 and 48 infective bites per person per year in Nyabessan and Olama, respectively (Bamou et al., 2021, 2018).

Sample size

The required sample size was estimated using the Lorentz formula:

$$N \geq \frac{Z^2.P.q}{I^2}$$

considering the proportion of people infected with malaria (*p*) in the country (30–45%), with 5% error. The minimum sample size was estimated to be about 276 participants, while around 400 were included in the study. The number of HoH included for questionnaire interviews was 186 (93 in each site), representing more than 80% of households.

Study design and data collection

This was a household-based cross-sectional survey. After obtaining administrative authorization and ethical clearance, sampling was carried out randomly in both study sites, with almost all houses visited. Houses where people were absent were revisited. In the presence of the head of household (HoH) or their spouse, or an inhabitant over 18 years of age, the purpose of the study was explained and their willingness to participate in the study requested. People included in this study thus comprised households with informed consent approval. Only the HoH or their spouse, or inhabitants aged over 18 years, were interviewed. For the purpose of malaria diagnostics, in addition to the questionnaire participants, children were included after obtaining consent from their parents.

The door-to-door survey was conducted by well-trained field staff. A well-designed, pre-tested questionnaire was submitted to the HoH in both villages after obtaining their free and informed consent. In cases where the HoH was absent, the spouse or another family member over the age of 18 was interviewed. The questionnaire comprised 30 questions, and was divided into three sections. The first section collected information on sociodemographic characteristics (age, gender, number of family members, and levels of education). The second section addressed the economic status of residents/households (type of cooking fuel, source of income, source of water for domestic use, assets in possession, types of walls and roofs). The last section concerned malaria knowledge (vectors, signs, and symptoms) and control measures, evening activities of residents, and sleeping behaviour (time of sleeping and waking up). Those going to bed before 9 pm were classed as 'sleep early', and those going to bed after 9 pm as 'sleep late'. Those waking up before 6 am were classed as 'wake up early' and those waking up after 6 am as 'wake up late.

Parasitological analysis

In addition to the household survey, malaria rapid diagnostic tests (mRDTs) were performed in households that consented to participate in the study to determine malaria prevalence in the population within the two villages during the dry season (December 2016) and rainy season (November 2017). Parasite screening in blood samples was performed using the SD BIOLINE Malaria Ag. *Plasmodium falciparum*/Pan rapid diagnostic test kit (Standard Diagnostics, Inc., Republic of Korea), according to the manufacturer's instructions. This targets histidine-rich protein 2 (HRP2) and lactate dehydrogenase (pLDH), and has 98% specificity and 99.5% sensitivity (Tadesse et al., 2016).

Data analysis

The collected data were analysed using SPSS version 20.0. Ages of participants, times of going to bed and times of waking up were categorized. For categorical or qualitative variables, data were presented as frequencies or percentages, while for continuous variables (age) they were presented as means. The chi-squared test was used for comparisons of proportions at the 0.05 significant level. A univariate analysis was also carried out to determine whether any of the prospectively defined independent factors (age, sex, net usage and sleeping behaviour) were significantly associated with malaria prevalence. To assess risk factors, odds ratios as well as their 95% confidence intervals were computed using Medcalc version 20.015 software.

Level of knowledge was assessed by considering answers to two questions regarding (1) the mode of transmission (vector) and (2) malaria symptoms. Participants with correct answers to these two questions (knowledge of the vector and capable of citing at least two symptoms of malaria) were considered to have correct knowledge, while others were considered to have incorrect knowledge.

Results

Background characteristics of the studied population

Interviews were performed in 93 houses in each locality during the study period. The majority of respondents (HoH) were males (56.45%) — 62.40% in Olama and 50.50% in Nyabessan (Table 1). More than half of the respondents/HoH (n = 134; 72.04%) had been educated to at least secondary school level (Figure 1) and were working for the Sino-Hydro Company constructing roads and finalising the dam project. Livestock ownership was higher in Olama compared with Nyabessan (62% vs 34%) (Table 1). Bedtimes and waking-up times in both villages varied according to age and gender. The majority of the people (HoH and their house members) were found to go to bed after 9 pm (sleeping late behaviour) — 73.5% and 83.5% for Olama and Nyabessan, respectively. Women were more likely to wake up early — before 6 am. Activities keeping people outdoors during the night were cooking for women, selling or drinking with friends for men, and studying for young boys and girls. In Olama, playing or talking with friends in the evening was also recorded.

House characteristics

House characteristics varied significantly between sites ($p < 0.001$); they were predominantly constructed with mud and iron/zinc sheet roofing (54.8%) in Olama and with wooden planks and iron/zinc sheet roofing (75.3%) in Nyabessan (Figure S1). More than 90% of the houses in both villages had open eaves. Household composition varied significantly from one locality to the other ($p < 0.001$). In Olama, the total number of people per house ranged from 1 to 25 individuals, with a mean of 9.16. The average number of people per house in Nyabessan was 5.14. Children under 5 years old were found in the majority of houses.

General knowledge about malaria

All respondents (HoH) of both study sites declared to have heard about malaria before, and almost all of them (88.17%) attributed the cause of malaria to mosquito bites (Table 2). Fever and headache were the most cited symptoms of malaria. In general, more than 80% of HoH were able to give at least two correct symptoms of malaria (n = 82; 88.17% and n = 79; 84.95% in Olama and Nyabessan, respectively).

Mosquito control practices and prevention of malaria in Olama and Nyabessan

Mosquito net ownership rate (number of households possessing at least one bed net) was high – 96.8% of households in both sites (Tables 2 and 3). Other control measures used to protect residents from mosquito bites included insecticide coils (8.1%), insecticide sprays (15.6%), repellents (9.1%), and screens on windows (1.6%).

The mosquito net brands used in both localities were mostly Olyset® and Permanet®. In Olama, about 94% of LLINs were acquired from free distribution campaigns conducted by the Ministry of Health (MoH), while in Nyabessan, in addition to free distribution campaigns, some residents declared that their bed nets were bought from a local shop or clinic (43.8%). Net usage rate was high in both sites, with 93.3% and 95.6% of people in Nyabessan and Olama, respectively, claiming regular net use. All house members reported sleeping under mosquito nets at least 5 days per week in both localities, with net usage particularly high for children under 5 years of age.

Despite this high rate of net possession, only 64.43% of households reported access to one LLIN for every two inhabitants, as recommended

Table 1
Data obtained from the heads of households surveyed in Olama and Nyabessan.

	Olama		Nyabessan		Total	
	N	%	*N*	%	*N*	%
Gender						
Male	58	62.4	47	50.50	105	56.45
Female	35	37.6	46	49.50	81	43.55
Age (years)[#]						
18–34	30	33.71	48	59.26	78	45.88
35–54	37	41.57	27	33.33	64	37.64
> 54	22	24.72	6	7.41	28	16.47
Educational level of household heads						
University	15	16.13	7	7.52	22	11.83
Secondary	51	54.84	61	65.60	112	60.21
Primary	27	29.03	20	20.51	47	25.27
None	0	0.00	5	5.37	5	2.69
Occupation/source of revenues						
Small-scale farming	66	70.96	8	8.60	74	39.78
Employment	11	11.82	43	46.23	54	29.03
Small-scale business	16	17.20	36	38.78	52	27.96
Others	0	0.00	6	6.45	6	3.27
Household asset ownership[*]						
Radio	58	65.20	36	16.90	94	52.80
Television	59	66.30	25	28.10	84	47.20
Phone	86	96.60	77	86.50	163	91.60
Gas cooker	27	30.30	17	19.10	44	24.70
Motocycle/car	29	31.18	16	17.02	45	24.19
Source of drinking water[*] Borehole/well	73	78.10	62	66.31	135	72.58
Source of energy for cooking: firewood	86	92.50	74	79.60	160	86.02
Possession of livestock	58	62.00	32	34.00	90	48.40
Number of household members						
1–5	23	24.70	55	59.10	78	41.90
6–10	41	44.10	33	35.50	74	39.80
≥ 10	29	31.20	5	5.40	34	18.30
Number of households with members < 5 years						
1–5	60	64.51	50	53.76	110	59.14
6–10	6	6.45	1	1.07	7	3.8
≥ 10	1	1.07	1	1.07	2	1.07
Number of rooms per house						
1–5	45	48.40	80	86.02	128	68.82
6–10	45	48.40	13	13.97	58	31.18
≥ 10	3	3.20	0	0.00	3	1.61

N: number of participants; %: percentage.
[*] The percentages do not add up to 100 because these results are from multiple-response questions.
[#] The number of respondents who declared their age is below the sample size.

by WHO. This observation was locality dependent, with Nyabessan having the highest proportion of households with one LLIN for two inhabitants (74.79%). LLIN usage rate (the proportion of people who slept under LLINs the night before the day of the survey) was 94.45% (Table 3).

Most of the nets were acquired in 2016 (59.7%), 2 years before the survey. In Olama the majority of LLINs were in good condition, without holes (86.5%), whereas in Nyabessan the figure was only 22.7%.

The interviews revealed that family members regularly complained of fever. The proportions of people complaining of fever 2 weeks before the interview were 62.9% and 45.7% in Nyabessan and Olama, respectively (Table 2). The majority of people interviewed reported going to the hospital or clinic in cases of fever (85.4%). Some reported self-medication (17.15%) or boiling and drinking plant extracts macerated in water (11.6%).

Malaria detection in human populations

Characteristics of participants screened for malaria

In total, 836 individuals (household members), belonging to 258 houses (147 in Nyabessan vs 111 in Olama), were screened for malaria during the study, using mRDT. Most of those screened were children under 11 years old. The majority of these participants used LLINs (69.74% in Nyabessan vs 88.31% in Olama).

Age and exposure to Plasmodium infection

Of the 836 participants tested for malaria (430 in Olama and 406 in Nyabessan), 351 were found to be infected with *Plasmodium* sp., representing a prevalence of 42%. Malaria prevalence was significantly different between the two villages ($\chi^2 = 41.3$; df = 1; $p < 0.0001$). Prevalence of infections in both sites was significantly higher in the 5–16 years age group compared with the other age groups ($p < 0.0001$). In Olama, 200 people participated in the dry season and 230 in the rainy season, resulting in prevalences of 18% ($n = 36$) and 32% ($n = 74$), respectively, showing a significant difference between the seasons ($\chi^2 = 11.011$; df = 1; $p < 0.001$). In Nyabessan, 208 people were screened in the dry season and 198 in the rainy season, revealing prevalences of 65.38% ($n = 136$) and 55.03% ($n = 105$), respectively (Table 4), also showing a significant difference between the seasons ($\chi^2 = 4.52$; df = 1; $p = 0.03$).

House type and malaria prevalence

In total, 258 houses (147 in Nyabessan vs 111 in Olama) were visited for malaria detection during the study. Taking all house types, malaria parasite prevalence was high in Nyabessan (63.9%, CI: 51.67–78.25) compared with Olama (48.65%, CI: 36.55–63.48) ($\chi^2 = 19.69$; df = 1; $p < 0.0001$). A significant association was observed between malaria parasite prevalence and house characteristics ($\chi^2 = 4.58$; $p = 0.032$). In

Table 2
Population knowledge and attitude concerning malaria prevention and the use of LLINs in Olama and Nyabessan.

	Olama	Nyabessan	Total
Heard about malaria			
Yes	(93) 100.0[#]	(93) 100.0	(186) 100.0
No	(0) 0.0	(0) 0.0	(0) 0.0
Mode of transmission of malaria			
Mosquito bites	(85) 91.4	(79) 84.9	(164) 88.2
Dirt	(2) 2.2	(3) 3.2	(5) 2.7
Other	(6) 6.5	(7) 7.5	(13) 6.9
No idea	(0) 0.0	(4) 4.3	(4) 2.15
Purpose of using net (%)[*]			
Stop mosquitoes biting	(42) 46.7	(54) 60.0	(96) 53.3
Stop buzzing	(1) 1.0	(4) 4.4	(5) 2.8
Be able to sleep	(5) 5.6	(7) 7.8	(12) 6.7
Fear of malaria	(42) 46.7	(26) 29.0	(68) 37.8
Other malaria control tools in use (%)			
Coils	(10) 10.8	(5) 5.4	(15) 8.1
Insecticide sprays	(15) 16.1	(15) 15.1	(30) 15.6
Burning of organic materials	(2) 2.2	(2) 2.2	(4) 2.2
Opening drain	(2) 2.2	(7) 7.5	(9) 4.8
Door and window screening	(0) 0.0	(3) 3.2	(3) 1.6
Repellents	(8) 8.6	(9) 9.7	(17) 9.2
Others	(1) 1.1	(4) 4.3	(5) 2.7
Household members having fever in past 2 weeks (%)	(42) 45.2	(59) 63.4	(101) 54.3
Action undertaken by household member in case of fever (%)[**]			
Self-medication	(7) 16.7	(11) 18.6	(18) 17.8
Visiting a traditional healer	(4) 9.5	(8) 13.6	(12) 11.9
Visiting hospital	(19) 45.2	(34) 56.6	(53) 52.5
Visiting local clinic	(24) 57.1	(7) 11.9	(31) 30.7

[#] *n* (%): sample size (percentage).
[*] Frequencies were calculated using only the number of households with access to LLINs, ie 90 in each study site.
[**] Frequencies were calculated using only the number of households where fever was observed in the 2 weeks prior the questionnaire.

Table 3
Ownership, access to, and usage of LLINs in Olama and Nyabessan.

	Olama	Nyabessan	Total
Households with access to LLINs (%)[*]	90 (96.8)[***]	90 (96.8)	180 (96.8)
Household members who slept under LLINs (%)[*]	89 (95.7)	87 (93.3)	176 (94.4)
Households with children under 5 years old who slept under LLINs (%)[**]	55 (82.1)	52 (72.2)	107 (77.0)
Households with at least one LLIN for every two people (%)[*]	54 (58.1)	70 (74.79)	124 (64.43)
Household usage of ITNs 5–7 times per week (%)[*]	96.50	100.00	98.25

[*] Sample size is the number of HoH who participated in the study, i.e. 93 per study site.
[**] Sample size is the number of HoH who declared having children under 5 years old, ie 67 in Olama and 72 in Nyabessan (see Table 1).
[***] *n* (%): number (percentage).

Olama, people living in cement houses were found to be less infected by malaria parasites (Table 4).

Impact of sleeping behaviour on exposure to Plasmodium infection

People sleeping early were found to be more infected than those going to sleep late, in both Olama ($\chi^2 = 7.1$; df = 1; $p = 0.007$) and Nyabessan ($\chi^2 = 9.64$; df = 1; $p = 0.002$). No significant differences were recorded between people waking up early or late in Olama ($\chi^2 = 2.61$; df = 1; $p = 0.07$) and Nyabessan ($\chi^2 = 0.02$; df = 1; $p = 0.088$) (Table 4).

Discussion

The study objective was to assess the influence of human behavioural factors and housing characteristics on exposure to malaria transmission risk in the equatorial forest region of Cameroon. According to the results, poor house construction, human activities during the night, and the poor physical integrity of LLINs were exposing the population to higher risks of malaria transmission. The majority of people interviewed had good knowledge of the vector and prevention measures (86.50%). This was consistent with previous studies in the country (Kimbi et al., 2014; Ndo et al., 2011; Nkuo Akenji et al., 2005).

Sound knowledge of the vector and prevention measures could reduce malaria transmission, especially if the population applied this knowledge through the use of effective control tools, such as LLINs. In Mwa, Kenya such knowledge was observed to contribute to the reduction of malaria in the locality (Oketch et al., 2008). Most people interviewed had been educated to at least secondary level, which might have increased their knowledge about the disease, since malaria and its control measures are part of the education program (Talipouo et al., 2019; Tassew et al., 2017; Woyessa et al., 2014). The presence of secondary schools and basic infrastructure such as health centres would have increased the prevalence of well-educated people in the study areas.

The fear of contracting malaria and desire to avoid mosquito bites were the main reasons pushing people to use LLINs. Frequent and correct use of LLINs could help reduce malaria morbidity and the related costs of treatment for poor communities. As the study was conducted a few months after a mass distribution campaign of nets, net ownership was high (95%) in the region, with more than 58% of households possessing

Table 4
Factors associated with malaria prevalence in Olama and Nyabessan.

	Nyabessan			Olama		
	Prevalence (%) *n/N*	OR (95% CI)	*p*-value	Prevalence (%) *n/N*	OR (95% CI)	*p*-value
House type						
Cement	(60.0) 30/50	1	NA	(23.0) 31//135	1	NA
Wood	(54.1) 178/329	0.76 (0.43–1.44)	0.43	(38.5) 10/26	2.1 (0.84–5.08	0.1
Mud	(58.3) 7/12	0.93 (0.26–3.55)	0.92	(25.5) 66/259	1.15 (0.7–1.87)	0.58
Sleeping behavior						
Sleep early	(59.0) 162/274	1	NA	(29.0) 92/321	1	**0.007**
Sleep late	(42.0) 53/125	0.51 (0.33–0.78	**0.002**	(16.0) 17/108*	0.46 (0.26–0.82)**	
Wake up late	(54.0) 106/295	1	NA	(24.0) 82/345	1	NA
Wake up early	(54.0) 110/205	0.97 (0.65–1.44)	0.88	(33.0) 26/80	1.54 (0.91–2.62)	0.11
Age						
0–5	(59.0) 94/160	1[a]	NA	(23.0) 32/140*	1[a]	NA**
6–11	(74.0) 73/99	1.97 (1.14–3.40)	0.015	(39.0) 55/141	2.16 (1.28–3.63)	**0.003**
12–16	(67.0) 42/63	1.40 (0.76–2.59)	0.270	(24.0) 21/88	1.06 (0.56–1.98)	0.86
> 16	(20.0) 17/84	0.18 (0.09–0.33	0.001	(2.0) 1/61	0.06 (0–0.42)	**0.005**
Season						
Dry	(55.0) 105/208	1[a]	NA	(32.0) 74/200	1[a]	
Rainy	(65.4) 136/198	2.15 (1.43–3.22)	**0.001**	(18.0) 36/230	0.03 (0.20–0.49)	**0.001**

* (%) *n/N*: (Percentage) number of positive RDT/tested RDT; OR (95% CI): odds ratio (95% confidence interval).
** NA: Not applicable.
[a] Reference.

at least one net for two people. Most of the people (HoH) interviewed declared sleeping regularly under a mosquito net, thus increasing community protection (Koenker et al., 2018; Koenker and Kilian, 2014). The ownership and usage of LLINs recorded during our study were similar to those recorded in the city of Yaoundé (Talipouo et al., 2019). However one should keep in mind that these data were recorded through self-reporting, which has been demonstrated to overestimate the real use of LLINs by the population (Talipouo et al., 2019).

Despite the recent distribution of bed nets, many were found with holes. This rapid degradation of mosquito nets just a few years after their acquisition may be due to their frequent use by residents, the low quality of material used, poor handling of the nets by the population (particularly children), and the means of hanging them. Similar physical deterioration of nets after only a year of use has been reported elsewhere (Githinji et al., 2010; Protopopoff et al., 2007). With the spread of insecticide resistance in vector populations, deteriorated bed nets become neither chemical nor physical barriers to mosquito bites. Permanet® 2.0 and Olyset® bed nets were the two brands found in use in the two localities. Despite the rapid expansion of insecticide resistance across the country (Antonio-Nkondjio et al., 2017; Piameu et al., 2021), pyrethroid-only nets are still widely distributed to the population for malaria prevention. Since insecticide resistance in vector populations is mainly conferred by monoxygenase-based mechanisms, the use of new-generation nets that combine pyrethroid and piperonyl butoxide (PBO) should be prioritized for combating malaria in the country (Martin et al., 2021; Gleave et al., 2021; Martin et al., 2021).

In most households, the use of LLINs was associated with other prevention methods against mosquito bites, such as insecticide sprays, insecticide coils, insect repellents, or the use of screens on windows. The use of different insecticide-based control measures, such as insecticide sprays and coils, alongside pesticides in agriculture could increase selection for insecticide resistance in mosquito populations (Antonio-Nkondjio et al., 2019; Bamou et al., 2019; Chouaïbou et al., 2008; Mouhamadou et al., 2019). Despite the importance of LLINs for controlling malaria, the fact that this tool is mostly efficient against indoor biting mosquitoes stresses the need for additional control measures to also target outdoor biting mosquitoes and to increase protection against malaria transmission.

The vast majority of those interviewed reported visiting a hospital or clinic for consultation when suspecting a case of fever. Some people admitted visiting traditional healers or treating themselves with local plants. These findings are in contrast with the results of studies conducted in urban settings, which suggest a higher rate of self-medication (Talipouo et al., 2019). The widespread use of hospitals and clinics by the study population could be a result of the Government of Cameroon subsidizing the treatment of malaria in public healthcare facilities (PNLP 2019). In addition, both study sites have community health workers, providing primary care services to people suffering from uncomplicated malaria or other common diseases. The frequent hospital visits in cases of sickness could also reflect a high level of confidence in, and close relationship with, healthcare workers.

Except for children under 5 years old, fewer than 50% of the population went to bed before 8 pm. They stayed outdoors during the first part of the night for social, educational and economic activities, such as playing, selling, discussing or watching television. These types of outdoor activity may lead to increased exposure to mosquito bites and malaria transmission. Outdoor malaria transmission has been identified as a major gap in malaria control (Finda et al., 2019; Monroe et al., 2019a, 2019b, 2015). Drivers for residual malaria transmission or factors promoting persistent malaria transmission have been explored in a range of studies (Monroe et al., 2015; Msellemu et al., 2017; Thomas et al., 2018).

A high prevalence of asymptomatic malaria was observed in both localities, despite extensive bed net coverage, which could be associated with household- or individual-related factors. Children aged 5–16 years were more infected than other age groups. It also appeared that sleeping time and the number of people under a net could also affect the level of exposure to mosquito bites, as reported elsewhere (Msellemu et al., 2017). All these findings highlight the need to improve malaria control strategies through the early detection of cases, prompt treatment, and sensitization campaigns.

Previous studies in the same region indicated that *P. falciparum* infection rates among non-users of treated nets were twice those found among users (Bamou et al., 2021, 2018), highlighting the importance of treated net use despite the increased prevalence of insecticide resistance in vector populations. House characteristics were also found to affect to malaria transmission risk, with people living in wooden houses exposed to a higher risk than those living in well-constructed, cemented houses. Previous studies have also reported a close association between the prevalence of malaria or mosquito abundance and house characteristics (Githinji et al., 2010; Liu et al., 2019; Ngadjeu et al., 2020; Nguela et al., 2020).

Limitations

Despite the strength of this study in showing the prevalence of malaria in a forested area of Cameroon, and the associated risk factors, there were some limitations. First, the questionnaire used only two questions — regarding the mode of transmission (vector) and malaria symptoms — to assess knowledge on malaria. Second, the study used only malaria diagnostic testing (mRDT) to estimate disease prevalence, without the support of microscopy and/or molecular biology to confirm cases.

Conclusion

This study highlights the need for additional control measures specifically addressing existing gaps, such as outdoor transmission of malaria, resistance of mosquitoes to insecticides, poor use of LLINs, or poor house construction. Despite the high coverage of the population with LLINs, the prevalence of malaria in the Cameroon equatorial forest region remains high, and requires further attention with regard to eliminating malaria in the country.

Authors' contributions

RB, JM, and CAN conceived and designed the study protocol. RB, TT, EK, PAA, and CAN participated in field activities and data acquisition. EK, TT, PAA, FN, and JM critically revised the manuscript. BR and CAN interpreted and analysed data, and wrote the paper with the contribution of other authors. FN, JM, and BR supervised the work. All the authors read and approved the final version.

Availability of data and material

The datasets supporting the findings of this paper are included in this paper.

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Ethical approval

The study was conducted under ethical clearance delivered by the Cameroon National Ethics Committee for Research on Human Health (no. 2016/01/685/CE/CNERSH/SP) and the World Health Organization Ethics Review Committee (protocol ID ERC.0002666).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for Publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijregi.2022.11.003.

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