Evaluation of malaria preventive measures among adult patients attending the Bamendjou and Foumbot District hospitals of the West Region of Cameroon

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Abstract

Background: Although significant decrease in entomological and epidemiological indicators was reported in Cameroon since the introduction of insecticide treated bed nets, malaria prevalence remains high also in some parts of the West Region of Cameroon. Therefore this study was designed to evaluate malaria preventive measures among patients attending the Bamendjou and Foumbot District hospitals of the West Region of Cameroon.

Methods: This was a cross sectional study carried out within a period of three months, from January to March 2020. Data was obtained using a structured questionnaire and laboratory analysis. The *CareStart*™ Malaria HRP2 (Pf) qualitative rapid diagnostic test was used for malaria diagnosis. The questionnaire was designed to collect information on respondent's socio demographic characteristics, and use of malaria preventive measures. Data was analyzed using descriptive statistics, regression analysis and Chi-square (and Fisher's exact) test.

Results: A total of 170 study participants were recruited in Foumbot and 197 in Bamendjou. Malaria was significantly ($P < 0.0001$) more prevalent in Foumbot (47.06%) than in Bamendjou (19.8%). In Foumbot, nonuse of insect repellent spray ($P = 0.0214$), insect repellent body cream ($P = 0.0009$), mosquito spray ($P = 0.0001$) and not draining stagnant water ($P = 0.0004$) predisposed to higher risk of malaria. But in Bamendjou, nonuse of insect repellent spray ($P = 0.0012$), long lasting insecticidal bed nets ($P = 0.0001$), window and door nets ($P = 0.0286$), predisposed to higher risk of malaria.

Conclusions: Malaria prevalence was high among the study participants especially in Foumbot. Adequate follow-up to ensure effective execution of the recently launched third phase of LLINs distribution campaign in Cameroon is recommended. Additionally, Intergrated Vector

Management is required to ensure effective control of malaria transmission in Foumbot and Bamendjou.

Keywords: Malaria: Preventive measures: Long lasting insecticidal nets: Insecticidal sprays: Risk

Background

The estimated yearly suspected malaria cases in Cameroon is 3.3-3.7 million in health services (1). In Cameroon the main method of malaria prevention is the use of different types (e.g. PermaNet, Olyset, Interceptor) of long-lasting insecticidal nets (LLINs) (2). There have been three free distribution of ITNs/LLINs campaigns; in 2004-2005 (2 million ITNs), 2011(8 million LLINs) and in 2015 (over 12 million LLINs) (1, 3). A national coverage is anticipated with the third mass distribution campaign of LLINs launched in February 2019 (4). Significant decrease in entomological and epidemiological pointers was reported in Cameroon since the introduction of ITNs/LLINs (5, 6). But in the west region, a high prevalence (53.4%) of malaria was recently reported among pregnant women in Foumban, a neighboring town to Foumbot (7). It was reported that increased access to impregnated mosquito bed nets is needed to reduce the risk of malaria infection (7). With increase in coverage rates and correct usage, LLIN could greatly assist in malaria elimination in Cameroon (5).

Despite nation-wide sensitization campaigns (8), the disparity between possession and actual usage has affected the performance of LLINs at the different epidemiological settings in Cameroon (8-13). In Cameroon, door-to-door hang-up and behavior change communication (BCC) campaign scaled up the use of bed nets from 75% to 92% after the campaign (4). During door-to-door mass distribution of LLNs in Zambia, the practice of net hanging and face-to-face health education on adequate use to prevent wear and tear of LLNs, increased its usage and coverage rates (14).

Therefore the effectiveness of LLINs could be well-maintained by evaluating its quality, sustainable usage, insecticidal persistence and efficacy with changing seasons. Indoor residual spraying and larviciding can effectively complement the existing malaria transmission control strategies (15). Also, the effect of hygiene and sanitation on the reduction of permanent mosquito breeding sites cannot be overemphasized. Routine epidemiological investigative activities are requested in order to monitor changes in malaria occurrence, mosquito biting, entomological inoculation rate and insecticide resistance (5). In Cameroon, the following anopheline species transmit malaria parasite: *An. moucheti*, *An. coluzzii*, *An. nili, An. funestus, An. arabiensis* and *An. gambiae (5, 15).* The performance of LLINs have been threatened by increase in carbamate, pyrethroid and DDT resistance in *An. gambiae*, *An. coluzzii*, *An. arabiensis* and *An. funestus* (5).

Malaria research uptake on preventive measures are fundamental in a socio-variable community like Cameroon (16). The investigation of combined preventive measures could provide valuable insights helpful in the update of control strategies. Moreover due to increase in insecticide resistance, the use of combined interventions is recommended in malaria hyper endemic areas (17). Even in areas with seasonal malaria parasite transmission, combining insecticide resistance sprays and LLINs has been shown to be helpful (17). In Cameroon, challenges associated with malaria control strategies could be effectively handled if considered according to defined local epidemiological settings. Varied malaria endemicity has been reported in different localities of the West region of Cameroon. For example Bamendjou is hypoendemic for malaria and has seasonal malaria parasite transmission (5). Whereas malaria transmission in Foumbot is stable with most infections being asymptomatic (7). Therefore, this study was designed to evaluate malaria preventive measures among patients attending the Bamendjou and Foumbot District hospitals of the West Region of Cameroon.

Methods

Study Area

The West region of Cameroon has a rainfall lasting about 8 months and is situated in the highland areas. Generally, this region has a temperate climate with a dominant grassland vegetation and average annual rainfall estimated at 1800 mm/year lasting for about eight months. The West region has an estimated population of 1.9 million and covers an area of 13,892 km^2. Before the free LLINs campaigns, malaria prevalence in this region was estimated to be 25% in children (18, 19). Meanwhile after free LLINs campaigns malaria prevalence was estimated to vary from 9.3-22.4% (20, 21). In 2010, the entomological inoculation rate in this region was shown to fluctuate from 62.8 to 90.5 infective bites/person/year (22). Whereas in 2018, entomological inoculation rate in the West region was 2.24 infective bites/person/month (22, 23).

Foumbot, located at Latitude 5 ^{0} 30'00''N, Longitude 10 ^{0}37'59''E and average altitude 1071m has an equatorial climate with two climatic seasons and four ecologically dry months. Foumbot covers an area of 579 km^2 with an estimated population of 77,130 inhabitants and located 25km from the West Regional headquarter, Bafoussam. The main economic activity of more than 84% of the inhabitants of Foumbot remains agriculture. The rest of the inhabitants practice agriculture as a secondary activity (24). Bamendjou, located at Latittude 5 ^{0} 23'55.99''N, Longitude 10 ^{0}18'60.00''E and average altitude 1595m has an equatorial climate and an average rainfall of 1500mm, usually lasting 9 months (March to November). Bamendjou covers an area of 197 km^2 with an estimated population of 34,269 inhabitants and located 15km from the West Regional headquarter, Bafoussam. The main economic activity of the inhabitants of Bamendjou is agriculture and animal husbandry. The Bamendjou council signed a contract with a hygiene and sanitation company since

2018 for the cleaning and maintenance of the city center and also received a national award for its role in promoting good governance (25).

Study Design/study participants

This is a cross sectional study carried out for three months, starting from January to March 2020. The inclusion criteria for the study was all adult (≥18 years) patients attending the Bamendjou and Foumbot District hospitals within the study period and who were sent to the laboratory for a malaria test. Patients who gave their consent by signing the informed consent were consecutively enrolled into the study within the study period.

The sample size calculation was done using the following formula:

$N = z^2pq/d^2$ (26). Where:

$z^2 = (1.96)^2$

p (previous malaria prevalence) = 29% (0.29) (9).

$q = (1 – 0.224)$

$d^2 = (0.05)^2$

N = minimum sample size (316).

Ethical Consideration

The ethical clearance for this study was gotten from the Ethical Review Committee of the University of Bamenda. The ethical clearance numbers are 2020/0148H/UBa/IRB and 2020/0142H/UBa/IRB for data collection in Foumbot and Bamendjou respectively. Signed informed consent was acquired from those who accepted to be enrolled in the study.

Data Collection

Data was obtained using a structured questionnaire and laboratory analysis. The *CareStart*™ Malaria HRP2 (Pf) qualitative rapid diagnostic test was used for malaria diagnosis, using about 5μL of capillary blood collected by a finger prick (27). The questionnaire was designed to collect information on respondent's socio demographic characteristics, and use of malaria preventive measures. The socio demographic characteristics were; sex, age, marital status, educational level, religion, internal displacement status, monthly income and occupation. The preventive measures under consideration were; use of LLINs, use of window and door nets, use of insect repellent spray, draining stagnant water, killing mosquito with a broom, use of mosquito coil, use of insect repellent body cream, use of mosquito candles and use of mosquito spray. Nonuse of malaria preventive measures by study participants, were considered exposed to malaria.

Data Analysis

Baseline characteristics of malaria preventive measures and socio demographic factors of patients with or without malaria were determined using excel. The base line characteristics include sums and mean percentages. Amongst patients in Foumbot and Bamendjou communities, the difference in malaria occurrence and socio demographic characteristics were determined using independent t-test. Regression analysis was used to evaluate the association between malaria incidence and sociodemographic factors. Malaria occurrence was considered the dependent variable and socio demographic factors, the independent variables. A fourfold (2×2) contingency table displaying the frequency distribution for each malaria preventive measure was entered into Graph Pad Prism version 8.2.1. In each of the four cells, the contingency table had frequencies for use and nonuse of preventive measures by both the negative and positive malaria cases. Chi-square (and Fisher's exact) test was used to determine the relative risk, attributable risk, odds ratio and likelihood ratio of malaria occurrence in malaria exposed patients. The sensitivity and specificity for the prediction of risk of malaria in exposed patients was also determined by Chi-square (and Fisher's exact).

Results were determined at 95% Confidence level. Graph Pad Prism version 8.2.1 was used for all statistical analysis.

Results

A total of 367 patients were recruited for the study with a total malaria prevalence of 32.43% (119/367). Malaria was significantly (P < 0.0001) more prevalent in Foumbot (47.06%) than in Bamendjou (19.8%). The female to male ratios were 1.33:1 and 4.27:1 in Foumbot and Bamendjou respectively. There were significant differences in the distribution of gender, age, marital status, educational level, religion, internal displacement status and occupation, among the study participants in Foumbot and Bamendjou (Table 1).

Table 1: Socio demographic data of study participants in Foumbot and Bamendjou

	Study area	Foumbot			Bamendjou			
	Diagnostic test	RDT Pos (%)	RDT Neg (%)	Total (%)	RDT Pos (%)	RDT Neg (%)	Total (%)	P value
	Number Examined	80 (47.06)	90 (52.94)	170	39 (19.8)	158 (80.20)	197	<0.0001
Sex	Females	55 (68.75)	42(46.67)	97 (57.06)	30(76.92)	128(81.01)	158 (80.2)	<0.0001
	Males	25 (31.25)	48(53.33)	73 (42.94)	9(23.08)	30(18.99)	39 (19.8)	
Age (yrs)	18-30	30(37.5)	30(33 .33)	60 (35.29)	11(28.21)	29(18.35)	40 (20.3)	
	31-40	25 (31.25)	30(33.33)	55 (32.35)	10(25.64)	57(36.08)	67 (34.01)	0.0008
	41-50	15 (18.75)	20(22.22)	35 (20.59)	9(23.08)	44(27.85)	53 (26.9)	
	>50	10(12.5)	10(11.11)	20 (11.76)	9(23.08)	28(17.72)	37 (18.78)	
Marital Status	Single	50(62.5)	50(55.56)	100 (58.82)	18(46.15)	60(37.97)	78 (39.59)	
	Married	30(37.5)	35(38.89)	65 (38.24)	15(38.46)	72(45.57)	87 (44.16)	0.0019
	Widow/Widower	0	0	0	6(15.38)	24(15.19)	30 (15.23)	
	Divorced	0	5(5.56)	5 (2.94)	0	2(1.27)	2 (1.02)	
Educational level	No formal education	0	5(5.56)	5 (2.94)	4(10.26)	22(13.92)	26 (13.2)	
	Primary	10(12.5)	30(33.33)	40 (23.53)	10(25.64)	42(26.58)	52 (26.4)	<0.0001
	Secondary level	55 (68.75)	30(33.33)	85 (50%)	19(48.72)	78(49.37)	97 (49.24)	

	Higher education	15 (18.75)	25(27.78)	40 (23.53)	6(15.38)	16(10.13)	22 (11.17)	
Religion	Christian	50(62.5)	35(38.89)	85 (50)	36(92.31)	141(89.24)	177 (89.85)	
	Moslem	25(31.25)	55(61.11)	80(47.06)	0	3(1.2)	3 (1.52)	<0.0001
	Others	5(6.25)	0	5 (2.94)	3(7.69)	14(8.86)	17 (8.63)	
Displacement Status	An IDP?	20(25.0)	15(16.67)	35 (20.59)	1(2.56)	14(8.86)	15 (7.61)	0.0003
	Not an IDP	60(75.0)	75(83.33)	135 (79.41)	38(97.44)	144(91.14)	182 (92.39)	
Monthly Income (frs)	low (<30000)	40(50.0)	50(55.56)	90 (52.94)	28(71.79)	123(77.85)	151 (76.65)	
	medium 30000 - 250000)	35(43.75)	40(44.44)	75 (44.12)	9(23.08)	33(20.89)	42 (21.32)	0.0527
	High >250000	5(6.25)	0	5 (2.94)	2(5.13)	2(1.27)	4 (2.03)	
Occupation	Civil Servants	5(6.25)	0	5(2.94)	8(20.51)	17(10.76)	25(12.69)	
	Business	5(6.25)	5(5.56)	10(5.88)	2(5.13)	22(13.92)	24(12.18)	0.0035
	Farmer	30(37.5)	34(37.78)	64(37.65)	11(28.21)	49(31.01)	60(30.46)	
	Others	40(50.0)	51(56.67)	91(53.53)	18(46.15)	70(44.30)	88(44.67)	

There were no significant association between the sociodemographic factors and malaria incidence in Bamendjou. However in Foumbot, being a female (P = 0.0001), Christianity (P < 0.0001), increased educational level (P < 0.04) and decreased monthly income (P < 0.0001) were significantly associated with the likelihood of malaria (table 2).

Table 2: Summary of Regression Analysis on socio-demographic data

	Foumbot		Bamendjou	
Variable	|t|	P value	|t|	P value
Intercept	3.529	0.0005*	0.9429	0.3469
Sex	3.93	0.0001***	0.3365	0.7369
Age	0.9931	0.3222	0.1962	0.8447
Marital Status	1.281	0.2019	0.5281	0.598
Religion	6.075	<0.0001****	0.3396	0.7345
Educational level	2.071	0.04*	0.1516	0.8796
Occupation	0.06659	0.947	0.01536	0.9878
Are you an IDP?	0.5037	0.6152	1.182	0.2387
Monthly Income	3.133	0.0021**	0.9842	0.3263

In Foumbot, the most used preventive measures were LLINs (79.41%) and window and door nets (70.59%). Meanwhile the least was to kill mosquitoes with a broom (23.53%), mosquito candles

(26.47%) and mosquito sprays (26.47%). In Bamendjou, the most used preventive measures were window and door nets (87.82%) and the least were insect repellent body cream (8.63%), mosquito candles (13.2%) and mosquito sprays (15.23%) (Table 6).

Table 3: Preventive measures used by the study participants for malaria control

	Foumbot Community			Bamendjou Community		
	RDT Pos (%), N=80 (47.06)	RDT Neg (%), N=90 (52.94)	Total (%), N=170	RDT Pos (%), N= 39 (19.8)	RDT Neg (%), N=158 (80.20)	Total (%), N = 197
Use of LLINs	60 (75)	75 (83.33)	135 (79.41)	30 (76.92)	45 (91.77)	75 (38.07)
Use of window and door nets	55 (68.75)	65 (72.22)	120 (70.59)	30 (76.92)	143 (90.51)	173 (87.82)
Using insect repellent spray	30 (37.5)	50 (55.56)	80 (47.06)	10 (25.64)	87 (55.06)	97 (49.24)
Draining stagnant water	40 (50)	69 (76.67)	109 (64.12)	20 (51.28)	90 (56.96)	110 (55.84)
Killing mosquito with a broom	20 (25)	20 (22.22)	40 (23.53)	18 (46.15)	50 (31.65)	68 (34.52)
Using mosquito coil	25 (31.25)	35 (38.89)	60 (35.29)	10 (25.64)	28 (17.72)	38 (19.29)
Insect repellent body cream	15 (18.75)	39 (43.33)	54 (31.76)	3 (7.69)	14 (8.86)	17 (8.63)
Use of Mosquito candle	25 (31.25)	20 (22.22)	45 (26.47)	3 (7.69)	23 (14.56)	26 (13.2)
Use of Mosquito sprays	10 (12.5)	35 (38.89)	45 (26.47)	5 (12.82)	25 (15.82)	30 (15.23)

In Foumbot, nonuse of insect repellent spray, insect repellent body cream, mosquito spray and not draining stagnant water, were all significantly associated with increased relative risk, attributable risk, odds ratio and likelihood ratio. Nonuse of these preventive measures were equally significantly associated with good sensitivity and specificity for the prediction of risk of malaria, but for nonuse of mosquito spray, with a poor specificity (38.89%) (Table 4).

Table 4: Risk of malaria occurrence among exposed study participants in Foumbot

Variable	Relative Risk (95% CI)	Attributable risk (95% CI)	Odds ratio (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	LR	P-value
Non-use of LLINs	1.29 0.88 to 1.76	0.13 -0.07 to 0.31	1.67 0.81 to 3.65	25 16.81 to 35.48	83.33 74.31 to 89.63	1.5	0.1898
Non-use of window and door nets	1.09 0.76 to 1.5	0.04 -0.13 to 0.21	1.82 0.62 to 2.22	31.25 22.15 to 42.07	72.22 62.20 to 80.42	1.23	0.7362
Non-use of insect repellent spray	1.48 1.07 to 2.1	0.18 0.02 to 0.33	2.08 1.11 to 3.82	62.5 51.55 to 72.31	55.56 45.27 to 65.38	1.41	0.0214*
Not draining stagnant water	1.79 1.31 to 2.43	0.29 0.12 to 0.43	3.29 1.72 to 6.29	50 39.3 to 60.7	76.67 66.95 to 84.2	2.14	0.0004***
Not Killing mosquito with a broom	0.92 0.66 to 1.37	0.04 -0.14 to 0.22	0.86 0.41 to 1.79	75 64.52 to 83.19	22.22 14.87 to 31.85	0.96	0.7191
Non-use of mosquito coil	1.2 0.86 to 1.74	0.08 -0.08 to 0.23	1.4 0.75 to 2.68	68.75 57.93 to 77.85	38.89 29.47 to 49.22	1.13	0.3366
Non-use of insect repellent body cream	2.02 1.32 to 3.26	0.29 0.11to 0.42	3.31 1.63 to 6.68	81.25 71.34 to 88.29	43.33 33.58 to 53.64	1.43	0.0009***
Non-use of mosquito candle	0.79 0.58 to 1.12	0.12 -0.05 to 0.3	0.63 0.31 to 1.23	68.75 57.93 to 77.85	22.22 14.87 to 31.85	0.88	0.2234
Non-use of mosquito spray	2.52 1.5 to 4.55	0.34 0.16 to 0.47	4.46 2.03 to 9.42	87.5 78.5 to 93.07	38.89 29.47 to 49.22	1.43	0.0001***

In Bamendjou nonuse of insect repellant spray and window and door nets, was significantly associated with increased relative risk, attributable risk, odds ratio and likelihood ratio. Nonuse of window and door nets was significantly associated with poor sensitivity and very good specificity, for the prediction of risk of malaria. Nonuse of insect repellent spray was significantly associated with good sensitivity and average specificity, for the prediction of risk of malaria. However, nonuse of LLINs was rather significantly associated with decreased relative risk, attributable risk, odds ratio and likelihood ratio, but also associated with poor sensitivity and specificity for the prediction of risk of malaria infection (Table 5).

Table 5: Risk of malaria occurrence among exposed study participants in Bamendjou

Variable	Relative Risk (95% CI)	Attributable risk (95% CI)	Odds ratio (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	LR	P-value
Non-use of LLINs	0.18 0.093 to 0.36	0.33 0.2 to 0.45	0.12 0.05 to 0.28	23.08 12.65 to 38.34	24.48 22.02 to 35.96	0.32	<0.0001****
Non-use of window and door nets	2.16 1.13 to 3.77	0.2 0.01 to 0.43	2.86 1.2 to 7.36	23.08 12.65 to 38.34	90.51 84.93 to 94.16	2.43	0.0286*
Non-use of insect repellent spray	2.81 1.48 to 5.44	0.19 0.07 to 0.3	3.55 1.62 to 7.48	74.36 58.92 to 85.43	55.06 47.28 to 62.61	1.66	0.0012**
Not draining stagnant water	1.2 0.69 to 2.09	0.04 -0.08 to 0.16	1.26 0.61 to 2.58	48.72 33.87 to 63.80	56.96 49.17 to 64.43	1.13	0.5904
Not Killing mosquito with a broom	0.57 0.33 to 0.1	0.11 -0.02 to 0.23	0.49 0.24 to 0.98	53.85 38.57 to 68.43	29.76 23.36 to 37.07	0.77	0.0592
Non-use of mosquito coil	0.69 0.39 to 1.32	0.08 -0.1to 0.22	0.62 0.28 to 1.41	74.36 58.92 to 85.43	17.72 12.56 to 24.42	0.9	0.2639

Non-use of insect repellent body cream	1.13 0.46 to 3.34	0.02 -0.25 to 0.17	1.17 0.36 to 3.98	92.31 79.68 to 97.35	8.86 5.35 to 14.32	1.01	>0.9999
Non-use of mosquito candle	1.83 0.69 to 5.43	0.1 -0.11 to 0.21	2.04 0.63 to 6.74	92.31 79.68 to 97.35	14.56 9.9 to 20.9	1.08	0.3048
Non-use of mosquito spray	1.22 0.56 to 2.91	0.04 -0.16 to 0.16	1.28 0.47 to 3.25	87.18 73.29 to 94.40	15.82 10.95 to 22.31	1.04	0.8051

Discussion

The study participants in Foumbot and Bamendjou vary in their socio demographic characteristics, excluding monthly income. Malaria endemicity in Foumbot and Bamendjou also differ, as earlier reported (5, 7). Thus adequate attention to socio demographic characteristics is important in malaria control efforts (28). In Bamendjou the female to male ratio was 4.05:1. The malaria positive female to male ratio was 3.33:1 and malaria negative female to male ratio was 4:1. In Foumbot, the female to male ratio was 1.33:1. The malaria positive female to male ratio was 2.2:1 and malaria negative female to male ratio was 0.88:1. In addition to females being most of the study participants, they were also more infected. In line with findings from other studies, higher malaria prevalence among females can be associated with exposure patterns, influenced by socio-economic roles (29, 30). An earlier study suggested that poverty related issues affected female adoption of malaria control methods (31). However the proportion of infected males increased in Bamendjou, which had low malaria prevalence. This may be due to perceived reduced need for additional malaria control efforts.

The 31-40 years age group was most represented in Bamendjou while the 18-30 years age group was most represented in Foumbot. The > 50 years age group was the least represented in both communities. With a higher malaria prevalence in Foumbot, the young adults (18-30 years) age group was generally more at risk of malaria than the other age groups. Although the middle aged adult (31-40 years) group had the highest malaria prevalence in Bamendjou, this community generally had low malaria prevalence. Similar to findings from another study in the North West region of Cameroon (32), the young adult age group is more at risk of malaria. Although children < 5 years and pregnant women are naturally more predisposed to malaria (33-36), differences in exposure patterns may also increase risk of malaria among young adults. Compared to other age groups, young adults are more involved in outdoor activities like farming and could be casual towards malaria preventive measures. Because most of the young adults are not married, malaria prevalence was also higher among the unmarried in Foumbot.

There were more Muslims in Foumbot which had more malaria positive cases. Other studies reported strong correlation between religion and health seeking behavior towards malaria control and prevention (37-39). Most of the patients in both communities had secondary school level of education. Therefore in line with findings from other studies (40-42), education can moderate religious perceptions towards malaria prevention and control. With the current socio political crisis in the North West and South West regions of Cameroon, the West region has experienced a huge influx of internally displaced persons from the crisis plagued regions. The living conditions of the displaced persons are usually of lower quality, predisposing them to malaria and also probably to new strains of malaria parasites (31). In addition to malaria prevalence being higher in Foumbot, there were more internally displaced patients in Foumbot. Contrary to findings from Bamendjou, gender, religion, educational level and financial status were significantly associated with malaria in Foumbot, which also has a history of steady malaria transmission (7). In line with findings from malaria risk areas, religion, education and income was found to impact the use of ITN (39), which directly influence malaria transmission.

Although LLINs was the most used malaria preventive measure in Foumbot, nonuse of it was not significantly associated with risk of malaria. But in Bamendjou non-use of LLINs was rather significantly associated with a lower risk of malaria exposure. However, the sensitivity (23.08%) and specificity (24.48%) of LLINs usage to predict risk of malaria was low. Generally LLINs usage was a poor indicator for the prediction of risk of malaria. This could be due to low usage rate and poor maintenance of LLINs, in addition to biological and behavioral changes in the mosquito vector. A recent study in Foumban which is located 45.2km from Foumbot revealed low usage of LLINs and high malaria prevalence. Malaria prevalence among pregnant women was 53.4% and only 49.3% of the study participants made use of mosquito bed nets (7). Reduced chances of malaria infection was found among children who slept under intact nets, suggesting the importance of repair and care of ITNs by owners (43). Several other studies have emphasized the importance of correct usage of insecticide pre-treated bed nets (5, 7, 14, 44). Resistance to insecticide also seriously threatens the effectiveness of LLINs as a malaria control tool (45). There was scale up in the effective use of LLINs in Baré a rural part of Cameroon, following door-to-door hang-up and behavior change communication (BCC) campaign, after the third mass distribution campaign launched in February 2019 (4). Therefore with the extension of such door-to-door hang-up and behavior change communication (BCC) campaign to other rural areas like Foumbot and Bamendjou, LLINs usage could possibly yield better results. The current study reveal that approximately one year after the launching of the third LLINs campaign in Cameroon, malaria prevalence remains high especially among adult in Foumbot (47.06%).

Nonuse of window and door nets was also not significantly associated with risk of malaria in Foumbot. But in Bamendjou, non-use of window and door nets was significantly (P = 0.0286) associated with a higher odds of malaria. From the relative risk (2.16), non-use of window and door nets was associated with more than 100% higher risk of malaria. This is supported by the positive attributable risk (0.2). The odds ratio of 2.86 also indicates a greater odds of malaria occurring in those who did not use window and door nets. Also the likelihood ratio of 2.43 further indicates that non-use of window and door nets was associated with malaria in Bamendjou. Although the sensitivity of window and door net usage to predict risk of malaria was low (23.08%), the specificity was high (90.51%). Therefore, it is only 23.08% likely that those who did not use window and door nets will test malaria positive. However it is 90.51% likely that those who use window and door nets will test malaria negative. This probably explains why malaria prevalence was lower among the study participants in Bamendjou. Furthermore window and door nets which protects the home (accommodation area) from mosquitoes was found to be one of the effective measures against malaria (44). Window and door nets were also considered suitable alternatives for LLINs (46). Since it was suggested that the application of insecticide on window and door curtains could likely reduce malaria transmission (47), augmentation of window and door nets usage may possibly improve malaria control efforts, especially in low malaria transmission area like Bamendjou. Window and door nets even without insecticidal spray as used in this study was helpful. Similarly, LLINs with or without insecticidal residual spray prevented more than 99% of indoor mosquito bites (48).

In Foumbot, non-use of insect repellent spray and mosquito spray were significantly associated with a higher odds of testing malaria positive. The sensitivity of insect repellent spray (62.5%) and mosquito spray (87.5%) usage to predict risk of malaria, were good. However the specificity for insect repellent spray (55.5%) and mosquito spray (38.89%) were lower. The odds of malaria occurrence in those who did not use insect repellent spray (RR: 1.48, AR: 0.18, OR: 2.08 and LR: 1.41) and mosquito spray (RR: 2.52, AR: 0.34, OR: 4.46 and LR: 1.43) were high. From their relative risks, non-use of insect repellent spray and mosquito spray was associated with 48% and > 100% higher risk of malaria. This is strongly supported by their positive attributable risks. The odds ratio of 2.08 and 4.46 for nonuse of insect repellent spray and mosquito spray further indicates a greater probability of malaria occurrence in the exposed individuals. The likelihood ratio of 1.41 and 1.43 for nonuse of both sprays confirm that nonuse of insect repellent and mosquito sprays were associated with higher risk of malaria in Foumbot. In Bamendjou, nonuse of insect repellent spray was associated with higher risk of malaria. However nonuse of mosquito spray was not. The sensitivity (74.36%) and specificity (55.06%) to predict risk of malaria based on use of insect repellent spray, were good. Moreover the relative risk (2.81) for nonuse of insect repellent spray indicates more than 100% risk of malaria. The odds ratio (3.55) and likelihood ratio (1.66) further indicates greater odds and association of nonuse of insect repellent sprays with higher risk of malaria in Bamendjou.

In Bamendjou, non-use of insect repellent body cream was not significantly associated with odds of malaria occurrence. However in Foumbot, nonuse of insect repellent body cream was significantly ($P = 0.0009$) associated with risk of malaria. The relative risk of 2.02 means nonuse of insect repellent body cream was associated with more than 100% higher risk of malaria. In addition to a positive attributable risk of 0.29, the odds ratio of 3.31 indicates a greater odds of malaria occurring in the exposed individuals. Furthermore the likelihood ratio of 1.43 confirms an association between nonuse of insect repellent body cream and malaria, in Foumbot.

There was disparity in the sensitivities and specificities for the use of insect repellent spray, cream and mosquito spray in Foumbot and Bamendjou. In Foumbot, it is 62.5% likely that those who did not use insect repellent spray will test malaria positive and 87.5% likely that those who did not use mosquito spray will test malaria positive. Furthermore it is 55.5% likely that those who used insect repellent spray will test malaria negative and 38.89% likely that those who used mosquito spray will test malaria negative. Results show that it is 81.25% possible that those who did not use insect repellent body cream will test malaria positive and 43.33% possible that those who used it will test malaria negative. However in Bamendjou, it was 74.36% likely that those who did not use insect repellent spray will test malaria positive and 55.06% likely that those who used it will test malaria negative.

In Foumbot which had higher malaria prevalence, nonuse of insect repellent spray, cream and mosquito spray predisposed to higher risk of malaria. But nonuse of LLINs, window and door nets, were not associated with risk of malaria. Therefore, outdoor malaria transmission could be higher in Foumbot since malaria vectors with exophilic host-seeking and resting behavior bites more outdoor (49). But in Bamendjou with lower malaria prevalence, nonuse of insect repellent spray, LLINs, window and door nets all predisposed to higher risk of malaria. However nonuse of insect repellent cream and mosquito spray did not predispose to risk of malaria. Indoor malaria transmission may be higher in Bamendjou since the use of window and door nets provided protection against malaria (50). Although increasing intensities of insecticide resistance and outdoor transmission threatens the effectiveness of indoor residual spray (51), different methods of repellent deliveries (as sprays, body creams and on bed nets) are essential (52). Generally, the active ingredients in insect repellent sprays include picaridin, botanicals, citronella and N,N-diethyl-3-methylbenzamide (DEET). DEET, picaridin, MGK-326, MGK-264, IR3535, oil of citronella and oil of lemon eucalyptus has been approved for skin topical application (53). The effectiveness of each delivery may be affected by behavioral changes in both the human and vector hosts (51, 54). These changes also include insecticide resistance pattern. In Cameroon insecticide resistance was highly prevalent in both *An. gambiae* (*s.l.*) and *An. funestus*. DDT Dichloro-Diphenyl Trichloroethane, permethrin, deltamethrin and bendiocarb seemed to be the most affected compounds by resistance (15). In Foumbot, *An. gambiae* (*s.l.*) was shown to be resistant to DDT Dichloro-Diphenyl Trichloroethane, perm permethrin, deltamethrin delta, lambda-cyhalothrin, bend bendiocarb, and malathion (55, 56).

In another study, although Picaridin repellent reduced 97% of mosquito bites, daily use was low and the effectiveness of malaria preventive measures were found to be mainly influenced by human behavior (54). In the current study, only 8.63% and 31.76% of the study participants used insect repellent body cream in Bamendjou and Foumbot respectively. Topical repellent plus LLINs was also not found to be a suitable intervention against malaria, in an agricultural population in southern Lao PDR (57). In the current study topical repellent (body cream) was not effective in Bamendjou and LLINs was not effective in Foumbot, but other methods were effective. Although indoor residual spraying and LLINs were reported to be the most successful approaches in malaria control (58), as suggested by the Global Malaria Control Strategy, integrated vector management methods are needed for effective vector control (58).

In both Foumbot and Bamendjou, not killing mosquito with a broom, nonuse of mosquito coil and nonuse of mosquito candle were not associated with risk of malaria. Even though not draining stagnant water was not associated with risk of malaria in Bamendjou, it was significantly ($P = 0.0004$) associated with risk of malaria in Foumbot. The odds of malaria occurrence in those who did not drain stagnant water around homes was higher (RR: 1.79, AR: 0.29, OR: 3.29 and LR:

2.14). Those who did not drain stagnant water were 79% more at risk of malaria. Furthermore the positive attributable risk and high odds ratio indicates higher odds of malaria occurrence in those who did not drain stagnant water. The likelihood ratio of 2.14 also confirms an association between malaria and draining of stagnant water in Foumbot. Dirty environment has been reported to increase malaria transmission (59-63). Although Foumbot and Bamendjou are both rural areas, unlike Foumbot, Bamendjou municipality is committed to environmental sanitation. The clean environment of Bamendjou may have contributed to the low malaria prevalence. In Foumbot the sensitivity and specificity for the use of draining stagnant water to predict malaria occurrence was 50% and 76.67% respectively. Therefore it is 50% likely that those who did not drain stagnant water around homes will test malaria positive and 76.67% likely that those who drained stagnant water will test malaria negative. Environmental sanitation remain a main contributing factor in controlling malaria transmission, especially in rural parts of Cameroon like Foumbot.

Conclusions

Some of the malaria preventive measures in the current study did not sufficiently provide protection against malaria, especially in Foumbot which recorded a higher malaria prevalence. Differences in the effectiveness of preventive measures between Foumbot and Bamendjou suggest the need for Intergrated Vector Management. In order to ensure effective Intergrated Vector Management, current entomological studies on malaria transmission in these study areas are necessary. This will provide adequate insight into the behavioral ecology of malaria vectors. Proper follow-up to ensure effective execution of the recently launched third phase of LLINs mass distribution campaign in Cameroon is recommended.

List of abbreviations

LLINs**;** long lasting insecticidal bed nets: ITN; insecticide treated bed nets: RR; relative risk: OR; odds ratio: AR; attributable risk: LR; likelihood ratio

Declarations

Ethics approval and consent to participate

The ethical approval for this study was gotten from the Ethical Review Committee of the University of Bamenda. The ethical clearance numbers are 2020/0148H/UBa/IRB and 2020/0142H/UBa/IRB for data collection in Foumbot and Bamendjou respectively. Signed informed consent was acquired from those who accepted to be enrolled in the study.

Consent for publication

Participants' consents were obtained to publish this study.

Availability of data and material

All data generated or analysed during this study are included in this article (and its supplementary information files).

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

NO designed the study objectives, questionnaire, analysed and interpreted data collected from the laboratory analysis and questionnaires. NO also participated in the laboratory analysis and data collection. YC and TM participated in the laboratory analysis and data collection using the questionnaire. All authors read and approved the final manuscript.

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