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Community engagement and antimalarial drugs medication as the first line of defense in the fight against antimalarial drug resistance in some endemic localities in Cameroon

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ABSTRACT

Objectives: Malaria burden is primarily owing to resistance of parasites and vectors to frontline drugs and insecticides, respectively. Increasing awareness of factors contributing to parasite resistance to antimalarials within communities is crucial. This study assessed how community knowledge, attitudes, and practices (KAPs) influence factors contributing to antimalarial resistance across four malaria ecological zones in Cameroon.

Methods: To accomplish this, structured questionnaires were administered to 980 volunteers from four geographical locations in English or French (the official languages of Cameroon). The data were organized and tested for normality. Spearman rank correlation was used to examine the connection between KAP and malaria.

Results: The mean KAP scores were 5.69 ± 1.47, 5.91 ± 1.25, and 5.66 ± 1.84, respectively, on a nine-point scale. Antimalarials commonly used were artemisinin-based combination therapies (37.96%), chloroquine (4.29%), quinine (22.24%), paracetamol (12.96%), and native drugs (19.80%). Up to 49.49% of the participants practiced self-medication, whereas 76.43% bought medications from licensed pharmacies, 10.61% bought from roadside vendors, and 23.57% relied on traditional/herbal medicines. We observed significant and medium positive linear correlations at $P < 0.01$ between knowledge-attitude ($r = 0.528$), knowledge-practice ($r = 0.400$), and attitude-practice ($r = 0.496$).

Conclusions: Despite the general fair level of awareness of proper management and use of antimalarial drugs in the communities, the high level of self-medication and gross neglect of certain risk factors that may promote the emergence and spread of drug-resistant parasites is concerning.

Introduction

Malaria is a leading cause of morbidity and mortality in sub-Saharan Africa, accounting for 40-45% of physician visits, 57% of hospitalization days, and 40% of under-5 mortality in Cameroon [1]. Each year, over 400,000 people die from malaria, with more than 229 million cases recorded worldwide. As a result, the economy of the affected countries is severely burdened by increased hospital admissions, unnecessary drug use, and increased burden of diagnostic costs [2]. Since the discovery of the world's first synthetic antimalarial drug in 1926, antimalarial drugs have saved millions of lives and increased the average life expectancy of residents in malaria-endemic areas. However, the success of an antimalarial drug is measured by its ability to prevent the emergence of resistance in *Plasmodium spp* [3]. The ability of *Plasmodium falciparum* to undergo numerous drug-resistant mutations that have rendered many antimalarial drugs obsolete in most regions is a major setback to global progress toward malaria eradication. So far, all antimalarial drugs, except artemisinin-based combination therapies (ACTs), have been affected by this moving bandwagon [4,5]. Molecular, genetic, and biochemical analyses have shown that drug-resistant *P. falciparum* malaria is due to chromosomal mutations [6]. The availability of antimalarial drugs in unlicensed drugstores, excessive or misuse of antimalarial drugs during self-medication, non-adherence with prescribed dosages, inappropriate prescriptions, and the lack of antimalarial susceptibility testing can play critical roles in the development of antimalarial drug resistance [7].

Antimalarial drug resistance has become a global threat and it is important to understand the series of events that have brought the world to this predicament. The use of antimalarial drugs has saved millions of lives; however, their ubiquitous use to treat any infection, be it

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severe or mild has led to an increase in antimalarial drug resistance [1]. Antimalarial drugs target Plasmodium exclusively; however, it is sometimes difficult to distinguish between Plasmodium and other febrile infections with similar symptoms without expensive testing. It is often less time-consuming and more cost-effective to carry out presumptive treatment than the conventional test before treating approach [8]. Another problem with antimalarials is the inability to monitor patient intake. Antimalarial doses are designed to eradicate entire parasite populations. If antimalarial drugs are not taken for the full prescribed duration and at regular intervals, parasites can adapt to the presence of low-dose antimalarial drugs and eventually select a population that is completely resistant to the drug. After an unprecedented number of antimalarial discoveries in the last century, the number of newly identified antimalarials has fallen to an all-time low. Without new drugs that can keep up with the rate at which *Plasmodium* parasites can produce drug-resistant strains, society is running out of options to treat malaria infections. Factors favoring the emergence of resistance to existing antimalarial drugs include parasite mutation rate, total parasite burden, strength of selected drug, treatment adherence, poor adherence to malaria treatment guidelines, improper dosing, and counterfeit drugs [9]. Some of these factors contribute to insufficient drug exposure to parasites and low-quality antimalarials, which, together, can support and promote resistance [9]. Providing patients with effective and quality health care is currently one of the most important approaches to overcoming the problem [8].

Prevention has always been the first line of defense against any health threat and, in our case, much has been done to increase public awareness of the risk factors and control strategies for malaria. However, despite the deleterious effects of resistance, not much has been done to raise awareness on the risk factors for parasite resistance in malaria-endemic areas of Cameroon and the link between these risk factors and their antimalarial drug habits. In this study, we aimed to assess the impact of community knowledge, attitudes, and practices (KAPs) on factors that lead to parasite resistance to antimalarial drugs in some malaria-endemic areas of Cameroon.

Methods

Study design and settings

This study was conducted in four locations in Cameroon, including Douala (4.050° N and 9.683° E) in the Coastal Region, Bafoussam (5.4808° N and 10.4284° E) in the West Region, Bafia (4.450° N and 11.140° E) in the Central Region, and Mount Cameroon Area (MCA) including Mutengene, Limbe, and Buea (4.010° N and 9.140° E) in the southwest region. These selected locations belong to three epidemiological malaria areas in Cameroon (Figure 1) [10]. With an average annual rainfall of 3174 mm, the economic capital of Cameroon, Douala, located 13 m above sea level, is a swampy and industrial coastal city in the equatorial forest zone with a tropical monsoon climate, with a dry season from December to February and a wet season from March to November, with an average entomological inoculation rate (EIR) of 0.60 infective bites per person per night (ib/p/n). In this coastal town of Cameroon, poverty is a growing problem, largely owing to the ever-growing population. Unlike rural Cameroonians who can grow their food to reduce expenses, Douala is a port city known for its diverse cultures and bustling markets. The regional capital, the city of Bafoussam, is located at 1432 m above sea level in the highlands of western Cameroon and has an average annual rainfall of 1500 mm. In this semi-urban area, the main economic activity of the population is subsistence farming and trade. Bafoussam is covered with savanna vegetation and has a subtropical highland climate characterized by a dry season from mid-November to mid-March (4 months) and a wet season of 8 months, from mid-March to mid-November, with an average EIR of 0.17 ib/p/n. This city belongs to the western plateau strata of malaria epidemiological settings in Cameroon (Figure 1) [10]. Bafia, a semi-urban city in the Mbam and Inoubou division (central region of Cameroon), is in a forest-savanna transition zone and belongs to the south-equatorial strata of the malaria epidemiological areas in Cameroon, with an average EIR of 0.20 ib/p/n. It has an average annual rainfall of 1199 mm and is 467 m above sea level. The main occupation of the population is the cultivation of maize for self-sufficiency, and the nature of the land is swampy. The rainy season is mostly oppressive, the dry season is humid and mostly cloudy, and it is hot all year round. The main economic activity is agriculture, mostly subsistence farming.

Finally, the MCA, defined as Mutengene, Limbe, and Buea, lies in the tropical rainforest region on the slopes of Mount Cameroon in the southwest region of Cameroon, with a subtropical highland climate, with an average EIR ranging from 2.80 to 0.34 ib/p/n in the rainy and dry seasons, respectively. In the MCA, the wet season is comfortable and the dry season is warm and mostly cloudy. This area belongs to the coastal strata. Agriculture is the main industry in the MCA; however, recently, education has become one of the main activities for which the region is known, with a large number of elementary, secondary, and higher education institutions [10,11]. This assessment was done as a KAP-based survey as described by Kwenti et al. [10]. The research was designed as a questionnaire-based cross-sectional study of the population at the target sites. Study participants were made up of community members enrolled from places of common interest, such as educational institutions, households, marketplaces, etc., provided that the consent of the volunteers is obtained. The participants were asked to answer the questionnaires on site and the questionnaires were collected upon completion. The study enrolled healthy individuals aged 15 years and older who were free of physical or mental disabilities, were not taking any medication, and were proficient in English or French (the national languages of Cameroon). Immigrants from other countries and patients were excluded from data collection.

Ethical considerations

Ethical approval was obtained from the Faculty of Health Sciences Institutional Review Board with the following study registration number: Ref. N: 2019/1018-08/UB/SG/IRB/FHS. Administrative approvals were obtained from the Department of Public Health through the Littoral, West, Center, and South-West Regional Health Delegations (R11/MINSANTE/SWR/RDPH/PS/268/784) and written consent was also obtained from respondents or guardians for participants less than 18 years before the start of the study.

Study tools

A 40-item questionnaire of four sections was used for data collection. In addition to demographic data, nine questions examined knowledge about malaria, nine questions focused on attitudes, and nine questions addressed malaria treatment practices. The respondents were asked to answer in restricted and multiple-choice formats. The primary version of the questionnaire was developed through an extensive literature review in English. It was later translated into the French language using standard translation techniques [12]. When necessary, we sought the help of translators in local dialects. The English version of the questionnaire was tested for reliability and validity. Consistency and validity of the study questionnaire were stabilized, and the instrument for data collection was made available. The assessment of KAP was performed as previously described by Cohen [13], covering various aspects of malaria, including its causes, symptoms, transmission, treatment, and management. Each response was categorized as “yes” or “no.” For assessing the participants’ attitudes toward malaria, responses were categorized as positive or negative. A positive attitude was assigned a score of 1, whereas a negative attitude received a score of zero and answers related to antimalarial practices were denoted as either 0 (poor practice) or 1 (good practice). For all three categories, each with nine questions, an individual could score between 0 (minimum) and 9 (maximum). A

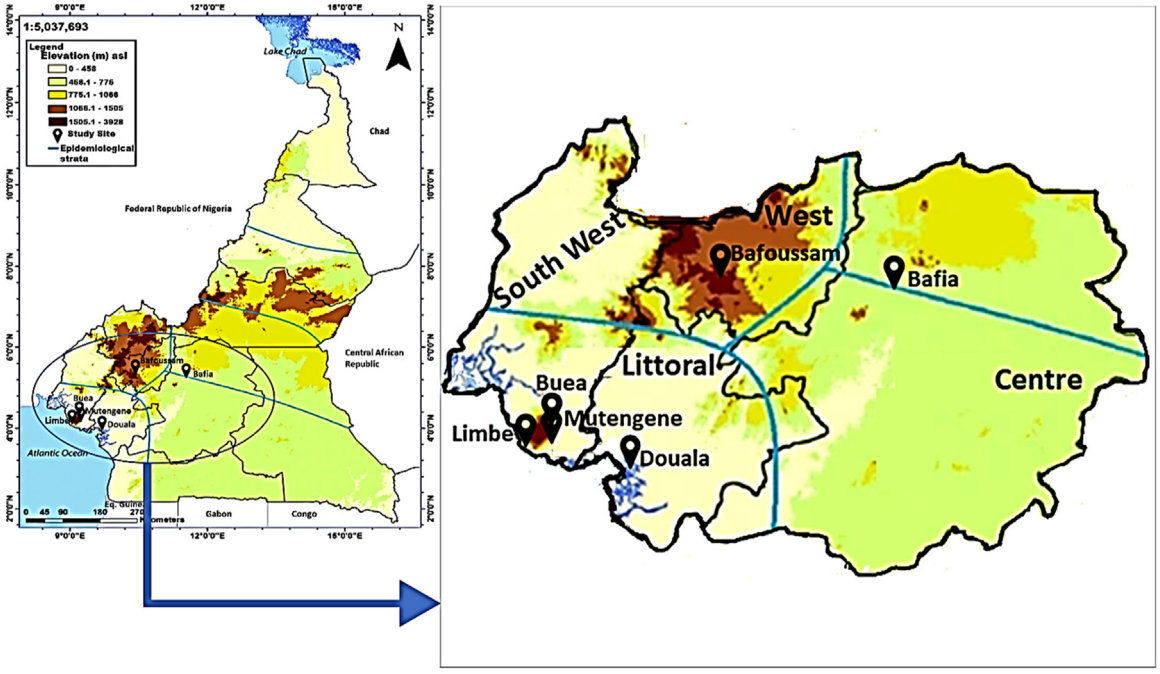

Figure 1. Map depicting the position of the selected study sites within the Malaria epidemiological strata of Cameroon as delineated by Kwenti et al. [10].

general KAP was categorized as good if the score was >5 and poor if the score was ≤5. The general practice was good if the rating was >5 and poor if the rating was ≤5. Individual KAP scores were calculated and then combined to obtain overall KAP scores.

Statistical analysis

The data for this study were coded and entered into Excel. The matched data were exported to SPSS version V23. Data were grouped and organized KAP was performed as previously described by Cohen [13]. Respondent demographics were illustrated using descriptive statistics. Categorical variables were measured as percentages, whereas continuous variables were expressed as mean ± SD. The relationship between study variables was assessed using the Spearman rank correlation. For the correlation analysis, a *P*-value of <0.01 was accepted as significant. The correlation between KAP can be very valuable in predicting and influencing human behavior, especially in the area of health, because it can guide action and policy development. Questions that were not answered by more than 10% of the respondents were not included in the study. The *P*-value of statistical significance was assumed to be $P < 0.05$.

Results

Sociodemographic characteristics

Over 1000 questionnaires were successfully administered, some of which were not consistent and were disqualified for the study. A total of 980 questionnaires were classified as suitable for the analysis (Table 1). Of the 980 participants, 526 (53.67%) were women, 535 (54.59%) belonged to the 15-25 years age group. This pattern was different in Bafia where the majority of the participants (58.71% [182/310]) were between 26 and 45 years old. A considerable proportion of the participants (53.1% [520/980]) had secondary school as the maximum level of education they have obtained. However, this overall picture was not the case in the MCA, where over 80.00% (188/234) of the participants had a higher level of education; in the MCA, 60.00% (153/234) of the participants were students. Most (77.55% [760/980]) of respondents declared that they use bed nets to prevent malaria, with an average of 0.33 ± 0.35 bed nets per person. Health centers or health workers (59.00% [578/980]); radio, television, or newspapers (30.41% [298/980]); and schools, neighborhoods, or churches (10.61% [104/980]) were the sources from which participants said they had heard of malaria.

Malaria awareness

Figure 2a compiles the replies of the participants on their knowledge about malaria. Almost every individual (98.37% [964/980]) in the various study localities had ever heard of the term malaria before, 94.29% (924/980) were aware that mosquito bites are the primary means through which malaria is transmitted, and 94.39% (925/980) were aware that malaria can have lethal consequences. However, only a handful of 16.22% (59/980) knew about the many other means by which malaria can be transmitted besides mosquitoes. Unexpectedly, only 42.45% (416/980) had an idea of the recommended drug used for malaria treatment in Cameroon. Nevertheless, a total of 57.2% (561/980) of the participants demonstrated adequate knowledge of malaria, with mean score of 5.69 ± 1.47 (Table 2).

Attitude toward malaria control

Only about 60% of participants are convinced that conventional medicines in general are legitimate. The survey results further revealed that 62.65% (614/980) of the participants were unwavering in their belief that conventional medicines are the most effective method of treating malaria treatment, and 63.98% (627/980) support adhering to antimalarial doses and schedules. However, about three-quarters of the participants' commitment to best practices regarding malaria control will be affected by distance cost and availability of medical personnel. It was stimulating to observe the overall belief in the possibility of malaria eradication because 97.76% (958/980) of respondents believe malaria can be eradicated. In general, a total of 69.08% (677/980) of the participants showed a good attitude toward malaria, with an average score of 5.91 ± 1.25 (Table 2). The proportion of participants with right attitude are shown in Figure 2b.

Table 1
Sociodemographic characteristics of the participants.

Item no	Sub items	Results for each city				
	Localities	Douala	Mount Cameroon Area	Bafia	Bafoussam	Total
	n=	174	234	310	262	980 (%)
Gender	Male	78	102	139	136	454 (46.33)
	Female	96	132	171	126	526 (53.67)
Age	15-25	117	156	49	213	535 (54.59)
	26-35	36	48	98	39	221 (22.55)
	36-45	10	24	84	6	124 (12.65)
	46-55	6	6	46	4	62 (6.33)
	56-65	2	0	15	0	17 (1.73)
	Above 66	2	0	18	0	20 (2.04)
Marital status	Single	143	204	109	235	691 (70.51)
	Married	29	30	200	21	279 (28.47)
	Divorced	2	0	1	6	9 (0.91)
Religion	Christian	159	231	259	229	878 (89.59)
	Muslim	6	3	51	15	75 (7.65)
	Non-Believer	4	0	0	13	17 (1.73)
	Others	4	0	0	6	11 (1.12)
Occupation	Employed	21	30	59	31	141 (14.39)
	Farmer	15	3	62	6	86 (8.77)
	Student	102	153	58	211	523 (53.37)
	Businessman	21	24	36	10	92 (9.39)
	Self employed	11	21	60	4	96 (9.80)
	Unemployed	3	3	36	0	42 (4.29)
Highest level education	No formal education	6	3	11	0	20 (2.04)
	Primary education	19	0	60	2	81 (8.27)
	Secondary education	85	43	208	184	521 (53.16)
	Higher education	63	188	31	76	358 (36.53)

First four numbers from the left are the number of participants from each study area who choose the specific response, and the last column is the sum of the previous four including a value in parenthesis indicating the percentage of the sum in the total number of respondents.

Table 2
Global and local averages for knowledge, attitude, and practice.

Item	Douala	Bafoussam	Bafia	Mount Cameroon Area	Total
Knowledge	5.42 ±1.56	5.37 ±1.76	5.41±1.24	6.55±1.32	5.69 ±1.47
Attitude	5.82 ±1.15	5.24 ±1.71	6.69±0.79	5.90±1.34	5.91 ±1.25
Practice	5.51 ±1.94	5.59 ±2.17	5.65±1.50	5.88±1.74	5.66 ±1.84

The numbers represent mean scores ± SD.

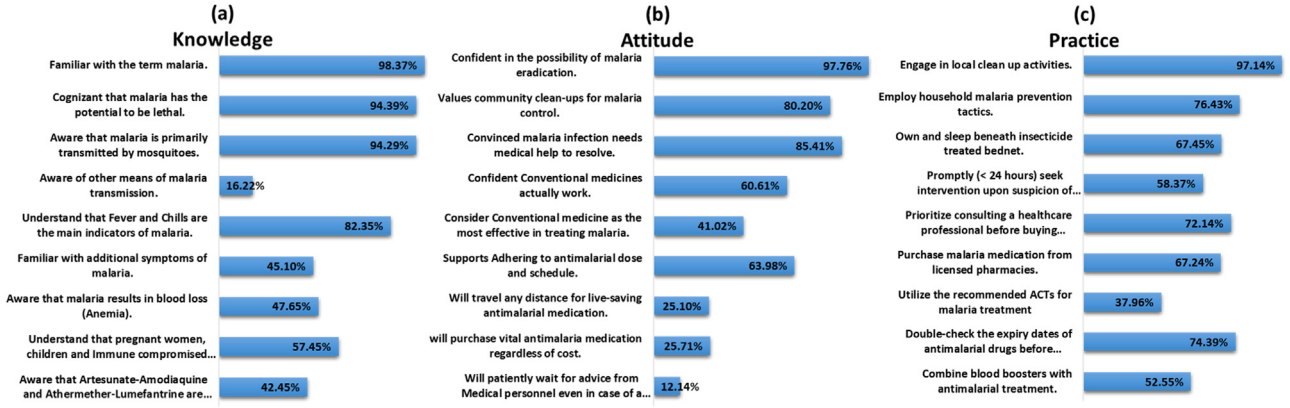

Figure 2. Percentage of participants with good responses to knowledge, attitude, and practice assessing questions: (a) percentage of participants knowledgeable about malaria; (b) percentage of participants who have the right attitude toward malaria prevention; and (c) percentage of participants using good practices steps to prevent malaria.

Malaria control practices

Among some actionable practices that participants were taking to control malaria in their localities, 97.14% (952/980) engage frequently in local clean-up activities programs to protect themselves from malaria. In addition, 67.45% (661/980) own and sleep under an insecticide-treated bed net. After suspected malaria, 72.14% (707/980) of the participants will prioritize seeking out a health care professional before purchasing medication. Over half of the cohort (58.37% [572/980]) promptly seek intervention at least within 24 hours of suspecting malaria infection. Sadly, only 37.96% (372/980) use the recommended medications ACTs for malaria treatment. Refreshingly about, 74.38% (729/980) of participants do double-check the expiration date of the drugs before use. The mean score for malaria-related practices was 5.66

± 1.84 (Table 2), showing a slightly positive good practice score among study participants because 57.86% (567/980) of the cohort had a positive good practice score. Good practices on malaria control are shown in Figure 2c.

Association between demographic characteristics and mean KAP scores

Age and educational level were the only sociodemographic factors that were significantly positively associated with the mean KAP scores (P <0.01); older individuals and those with higher education levels exhibited higher KAP scores. This shows that the levels of KAP relevant to malaria control in our study population are significantly influenced by age and level of education.

Correlation between knowledge, attitude, and practice

The following criteria were used to interpret the correlations between KAP: 0.00-0.25 = weak correlation, 0.25-0.50 = fair correlation, 0.50-0.75 = good correlation, and greater than 0.75 = excellent correlation [13]. The correlation analysis revealed significant and positive linear correlations at P <0.01 between knowledge-attitude (r = 0.53), knowledge-practice (r = 0.40), and attitude-practice (r = 0.50) (all at P <0.01).

Antimalarial drug resistance risk-increasing behaviors

The KAP survey was designed to assess the KAPs of the general population concerning malaria. In addition, the survey questions were formulated to address particular negative habits that contribute to the risk of antimalarial drug resistance within the population and the results are shown on Figure 3. These risk factors have the potential to sustain or elevate drug pressure in certain regions, thereby preventing it from falling below the World Health Organization's threshold for reintroduction of an antimalarial drug (treatment failure <10%). From our participant pool of 980, a significant proportion 76.53% (750) admitted to only seeking treatment from licensed pharmacies if they suspect malaria infection; however, notably, nearly 30% (273) still use local herbs to treat malaria and 10% (104) still purchase drugs from street vendors Figure 3a. Three-quarters (729) of the participants consistently double-check the expiration date before taking medication (Figure 3b). Regarding participant antimalarial drug preference, 40% (372) primarily opt for ACTs, whereas 22.24% (218) used quinine. Paracetamol is mentioned by almost 13% (127) of the participants, whereas almost 5% (42) continue to use chloroquine (CQ) for malaria treatment (Figure 3c). Approximately 65% (630) affirm that they consistently adhere to prescribed doses and schedules for their antimalarials (Figure 3d). Intriguingly, almost half of the respondents do not consult a doctor before purchasing antimalarials (Figure 3e).

Discussion

This study aimed to evaluate the KAPs toward malaria in healthy subjects in Bafoussam, Douala, Bafia, and the MCA, four locations in Cameroon with different ecological and socioeconomic settings. The results of the study showed a good KAP on malaria. The mean knowledge score was 5.69 ± 1.47 on a scale of 9, indicating a higher-than-average level of knowledge about malaria among the surveyed population. Over 97% of respondents in all four areas had heard of malaria, and most respondents in this study (>82%) knew that malaria was mosquito-borne. Almost 90% knew at least one malaria symptom. Almost 89% acknowledged the potential fatality of malaria, and at least 41% of them believed that conventional medicines were effective. The primary source of information was community and health centers. This high level of knowledge corresponds to previous studies in Cameroon [14,15]. Good attitude and good practices were also evident in all four sites, with an average attitude score of 5.91 ± 1.25 and an average practice score of 5.66 ± 1.84 on a scale of 9. The observed positive correlations between knowledge-attitude, knowledge-practice, and attitude-practice reinforce the link between KAPs in the context of infection control interventions [16]. Positive significant R^2 indicate that adequate knowledge can lead to a positive attitude that leads to good practices. These results agree with the results of Singh et al. [17]. Furthermore, age and level of education emerged as significant factors positively influencing the mean KAP scores. Specifically, older individuals and those with higher education levels exhibited higher KAP scores. Further exploration of these relationships could provide insights into the varying perspectives and behaviors concerning malaria control across different demographic groups. A majority of participants (>72%) across all locations still prioritize buying medications from certified pharmacies and 60% double-checked the expiration dates before use, reflecting relatively minimal use of counterfeit or expired drugs. However, roughly 14% admitted to sourcing medications from drug dealers or street vendors. Although medicines from hospitals and authorized pharmacies undergo quality control in analytical laboratories before distribution [5], which increases the people's confidence in the medicines they consume, consuming expired or counterfeit drugs with possible suboptimal dosages from street vendors poses significant risks because these sources can provide suboptimal or counterfeit drugs, potentially leading to toxicity and drug resistance [18]. Previous investigations aimed at evaluating the quality of antimalarial drugs sold by street vendors and informal sellers in Cameroon have highlighted disturbing findings because they indicated the availability of poor-quality ACTs in the Cameroonian market [19,20]. Furthermore, studies conducted in neighboring Nigeria have reported a significant presence of substandard antimalarial drugs being sold in retail establishments. These drugs may be transported across the Nigeria-Cameroon borders through illicit trading channels and distributed via unofficial channels, such as market vendors, drug dealers, and unauthorized pharmacies. These drugs may contain insufficient active ingredients or different active ingredients, which would impair drug efficacy and increase drug pressure owing to the need to administer more than the required dose for treatment [21]. This problem emphasizes the need for stronger regulatory controls and better surveillance to deal with the distribution of substandard and fake antimalarial drugs. Despite the ban on CQ, a small portion (<6.5%) of the study population still reported using it for malaria treatment. This suggests that the ban is being followed to some extent; however, smuggling and unauthorized distribution might contribute to its continued use. The fact that artemether-lumefantrine remains a secondary choice to artesunate-amodiaquine could be owing to financial incentives rather than efficacy considerations [22]. Because low-income families are hit hard by the higher pricing of ACTs compared with previous antimalarial drugs, the government has made efforts to solve this problem by subsidizing the price of the recommended first-line antimalarial drug, artesunate-amodiaquine, [23] and, evidently, ACTs were still the drug of choice (38%) in all cities; the results were consistent with the 36.2% reported by Mbohou et al. [24] in Douala. However, in Bafia, which is more rural, ACTs were only the first choice for 19.1% because over half of the participants (54.5%) preferred to use herbal and traditional medicines and only resort to ACTs after failure of their more traditional methods. This, therefore, highlights a need for the government and non-governmental organizations to create campaigns and conduct sensitization that will make the public aware of more effective anti-malaria drugs [23].

About 13% of the participants reported taking paracetamol as a medication. This could be because headache and fever are among the troubling symptoms of malaria [25]. This could explain why people take paracetamol to alleviate the symptoms. This can also be explained by the fact that paracetamol is usually included in the pack prescribed for the treatment of malaria [26]. For at least 28% of the cohort, consulting a physician was the last resort. This is one of the factors that increase drug pressure through self-medication. According to the World Health Organization, self-medication refers to the use of a drug on one's own initiative or on the advice of loved ones to treat a disease or symp-

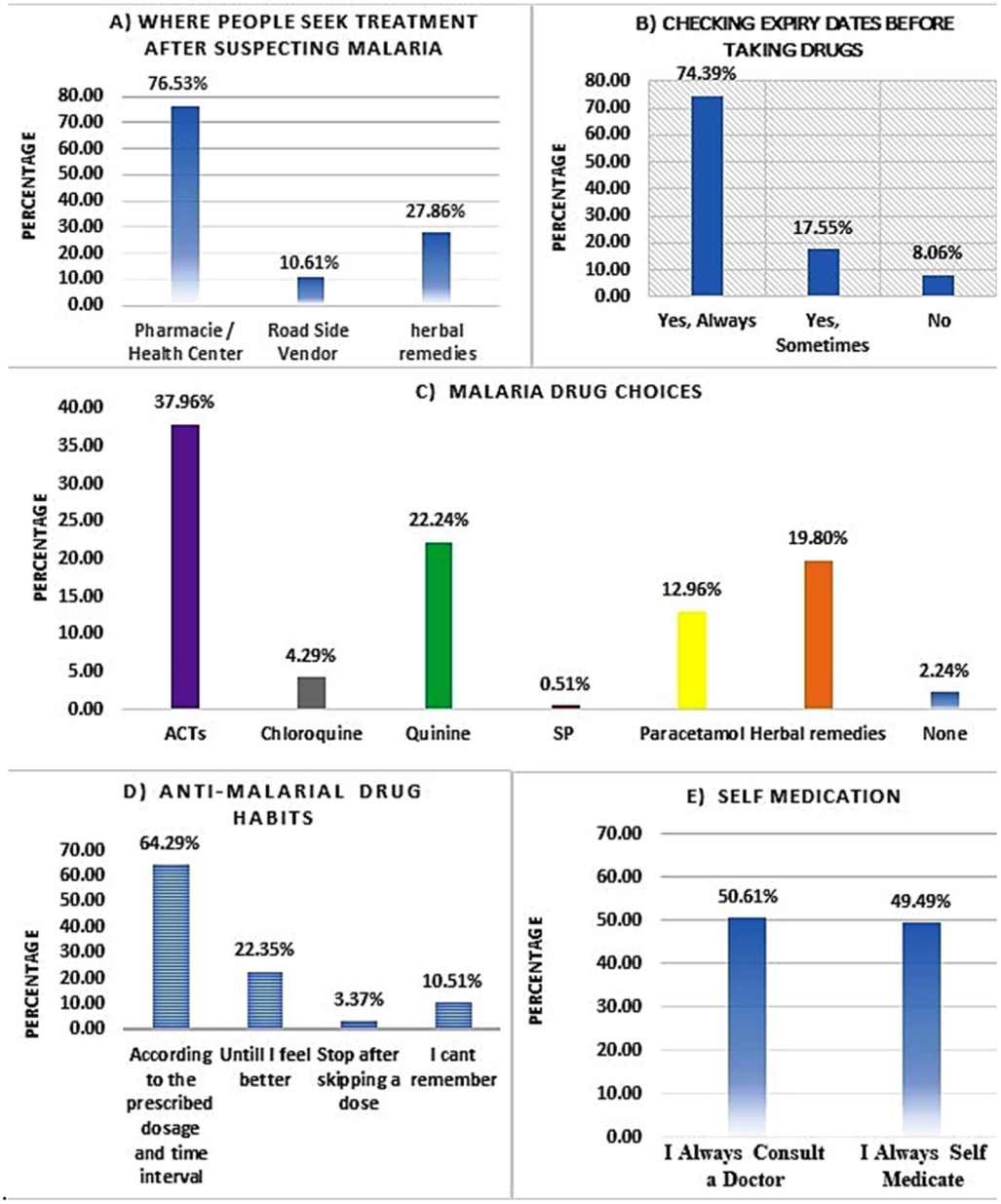

Figure 3. Risk factors for anti-malaria resistance; (a) where people seek treatment after suspecting malaria; (b) checking expiry dates before consumption of drugs; (c) malaria drug of choice; (d) anti-malarial drug habits; and (e) self-medication. ACTs, artemisinin-based combination therapies.

toms without the involvement of a health care professional [25]. Self-medication was 49.5%. This is more than the 30.1% reported in Douala [26] and in the Ndu [27] community of Cameroon. This is also consistent with studies from Tanzania [28] and Benin [29], which reported high levels of self-medication. Improper use of antimalarial drugs can trigger a chain reaction in Plasmodium parasites, resulting in an ecological phenomenon known as antimalarial drug resistance [28]. As such, self-medication reported in the present study fall among the main driver of drug resistance development in the field [30]. Despite the role it plays in the emergence of drug resistance, it would be challenging to advise the populace of suburban and rural areas to stop self-medicating because most of them can barely earn enough to afford medication from official sources. However, if used properly, self-medication could become an important tool in the fight against the malaria burden in sub-Saharan Africa. However, this is advisable if self-medication is accompanied by positive community engagement and education about the other risk factors of antimalarial resistance, including suboptimal dosing, incomplete treatments, purchasing drugs from unlicensed sources, and choice of antimalarial medication, which are considered risk factors in the occurrence and spread of antimalarial resistance.

Conclusion

This study highlighted an above-average level of public awareness of the proper management of malaria control measures and the use of antimalarial drugs within communities. Although CQ is still consumed by a small proportion of the population in the cities surveyed, the results overwhelmingly suggest that the CQ ban is respected. However, the majority of people are still self-medicated with both conventional and home remedies, increasing the risk factors for the emergence and spread of resistant parasites.

Limitations and recommendations

This study was limited to four regions (of 10) of Cameroon and further analysis of the current situation using data from other regions of the country may provide a better picture of the evolutionary dynamics and continued surveillance for markers of drug-resistant CQ mutants in Cameroon. In addition, the government should tighten policies on drugs imported into the country to reduce the availability of counterfeit and illicit drugs in the market. Campaigns should also be conducted to educate the community about the impact of underuse of antimalarial drugs and its potential impact, including the emergence and spread of drug-resistant parasites in the population.

Declarations of competing interest

The authors have no competing interest to declare.

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Ethical approval

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. Ethical approval was obtained from the Faculty of Health Sciences Institutional Review Board, Faculty of Health Sciences, University of Buea, with the following study registration number: Ref. N: 2019/1018-08/UB/SG/IRB/FHS. Informed consent was obtained from all individual participants included in the study.

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Author contributions

DDSF, GST, and MNM conceived and designed the study. FNA and MEE conducted the research including data collection. DDSF, VTJ, and GST were responsible for data management and analysis. FNA interpreted the results and wrote the first draft of the manuscript. DDSF, GST, and MNM supervised and critically reviewed the manuscript for important and intellectual content. All authors read and approved the final manuscript.

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