Malaria Associated Risk Factors Among Adolescent Living in Areas With Persisting Transmission in Senegal: a Case Control Study.

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Abstract

Background: In Senegal, malaria morbidity has shapely felt down over these past years. However, malaria epidemiology remains heterogeneous with persisting transmission in the southeastern part of the country and more important number of cases arising among older children and adolescents. Little is known about factors associated with clinical malaria among this group. A better understanding of malaria transmission among this new vulnerable group will guide future interventions targeting these key populations. This study aimed to identify factors associated with clinical malaria among adolescents in Senegal.

Methods: A case control study was conducted from November to December 2020 in four health posts located in Saraya district. Cases were defined as adolescents (10-19 years) with uncomplicated malaria episode with fever (Temperature>37.5°) or history of fever and a positive malaria RDT. Controls were from the same age group, living in the neighborhood of the case, presenting a negative RDT. A standardized, pre-tested questionnaire was administered to each participant followed by home visit to assess participant’s living conditions. Factors associated with clinical malaria was assessed using a Stepwise Logistic regression analysis.

Results: In total, 492 individuals were recruited (246 cases and 246 controls). In a multivariate analysis, factors associated with clinical malaria included non-use of bed net (aOR=2.65; 95% CI =1.58 - 4.45), non-use of other preventive measures (aOR=2.51; 95% CI=1.53 - 4.11) and indoor sleeping (aOR=3.22; 95%CI =1.66- 6.23). Protective factors included age of 15-19 years (aOR=0.38; 95% CI 0.23 - 0.62), absence of stagnant water around the house (aOR=0.27; 95% CI=0.16 - 0.44), having a female as head of household (aOR=0.47; 95% CI=0.25 - 0.90), occupation such as apprentice (OR=0.24; 95%CI=0.11 - 0.52).

Conclusions: The study revealed that environmental factors and non-use of malaria preventive measures are the main determinant of malaria transmission among adolescents living in areas with persisting malaria transmission in Senegal. Strategies aiming at improving disease awareness and access to health care interventions such as LLIN are thus needed to improve malaria control and prevention among these vulnerable groups.

Background

Malaria remains a major public health problem Worldwide particularly in Sub-Saharan Africa, despite the substantial decrease of malaria burden over these past 15 years, due to the scale up of standard control interventions such as prompt diagnosis and treatment, long-lasting insecticidal nets (LLINs), and indoor residual spraying (IRS) [1]. In 2019, 229 million malaria cases were notified in 87 endemic countries, with an estimate of 215 million cases representing 94% of cases, in Sub Saharan Africa (SSA); over 409 000 deaths were attributed to malaria globally among which, 384 000 occurred in SSA [2].

In Senegal, malaria is endemic and unevenly distributed in the fourteen regions of the country. In 2019, by the time of the current study initiation, the National Malaria Control Program (NMCP) reported 354 708 malaria cases representing an incidence of 21.9 per 1000. Most of these cases (81%) were reported in three regions located in the south-eastern part of the country, namely Kolda, Tambacounda, Kédougou [3]. From 2013 to 2017, proportional morbidity and mortality nationwide decreased from 5.4–3.3% and from 7.5–1.7% respectively. However, these indicators increased from 2017 to 2018, with proportional morbidity increasing from 3.3–4.8% and proportional mortality from 1.7–3.5% [4]. From 2018 to 2019, these indicators have decreased again, proportional morbidity dropping from 4.8–3.0% and mortality from 3.5–1.7% [3]. In addition, longitudinal routine malaria data from the NMCP, showed that over the past five years, the majority of malaria cases occurred among older children (10–15 years age) and adolescent (*Tine R, personal Communication*). A study conducted in Dielmo in the central part of Senegal, to assess evolution of malaria morbidity in adults before and after the implementation of LLINs, showed that 15–19 years old people were the most vulnerable group during malaria upsurges [5]. Recent studies conducted in Sub Saharan African countries, have shown higher prevalence of malaria among older children and adolescents [6–8], or an increased risk of malaria among these groups [9–12]. This could be explained by several reasons including the lack of optimal usage of Long Lasting Insecticide net (LLIN) [13, 14] and sub-optimal behaviour such as staying out door during the night, which corresponds to the time of the malaria vectors activities [14, 15]. Despite these trends, children under five years and pregnant women are still being considered as the most at-risk groups for malaria in Senegal and consequently represent the usual target of the majority of available control measures such as intermittent preventive treatments. This may lead to a residual human malaria reservoir with adolescents and older children who are not the primary target of control measures. There is thus an urgent need to adapt current control strategies in order to account for emerging new malaria vulnerable groups such as older children and adolescent. A better understanding of malaria associated risk factors and its determinants among older children and adolescent is needed in order to optimise malaria control among these specific key populations. But there is a lack of evidence about factors associated with clinical malaria among this age group. Studies are thus needed to fill these scientific gaps that may hamper malaria control and elimination efforts. The current case control study was conducted to assess factors associated with clinical malaria among adolescents in order to inform future control strategies among key vulnerable populations living in areas with persisting malaria transmission in Senegal.

Methods

Study setting

The study was conducted in the health district of Saraya, located in Kedougou region in the south-eastern part of Senegal, at 800 Km from Dakar, the capital. The district shares a border with Mali at the east, Guinea at the south, the region of Tambacounda at the north and the health district of Kedougou at the west. The health district occupies a land area of 6,837 km^2. The population is composed by the rural communities of Bembou, Medina Baffe, Sabadola, Khossanto and Missirah Sirimana. The district has 1 health centre, 22 health pots, 28 health huts and 78 villages with a village volunteer for malaria case management (DSDOM, Dispensateur de soins à domicile). The climate is Sudano-Sahelian with a dry season and a rainy season. Malaria is meso endemic and stable in Saraya, with a long transmission season lasting 4 to 6 months from July to December. Transmission intensity remains high with 20 to 100 infectious bites / man / year and high morbidity during the transmission period. The major vectors are *Anopheles gambiae, An. arabiensis sl, An. funestus and An. nili* [16]. Malaria incidence was 376.6 ‰ in 2017, 487.2 ‰ in 2018 and 379.8 ‰ in 2019 [3].

Study design and participants

A case control study was conducted from November to December 2020 in four health posts (Bembou, Diakhaling, Khossanto and Sambrambougou), selected purposively based on reported malaria morbidity in 2019 and community accessibility during the rainy season. The number of confirmed malaria cases in 2019 was 1,404 in Bembou, 1,485 in Diakhaling, 2,166 in Khossanto and 3,311 in Sambrambougou.

Cases were recruited from participating health posts while the controls were recruited within the same community, in the same village as the case but not in the same house (case and control houses were distant from each other by at least 2 others houses). A case was defined as an adolescent (10-19 years) coming to seek care at one of the participating health posts for uncomplicated malaria episode defined as fever (Temperature>37.5°) or history of fever within the previous 48 hours, with positive malaria RDT according to the National Malaria Control Program (NMCP) guidelines. Control was a person of the same age group, living in the neighborhood of the case, with negative RDT.

Non-inclusion criteria for both the cases and controls included: (i) Less than 10 years old children, (ii) Individual that does not live in the study area, (iii) Subject who received antimalarial treatment during a period of three weeks prior to the study.

Data collection methods

An electronic data collection platform was used. Data were collected using android tablets with the electronic questionnaire developed on REDCap, which is a Research Electronic Data Capture software compatible with android technology [17,18]. Data collected from the tablets were then synced via internet connection to a server hosted at University Cheikh Anta Diop for storage. Data were extracted from the server for cleaning and analysis. Prior to the start of the study nurses and a community health worker in participating health posts were trained on the study procedures including the inform consent and administration of the questionnaire. For each participant who gave informed consent, an electronic standardized questionnaire was administered to collect data on socio-demographic characteristics of the participant and those of the household head, the household assets (water source, type of toilet, ownership of certain items like television, radio, fridge, etc.), ownership and use of LLIN, use of other malaria control measures, individual behaviours during the mosquitos “biting time”(stay outdoor at the evening/night, sleeping outdoor during the night). Home visits were performed for both cases and controls to assess participants living conditions (types of wall, floor and roof), environmental factors such as presence or absence of stagnant water, overgrown vegetation/bushes inside and in the vicinity of the houses of the participants.

Statistical methods

Sample size calculation: For the sample size calculation, we considered the use of long-acting mosquito nets (LLINs) as the main determinant associated with malaria. The proportion of LLIN use among children in the study area is 62% [19]; assuming a risk alpha at 5%, with a ratio of 1 control for 1 case, the study was powered at 80% to detect an odds ratio of 0.6 if 492 individuals were recruited (246 cases versus 246 controls).

Data analysis: Data were extracted from the server and analyzed using STATA software [20]. A composite variable of wealth index was estimated, based on the assets of the households [21]. We have not included housing variables in the wealth index calculation as in the index used in the Demographic and Health Survey (DHS) [19] to avoid correlation between variables. We have assessed separately the impact of housing materials on malaria risk as shown in other studies [21,22]. The index was then categorized in five wealth quintiles (richest, rich, middle, poor, poorest) using Principal Component Analysis method (PCA) [19,23]. Variables characterizing household materials including type of wall, roof and floor were grouped according to the Demographic and Health Survey (DHS) definition [19] as traditional (rudimentary and natural) and modern to create a binary housing variable. Modern houses were then defined as those that have modern wall, modern roof and modern floor; while traditional houses were those that have rudimentary and natural wall, floor and roof [21]. Modern roof materials include cement/beton, wood planks, tile, metal while traditional roof materials include thatch/straw, bamboo. Modern floor materials include cement and ceramic tiles where as traditional floor materials include earth/mud and bamboo. Modern wall materials consisted of cement and wood/planks while traditional wall materials consisted of earth/mud and bamboo/palm.

Percentage was used to assess the frequency of each outcome with a 95% confidence interval. Characteristics of all participants included in the study were tabulated. Proportions were compared using chi square test or Fisher exact test where appropriated (univariate analysis).

Factors associated with malaria were assessed using a logistic regression model. Covariates with p value <0.20 in univariate analysis were introduced in the multivariate model. From the final model, adjusted odds ratios were derived with their 95% confidence interval. Model validity was tested using the Hosmer-Lemeshow goodness of fit test. The performance of the final model was assessed by the area under the curve, and Akaike and Bayesian information criterion. In addition, a test for multicollinearity between variables was done using the variance inflation factor. Significance level of the different tests was 0.05, two sided.

Ethical considerations

The study protocol was approved by the University Cheikh Anta Diop Institutional Review Board (CER/UCAD/AD/MSN /039/2020). Prior to the start of the study, administrative authorization was sought from the regional and district medical authorities in Kedougou and Saraya. In the field participation to the study was strictly voluntary. Prior to any enrollment, written informed consent was obtained from parents or caregivers for adolescents under 18 years old, while 18-19 years old individuals were invited to consent themselves. In addition, a child assent was sought from 15- 17 years old participants. A unique identification code was attributed to each participant. Personal Identified data collected for the household head were de-identified before the data extraction. All analysis were performed using participants identification code to ensure maximum confidentiality. Access to the study data was restricted and information collected only used for the study purpose.

Results

Participant's characteristics at enrolment

Demographics:

A total of 492 individuals were recruited, (246 cases and 246 controls). Cases and controls were similar in terms of demographic characteristics. There was no statistical difference between cases and controls (Table 1).

Table 1
Socio demographic characteristics of the participants and the household heads

	Case (246)		Control (246)		
Characteristics of the participants					
	Number (%)	95% CI	Number (%)	95% CI	P value
Age group 10–14 years	130(52.85%)	(46.49% – 59.22%)	106(43.09%)	(36.81% – 49.53%)	0.1356
15–19 years	116(47.15%)	(40.78% – 53.60%)	140(56.91%)	(50.47% – 63.19%)	0.1196
Gender					
Male	135(54.88%)	(48.43% – 61.21%)	136(55.28%)	(48.84% – 61.60%)	0.9472
Female	111(45.12%)	(38.79% – 51.57%)	110(44.72%)	(38.40% – 51.16%)	0.9523
Ethnicity					
Pular	46(18.70%)	(14.03% – 24.14%)	43(17.48%)	(12.95% – 22.81%)	0.8813
Malinke	171(69.51%)	(63.35% – 75.20%)	181(73.58%)	(67.60% – 78.98%)	0.3973
Bambara	17(6.91%)	(4.08% – 10.83%)	8(3.25%)	(1.41% – 6.30%)	0.7136
Others‡	12(4.88%)	(2.54% – 8.37%)	14(5.69%)	(3.15% – 9.36%)	0.9269
Occupation					
Student	161(65.45%)	(59.14% – 71.37%)	134(54.47%)	(48.02% – 60.81%)	0.0548
Maid	46(18.70%)	(14.03% – 24.14%)	35(14.23%)	(10.11% – 19.23%)	0.5937
Apprentice*	13(5.28%)	(2.84% – 8.87%)	48(19.51%)	(14.75% – 25.02%)	0.2199

*Apprentice includes tailor, driver, mechanic, mason apprentices
‡ other ethnicity include Diakhakhe, Dialouke, Mossi, Serere, Sarakhole, Wolof, Bassari
† Other occupation include farmer, taxi driver, seller and talibe (children in placement in Koranic school)

	Case (246)		Control (246)		
Gold digger	18(7.32%)	(4.39% – 11.32%)	13(5.28%)	(2.84% – 8.87%)	0.8197
Others†	8(3.25%)	(1.41% – 6.31%)	16(6.50%)	(3.76%- 10.35%)	0.7402
Characteristics of the household head					
Age					
23–33	26(10,57%)	(7.02% – 15.10%)	27(10,98%)	(7.36% -15.57%)	0.9616
34–43	57(23,17%)	(18.05% – 28.95%)	61(24,80%)	(19.53% – 30.68%)	0.8359
44–53	74(30,08%)	(24.42% – 36.23%)	55(22,36%)	(17.31% – 28.09%)	0.3275
54–63	52(21,14%)	(16.20% – 26.78%)	79(32,11%)	(26.32% – 38.34%)	0.1701
64–87	16(6,50%)	(3.76% – 10.35%)	24(9,76%)	(6.35% – 14.17%)	0.7166
Missing	21(8,54%)	(5.36% – 12.75%)	0(0,00%)	-	
Gender					
Male	222(90,24%)	(85.83% – 93.65%)	209(84,96%)	(79.87% – 89.18%)	0.0956
Female	24(9,76%)	(6.35% – 14.17%)	37(15,04%)	(10.82% – 20.13%)	0.5487
Education level					
None	79(32.11%)	(26.32% – 38.34%)	74(30,08%)	(24.42% – 36.23%)	0.7864
Koranic school	75(30.49%)	(24.80% – 36.65%)	86(34,96%)	(29.01% – 41.28%)	0.5470
Primary	69(28.05%)	(22.53% – 34.11%)	62(25,20%)	(19.90% – 31.11%)	0.7128

*Apprentice includes tailor, driver, mechanic, mason apprentices

‡ other ethnicity include Diakhakhe, Dialouke, Mossi, Serere, Sarakhole, Wolof, Bassari

† Other occupation include farmer, taxi driver, seller and talibe (children in placement in Koranic school)

	Case (246)		Control (246)		
Secondary	20(8.13%)	(5.04% – 12.28%)	20(8,13%)	(5.04% – 12.28%)	1.0000
University	3(1.22%)	(0.25% – 3.52%)	4(1,63%)	(0.44% – 4.11%)	0.9642
Matrimonial status					
Single	7(2.85%)	(1.15% – 5.78%)	8(3.25%)	(1.41% – 6.31%)	0.9642
Married	237(96.34%)	(93.17% – 98.31%)	229(93.09%)	(89.17% – 95.92%)	0.1160
Other	2(0.81%)	(0.10% – 2.91%)	9(3.66%)	(1.69% – 6.83%)	0.8345
Wealth index					
Poorest	61(24,80%)	(19.53% – 30.68%)	37(15,04%)	(10.82% – 20.13%)	0.2511
Poor	44(17,89%)	(13.31% – 23.26%)	55(22,36%)	(17.31% – 28.09%)	0.5832
Medium	48(19,51%)	(14.75% – 25.02%)	50(20,33%)	(15.48% – 25.90%)	0.9191
Rich	49(19,92%)	(15.11% – 25.46%)	50(20,33%)	(15.48% – 25.90%)	0.9594
Richest	44(17,89%)	(13.31% – 23.26%)	54(21,95%)	(16.94% – 27.65%)	0.6181
*Apprentice includes tailor, driver, mechanic, mason apprentices					
‡ other ethnicity include Diakhakhe, Dialouke, Mossi, Serere, Sarakhole, Wolof, Bassari					
† Other occupation include farmer, taxi driver, seller and talibe (children in placement in Koranic school)					

Preventives measures and housing conditions

Most of the cases (81.71%) and the controls (93.09%) reported bed-net ownership but bed net ownership was significantly higher among controls ($p = 0.0003$). The proportion of cases who reported the use of bed-net was 63.82% while that was at 82.52% among controls ($p = 0.0001$). Bed net usage the previous night was significantly higher among controls (78.46%) compared to cases (58.94%) ($p = 0.0001$). Almost all the controls (92.68%) reported sleeping outdoor sometimes, compared to the cases (72.76%) ($p < 10^{-3}$).

The proportion of individuals who reported presence of stagnant water in the vicinity of their house was 46.75% among cases and 22.76% among controls ($p = 0.0025$). The type of floor of the house was traditional for 80.49% of the control compared to 58.13% for the cases ($p < 10^{-3}$) (Table 2).

Table 2

Distribution of the study population according to the preventive measures and housing conditions

Variables	Case (246)		Control (246)		
	number (%)	95% CI	number (%).	95% CI	P value
Bed net ownership					
Yes	201(81.71%)	(76.29% - 86.33%)	229(93.09%)	(89.17% - 95.92%)	**0.0003**
No	45(18.29%)	(13.67% - 23.70%)	17(6.91%)	(4.08% - 10.83%)	0.2651
Bed net use					
Yes	157(63.82%)	(57.47% - 69.83%)	203(82.52%)	(77.19% - 87.05%)	**0.0001**
No	89(36.18%)	(30.17 %- 42.53%)	43(17.48%)	(12.94% - 22.81%)	0.0281
Bed net use the previous night					
Yes	145(58.94%)	(52.52% - 65.15%)	193(78.46%)	(72.79% - 83.43%)	**0.0001**
No	101(41.06%)	(34.85% - 47.48%)	53(21.54%)	(16.57% - 27.21%)	0.0154
Use of others preventives measures‡					
Yes	146(59.35%)	(52.93% - 65.54%)	163(66.53%)	(60.24% - 72.41%)	0.1915
No	100(40.65%)	(34.45% - 47.07%)	82(33.47%)	(27.59% - 39.76%)	0.3193
Sleep outdoor					
Yes	179(72.76%)	(66.74% - 78.23%)	228(92.68%)	(88.68% - 95.61%)	**0.0000**
No	67(27.24%)	(21.77% - 33.26%)	18(7.32%)	(4.39% - 11.32%)	0.0747

Stay outdoor outside at the evening/night					
Yes	245(99.59%)	(97.76% - 99.99%)	244(99.19%)	(97.09% - 99.90%)	0.5699
No	1(0.41%)	(0.010% - 2.24%)	2(0.81%)	(0.01% - 2.91%)	-
Stagnant water outside the house					
Yes	115(46.75%)	(40.38% - 53.19%)	56(22.76%)	(17.68% - 28.52%)	**0.0025**
No	131(53.25%)	(46.81 % - 59.66%)	190(77,24%)	(71.48% - 82.32%)	0.0000
Stagnant water inside the house					
Yes	19(7.72%)	(4.71% - 11.80%)	12(4,88%)	(2.55% - 8.37%)	0.7567
No	227(92.28%)	(88.20% - 95.29%)	234(95,12%)	(91.63% - 97.45%)	0.2089
Grass/bushes outside the house					
Yes	144(58.54%)	(52.10% - 64.76%)	126(51,22%)	(44.79% - 57.62%)	0.2276
No	102(41.46%)	(35.24% - 47.90%)	120(48,78%)	(42.39% - 55.21%)	0.2750
Grass/bushes inside the house					
Yes	43(17.48%)	(12.95% - 22.81%)	47(19.11%)	(14.39% - 24.58%)	0.8418
No	203(82.52%)	(77.19% - 87.05%)	199(80.89%)	(75.42% - 85.61%)	0.6725
Type of roof					
Traditional	114(46.34%)	(39.98% - 2.79%)	119(48,37%)	(41.98% -	0.7564

				54.81%)	
modern	132(53.66%)	(47.21% - 60.02%)	127(51,63%)	(45.19% - 58.02%)	0.7436
Type of wall					
Traditional	192(78.05%)	(72.35% - 83.06%)	201(81.71%)	(76.30% - 86.33%)	0.3653
modern	54(21.95%)	(16.94% - 27.65%)	45(18.29%)	(13.67% - 23.70%)	0.6520
Type of floor					
Traditional	143(58.13%)	(51.69% - 64.37%)	198(80.49%)	(74.98% - 85.25%)	**0.0000**
modern	103(41.87%)	(35.63% - 48.31%)	48(19.51%)	(14.75% - 25.02%)	0.0072
Type of house					
Traditional	205(83.33%)	(78.08% - 87.77%)	218(88.62%)	(83.97% - 92.30%)	0.1165
modern	41(16.67%)	(12.23% - 21.92%)	28(11.38%)	(7.70% - 16.03%)	0.5403
‡ other preventives measures include insecticide, smoke coil, weeding, indoor residual spraying, sewage evacuation, traditional methods.					

Factors associated with malaria among the study participants

In the multivariate analysis, in overall, factors associated with clinical malaria included non-use of bed net (aOR = 2.65; 95% CI = 1.58–4.45), non-use of other preventive measures (aOR = 2.51; 95% CI = 1.53–4.11) and indoor sleeping (aOR = 3.22; 95%CI = 1.66–6.23). Protective factors included age range between 15–19 years (aOR = 0.38; 95% CI 0.23–0.62), absence of stagnant water around the house (aOR = 0.27; 95% CI = 0.16–0.44), having a female as head of household (aOR = 0.47; 95% CI = 0.25–0.90), occupation such as apprentice (OR = 0.24; 95%CI = 0.11–0.52) (Table 3).

Table 3
Factors associated to clinical malaria in the study participants $

Parameters	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	aOR (95% CI)	P value
Age				
10–14 years	1		1	
15–19 years	0.68(0.47–0.96)	**0.031**	0.38(0.23–0.62)	**0.000**
Occupation of the participant				
Student	1		1	
Maid	1.09(0.66–1.80)	0.723	1.16(0.60–2.24)	0.663
Apprentice#	0.23(0.12–0.43)	**0.000**	0.24(0.11–0.52)	**0.000**
Gold Digger	1.15(0.54–2.44)	0.711	0.62(0.23–1.66)	0.337
Others‡	0.36(0.13–0.95)	**0.040**	0.50(0.16–1.55)	0.233
Bed net use				
Yes	1		1	
No	2.19(1.30–3.71)	**0.004**	2.65(1.58–4.45)	**0.000**
Use of others preventive measures†				
Yes	1		1	
No	1.36(0.94–1.97)	0.100	2.51(1.53–4.11)	**0.000**
Sleep outdoor				
Yes	1		1	
No	4.74(2.72–8.27)	**0.000**	3.22(1.66–6.23)	**0.001**
Stagnant water outside of the house				
Yes	1		1	
No	0.34(0.22–0.50)	**0.000**	0.27(0.16–0.44)	**0.000**
Household head gender				
Male	1		1	
Female	0.61(0.35–1.06)	0.077	0.47(0.25–0.90)	**0.022**

Parameters	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	aOR (95% CI)	P value
$ Analysis of factors associated with malaria was adjusted on the following factors: participant gender, participant age, participant occupation, household head gender, household head age, wealth index, bed net-use, use of others preventives measures, outdoor sleeping, presence of stagnant water outside the house, presence of stagnant water inside the house, presence of bushes/overgrown vegetation outside the house, type of house. Goodness of fit test: Hosmer-Lemeshow, $chi^2(7) = 12.38$, p = 0.0888. BIC= -2264.750, AIC = 1.186, AUC = 0.7640				
# Apprentice includes tailor, driver, mechanic, mason apprentices				
‡ Other occupation include farmer, taxi driver, seller and talibe (children in placement in Koranic school)				
† other preventives measures include insecticide, smoke coil, weeding, indoor residual spraying, sewage evacuation, traditional methods				

When stratify by age groups, factors associated with malaria among 10–14 years old children include non-use of bed-net (aOR = 3.36; 95% CI = 1.24–9.15), non-use of others preventive measures (aOR = 3.32; 95% CI = 1.61–6.85), indoor sleeping (aOR = 4.21; 95% CI = 1.30–13.66). Protective factors included occupation such as apprentice (aOR = 0.07; 95% CI = 0.02–0.30) and others occupation including children in placement in koranic school ("*talibe*") and seller (aOR = 0.13; 95% CI = 0.03–0.59); absence of stagnant water around the house (aOR = 0.26; 95% CI = 0.11–0.59) and absence of stagnant water inside the house (aOR = 0.14; 95% CI = 0.02–0.97) (Table 4)

Table 4
Factors associated to malaria among 10–14 years old adolescents¥

Parameters	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	aOR (95% CI)	P value
Occupation of the participant				
Student	1		1	
Apprentice	0.06(0.017–0.20)	**0.000**	0.07(0.02–0.30)	**0.000**
Others‡	0.12(0.03–0.45)	**0.001**	0.13(0.03–0.59)	**0.008**
Bed net use				
Yes	1		1	
No	4.34(1.91–9.85)	**0.000**	3.36(1.24–9.15)	**0.018**
Use of others preventive† measures				
Yes	1		1	
No	1.92(1.12–3.30)	**0.018**	3.32(1.61–6.85)	**0.001**
Sleep outdoor				
Yes	1		1	
No	4.06(1.70–9.70)	**0.002**	4.21(1.30–13.66)	**0.017**
Stagnant water outside of the house				
Yes	1		1	
No	0.23(0.12–0.44)	**0.000**	0.26(0.11–0.59)	**0.001**
Stagnant water inside of the house				
Yes	1		1	
No	0.39(0.10–1.48)	0.168	0.14(0.02–0.97)	**0.046**

¥ Analysis of factors associated with malaria was adjusted by the following variables: participant gender, participant occupation, age of the household head, wealth index, bed-net use, use of other preventive measures, outdoor sleeping, presence of stagnant water outside the house, presence of stagnant water inside the house, type of house. Goodness of fit test: Hosmer-Lemeshow, $chi^2(5)$ = 4.46, p = 0.4849. BIC= -972.891, AIC = 1.089, AUC = 0.7921

‡ other occupation includes talibe and seller

† disposal of waste water, wearing of long clothes and indoor residual spraying

Factors associated with malaria among 15–19 years old adolescents include non-use of bed-nets (aOR = 2.20; 95% CI = 1.22–3.98), indoor sleeping (aOR = 3.79; 95% CI = 1.64–8.77). Protective factors included having a female as head of household (aOR = 0.16; 95% CI = 0.04–0.60) and absence of stagnant water around the house (aOR = 0.46; 95% CI = 0.26–0.86) (Table 5)

Table 5
Factors associated to malaria among 15–19 years old adolescents§

Parameters	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	aOR (95% CI)	P value
Gender of the household head				
Male	1		1	
Female	0.15(0.04–0.52)	**0.003**	0.16(0.04–0.60)	**0.006**
Bed net use				
Yes	1		1	
No	2.70(1.59–4.59)	**0.000**	2.20(1.22–3.98)	**0.009**
Sleep outdoor				
Yes	1		1	
No	5.71(2.76–11.83)	**0.000**	3.79(1.64–8.77)	**0.002**
Stagnant water outside of the house				
Yes	1		1	
No	0.39(0.23–0.65)	**0.000**	0.46(0.26–0.82)	**0.009**

§ Analysis of factors associated with malaria was adjusted by participant gender, occupation of the participant, age and gender of the household head, wealth index, bed net use, outdoor sleeping, presence of stagnant water outside the house, presence of bushes/overgrown vegetation outside the house. Goodness of fit test: Hosmer-Lemeshow, $chi^2(4) = 11.11$, p = 0.0253. BIC= -994.099, AIC = 1.222, AUC = 0.7253

Other factors including gender of the adolescents, age and level of education of the household head, wealth index and type of house were not significantly associated with clinical malaria among study participants.

Discussion

Malaria is still an important public health problem in Senegal, with a shift of the disease burden from younger to older children and adolescents. The present study aimed at identifying factors associated with clinical malaria among children and adolescents aged of 10–19 years old, living in persisting transmission areas in order to guide future interventions.

Our results showed that adolescents who reported not sleeping under bed-net are more at risk of malaria compared to those who reported bed net usage. This result is consistent with the findings from others studies [12, 14, 24]. Non-use of other preventive measures is associated with an increased risk of malaria, specifically among 10–14 years old adolescents. In our study, other control measures included aerosol spraying, mosquito coils, weeding, indoor residual spraying, sewage evacuation, traditional methods. Most of the study participants reported the use of aerosols spraying, and the frequency of aerosol usage was higher among controls compared to the case. Other studies also have shown that use of mosquito control measures including aerosol sprays, herbs, and mosquito coils is associated with a lower risk of clinical malaria [25, 26]. However, a Cochrane systematic review has not shown evidence of association between spatial repellents such as mosquito coils and risk of malaria [27].

Several studies have reported an association between higher risk of malaria and outdoor sleeping [1, 28]. In contrast to these findings, in our study adolescents who reported not sleeping outdoors (e.g. indoor sleeping) have 4.74-fold the odds to be diseased of malaria compared to those that reported sleeping outdoor. This result is in line with findings from a study conducted in Myanmar among migrants in gold mining, rubber and oil palm plantation areas [29]. Mosquitoes behavior in our study area could explain this result. Entomological surveillance data showed that *Anopheles gambiae s.l.* is the most predominant vector in this area, with high biting and anthropophilic rates. It is also reported that the vectors are endophagic and exophagic [30]. Although, it is proved that Long Lasting Nets are effective on endophagic vectors [31], the participants might be bitten indoor when they are awake, before the use of the bed nets during sleeping time. To ensure maximum protective effect against malaria, high quality of LLIN is required [32]. The increased risk of clinical malaria among children who reported indoor sleeping as the main behavior, could also be due to poor LLIN quality; but the study did not assess LLIN quality across the different households.

Young adolescents aged 10–14 years old were at higher risk of malaria compared to their counterparts of 15–19 years old. In our study area, as in other southern regions in Senegal, where malaria is highly seasonal and transmission important, 3 months to 10 years old children were receiving seasonal malaria chemoprevention (SMC) with sulfadoxine-pyrimethamine and amodiaquine (SPAQ) for three to four months during the transmission season. SMC policy is being implemented in these locations since 2013 with average coverage of full treatment courses around 80% per year [3, 33]. As thus, younger children enrolled in our study have previously received several rounds of SMC. Although SMC has been proven to be efficacious on reducing malaria morbidity and mortality [34–36], the strategy has the potential to induce reduction in malaria antibodies [37, 38]. Therefore, the increased risk of clinical malaria among 10 to 14 years old children could be related to an increased susceptibility due to reduced antibody level after several rounds of SMC. Moreover, though SMC program has overall strongly positive health effects, a shift of morbidity into older children can be induced by the program if transmission levels remain static and not reduced by other interventions [39]. As malaria burden is shifting in these areas with older children becoming more at risk, increasing SMC target up to 15 years should be evaluated as an alternative option for controlling malaria in areas with persisting malaria transmission.

Absence of stagnant water in the vicinity of the house is protective against malaria in our study participants. This finding is in line with those of others studies [15, 28, 40, 41]. This could be explained by the fact that stagnant waters are potential breeding sites of *Anopheles* mosquitoes. So, having such water around the house could increase the population of mosquitoes and hence facilitate malaria transmission [42].

Compared to those that have male as household heads, participants that have female household head are protected against malaria in our study and this result is specific to older adolescent aged 15–19 years old. Similar to our findings, a study conducted in India reported that household with male head have greater risk of malaria [43]. It is well established that in many African contexts, women usually play a primary role of care giving to other members of the household [44], and therefore are more committed to promote disease prevention strategies such as bed net usage within their own families, as shown in a study conducted in Nampula province, in Mozambique [45]. In addition women are often responsible for hanging, washing and making nets usable [45].

Our study also showed reduced odd of clinical malaria among apprentice and "*talibe*" (children in placement in koranic school) compared to children attending classic school, particularly among 10–14 years old children. In our study, most of the apprentice are controls and have reported high bed-net use, this may explain their reduced risk against malaria. In this study, apprentice include tailor, driver, mechanic, mason, and is not part of occupation associated with high risk of malaria like gold mining, farming as shown in other studies [12, 43, 46]. Being "*talibé*" is associated with reduced risk of malaria comparing to students. This result is surprising, since these children are considered as vulnerable population and are at higher risk of infectious diseases such as malaria [47]. In our study, most of the "*talibe*" are controls and they have reported use of bed-net; this could explain our result. Serological studies assessing cumulative exposure to malaria parasite would provide more insights on malaria distribution among the group of *"talibé"*.

Limitation of the study

The main limitation of our study is the lack of entomological surveys to assess mosquitos' vectors and their biting behaviors as well as transmission intensity in the study area. However, a survey conducted in 2019 gave us insights on this information.

In this study, identification of cases and controls, relied on RDT results though this method is not the gold standard for malaria diagnostic. But, it still remains the operational definition of malaria episode according to national guidelines and in many health care settings, treatment practices as well as routine surveillance system are based on malaria confirmation using mRDT.

Conclusion

The study revealed that environmental factors and non-use of preventive measures are the main determinants of malaria risk among adolescents living in areas with persisting transmission in Senegal. Strategies aiming to improve disease awareness and access to health care interventions such as LLIN are thus needed to improve malaria control and prevention among these vulnerable groups. In addition, increasing SMC target up to 15 years might be an alternative option for accelerating malaria control in these areas with persisting malaria transmission.

Abbreviations

NMCP: National Malaria Control Program

RDT: Rapid Diagnostic Test

mRDT: malaria Rapid Diagnostic Test

aOR: adjusted odd ratio

SSA: Sub Saharan Africa

LLIN: Long Lasting Insecticide net

REDCap: Research Electronic Data Capture

DHS: Demographic and Health Survey

AIC: Akaike Information Criterion

BIC: Bayesian Information Criterion

AUC: Area Under Curve

SMC: Seasonal Malaria Chemoprevention

SPAQ: Sulfadoxine Pyrimethamine and Amodiaquine

Declarations

Ethics approval and consent to participate

The study protocol was approved by the University Cheikh Anta Diop Institutional Review Board (CER/UCAD/AD/MSN /039/2020). Prior to the start of the study, administrative authorization was sought from the regional and health district authorities in Kedougou and Saraya. In the field, participation to the study was strictly voluntary. Prior to any enrollment, written informed consent was obtained from parents or caregivers for adolescents under 18 years old, while 18-19 years old individuals were invited to give consent themselves. In addition, a child assent was sought from 15- 17 years old participants.

Consent for publication

Not applicable

Availability of data and materials

The datasets used for the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare they have no competing interests

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Authors ‘contributions

FT and RT conceived, designed the study protocol and analyzed the data. FT supervised data collection. AD, OS, AK supported the protocol design. FT drafted the manuscript and made final revisions. AD, OS, AK, SL, KS, IAK, DS, BF, CBF, MN and RT critically reviewed the manuscript; all authors read and approved the final manuscript.

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