ORIGINAL RESEARCH

Trend of Malaria Burden Among Residents of Kisii County, Kenya After More Than a Decade Usage of Artemisinin Combined Therapies, 11–Year Laboratory Based Retrospective Study

Josephat Nyabayo Maniga [ID][1–3], Mong'are Samuel [ID][4], Masai Rael[1], John Odda[5,6], Odoki Martin[2,3], Ibrahim Ntulume [ID][2,7], Pacifica Bwogo[1], Wilberforce Mfitundinda [ID][3], Saheed Adekunle Akinola [ID][2,8]

[1]Department of Biological Sciences, Kisii University, Kisii, Kenya; [2]Department of Microbiology and Immunology, Kampala International University Western Campus, Bushenyi, Uganda; [3]College of Medicine, Health and Life Sciences, School of Medicine, King Ceasor University, Kampala, Uganda; [4]School of Health Sciences, Kisii University, Kisii, Kenya; [5]School of Pharmacy, Kampala International University Western Campus, Bushenyi, Uganda; [6]Department of Pharmacology and Therapeutics, Makerere University, Kampala, Uganda; [7]School of Biosecurity, Biotechnical and Laboratory Science, College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University, Kampala, Uganda; [8]Department of Clinical Biology, School of Medicine and Pharmacy, College of Medicine and Health Sciences, University of Rwanda, Butare, Rwanda

Correspondence: Josephat Nyabayo Maniga, College of Medicine, Health and Life Sciences, School of Medicine, King Ceasor University, Kampala, Uganda, Tel +256750739527, Email josnyabayo@yahoo.com

Background: Malaria remains a major vector borne disease globally, with the majority of the casualties reported in Africa. Despite this fact, there is drastic reduction in malaria infection using Artemisinin combined therapies (ACTs). Malaria is characterized by significant inconsistency in different geographical locations due to different confounding factors. There is need to identify zone-specific malaria trends and interventions to completely eliminate the disease. Thus the study was aimed at assessing the 11-year trend of microscopically confirmed malaria cases in Kisii County, Kenya, so as to devise area-specific evidence-based interventions, informed decisions, and to track the effectiveness of malaria control programs.

Methods: This was a retrospective study carried out to determine 11-year malaria trend rates centered on the admission and laboratory records from health facilities located at four Sub-Counties in Kisii County, Kenya. Parasitological positivity rates of malaria were determined by comparing with the register records in health facilities which recorded confirmed malaria cases with the total number of monthly admissions over the entire year. Data was analyzed by using descriptive tools and chi-square test.

Results: There were 36,946 suspect cases, with 8449 (22.8%) confirmed malaria cases reported in this study. The overall malaria slide positivity rate over the last 11 years in the study area was 22.6%. The months of April and August showed the largest number of malaria cases (63%). The age group of ≥18 years contained the most positive confirmed cases, having a prevalence rate of 2953 (35.45%). Out of the confirmed malaria cases, 2379 (28.1%) were males and 6070 (71.9%) were females The highest malaria prevalence rate was recorded in 2014, with Marani Sub-County recording the highest positivity rate of 37.94%.

Conclusion: From the observed trends, malaria prevalence and transmission still remains stable in the study area. Thus more interventions need to be scaled up.

Keywords: malaria burden, artemisinin combined therapies, retrospective, ACTs

Introduction

Despite all intervention practices, malaria still remains a major threat to public health. Africa accounts for the largest portion of mortality and morbidities followed by Asia. Mortality resulting from malaria has been compacted using artemisinin-based combination therapies (ACTs) and other containment interventions, such as residual indoor spraying, the use of insecticide-treated nets, and appropriate environmental management. Additionally, WHO recommends other vital measures to prevent pregnant associated malaria (PAM) among the pregnant mothers. These includes; use of

5221

chemoprophylaxis (Intermittent prophylaxis during pregnancy [IPTp]) and sleeping under insecticides treated nets during pregnancy. Pregnant mothers who are in their second and third trimesters are more expected of having severe malaria compared to other groups residing in low malaria transmission settings. Thus in such cases Parenteral antimalarial agents are recommended to pregnant women with severe malaria in complete doses. Parenteral artesunate is the recommended drug for treatment in all trimesters. In case artesunate is out of reach, then intramuscular artemether should be given as an option, and if this is inaccessible then parenteral quinine should be considered instantly until artesunate is acquired. The policy in Kenya also offers Intermittent Preventive Treatment (IPT) in pregnancy which employs the use of Sulfadoxine/ Pyrimethamine three tablets taken Stat at 13 weeks of pregnancy and thereafter monthly till delivery. This preventative measure is to ensure the well-being of the mother and fetus during the pregnancy.

In 2020-, about 445,000 deaths were reported globally compared to 554,000 in 2015.[1] According to the World malaria report (WHO, 2021), approximately 3.4 billion of the world population reside in the geographical regions which are vulnerable to malaria transmission. In 2020, approximately 228 million cases were reported leading to 405,000 deaths globally.[2] The burden is heaviest in sub-Saharan Africa, where an estimated 88% of all malaria deaths occur.

Despite of the widespread deployment of malaria control measures by using ACTs as the mainstream intervention measures, still during the last years, there has been witnessed an increase of malaria in the world. In reference to the latest WHO malaria report of 2021, there was an upsurge of malaria cases. This was characterized with an increase of malaria incidence rates and malaria mortality rates. In the year of 2020, for instance there were 241 million cases reported globally compared to 227 million cases reported on the year of 2019. Moreover, the number of malaria deaths were 627,000 in 2020 which is an upsurge of about 69,000 deaths. This situation may worsen as a result of ongoing COVID-19 pandemic which has greatly compromised malaria treatment and control intervention measures.

The prevalence of malaria in Kenya is 19%. Malaria occurrence in Kenya, has variations across the country with the lake endemic zone having the highest prevalence (27%), followed by the coast endemic zone (8%) and the highland epidemic zone (3%) with semi-arid, seasonal and low risk areas reporting less than 1% respectively. Kenya has been ranked 9th in the world with over 43,490 deaths in 2018 and having one of the highest entomological inoculation rates in the world.[3] In Kisii County, malaria is distributed across the year with some variations in different sub counties in the county.

With the spread of malaria in Kenya and all over the world, Kenya has adopted the use of ACTs as the drug of choice for treatment of uncomplicated malaria caused by *Plasmodium falciparum*. Artemether-Lumefantrine (AL) was introduced in the year of 2004 after reports of Sulfodoxine-Phyrimetrine (SP) resistance in Kenya especially at the coastal region. But AL was made available in government health facilities in the year 2006.[4] Currently, there is insufficient data about the impact of ACTs on malaria epidemiology. Thus this current study used Retrospective analysis of malaria medical records to evaluate the temporal trends of malaria for the last 11 years in the study area during the era of ACTs deployment. Retrospective records serve as a tremendous resource for estimating regional-based disease problem. Such information is crucial for devising an evidence-based and area-specific interventions.

Materials and Methods
Study Area
The study was conducted in selected sub counties within Kisii County. They included Marani and Bonchari (high malaria transmission zone) and Kenyenya and Nyamache (low malaria transmission zone). Kisii County is located in Nyanza region, Kenya. The county has nine (9) Sub Counties and is located approximately 306 km from the capital city, Nairobi. It lies at Lat: 0.41°S; long: 34.46°E East. The county is majorly inhabited by the Abagusii ethnic group with other tribes comprising of small percentage. According to 2019 Kenya population and housing census, the population size is 1,266,660 persons.[5] The County exhibits a highland equatorial climate with average rainfall of 1500mm/year. The county records two rain seasons namely; long rains of between March and June; short rains of between September and November. The county health system consists of government and private based health facilities. The government sector has one teaching and referral hospital (KTRH), which serves as a regional reference hospital and a teaching hospital for Kisii University Medical School. The county contains 14 sub-county hospitals. The county also contains 84 dispensaries,

28 health centers and 32 community health units which serves as centers for minor health cases. The county records three rain seasons namely; April–May, August–September, and November–December, the main killer disease is malaria. The main malaria intervention approaches used to combat malaria in this region includes proper case management with antimalarial drugs such as ACTs, IPTp and use of mosquito nets. The current drug in use for treatment of uncomplicated malaria is AL. Diagnosis and treatment service of malaria are available in all government health facilities and some few private facilities. The average temperature range is between 21°C–30°C (Figure 1).

Study Design

This was a cross sectional health-based retrospective study carried out to determine the trends of malaria morbidities and mortalities over 11-year time period (2010–2021).
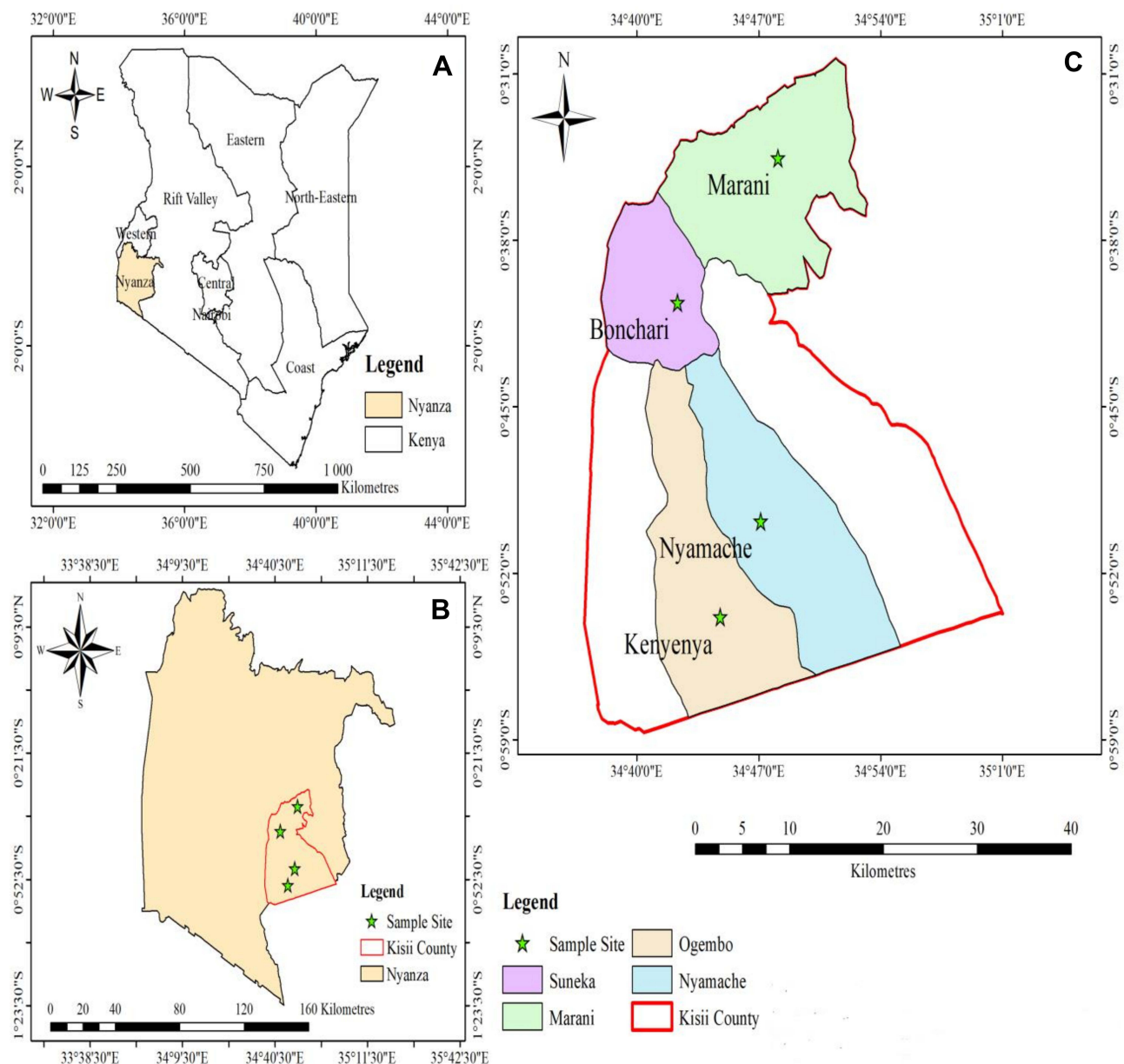

Figure 1 Study area. (**A**) Showing the entire country, Kenya. (**B**) Shows Nyanza region where Kisii county is located. (**C**) Shows sampled sub counties of Kisii county.

Data Collection

Data collection was done by evaluating health records present at different sites. Parasitological positivity rates of malaria were determined from 2010 to 2021. The data variables were initially collected by experienced laboratory scientists or laboratory technicians. Microscopy was used as the standard Gold method for *Plasmodium* parasite examination. The *Plasmodium* parasites were confirmed by examining peripheral stained blood films by using the Giemsa staining as outlined by WHO (2021), standard operating procedures. This was done by comparing with the register books in health facilities which recorded confirmed malaria cases with the total number of monthly admissions over the entire year. Other variables which were considered included patient address, age, and gender, date of diagnosis, diagnosis tools and result of diagnosis. The cases with incomplete records of essential variables were excluded from this study. Only cases confirmed by microscopy were considered for this study.

Operational Definitions

Suspected Case

A patient with a fever who has presented himself/herself to a clinician.

Positive Case

A Patient who has been diagnosed with malaria by using a standard acceptable procedure.

Slide Positivity Rate

The percentage of slides that tested positive for malaria out of the total number of slides evaluated.

Data Processing and Analysis

For data quality assurance, a well-prepared checklist was utilized. The collected data were checked for completeness and consistency daily. Data cleaning was also conducted by using SPSS. The data set was first grouped into different sub counties, socio-demographic characteristics, laboratory results and years. Data were entered into EpiData 3.1, exported to SPSS version 24 software. Descriptive statistics were used to summarize the data. The chi-square test was used to compare the association of malaria burden by age groups, sex, seasons, years and different sub counties. $P < 0.05$ was considered as statistically significant. The analyzed data was presented using tables and figures. Line graphs were used to show the trends over the 11 years.

Ethical Consideration

Ethical approval was obtained from University of East Africa, Baraton Institutional Review Board (UEAB/REC/4/2/2021). The research permit for this study was issued by Kenya National Commission for Science, Technology and Innovation (NACOSTI) License No: NACOSTI/P/21/8974 and Kisii County government (DTR/4/27). Permission was granted by different Sub Counties prior to the study. Written informed consent was acquired from the adult participants, while consent for those below 18 years of age was provided by their parents or the care-givers. All research procedures were conducted by following the ethical standards of the committees on human experimentation laid down in the Helsinki declaration of 1975 and revised in 2000. Moreover, the study was conducted in accordance with the guidelines of WHO good clinical practices.

Results

Prevalence of Malaria Cases in Relation to Demographics

The suspected cases were higher in females with 25,380 (68.7%) compared to 11,566 (31.3%) suspected cases among the male gender. In relation to age group the largest suspected cases was recorded among participants with >18 years (39.3%) while the least suspected cases were recorded among those from 0–5 years (15.4%). This study has reported fluctuations of confirmed malaria cases in relation to age and sex over the past 11 years. Confirmed malaria cases occurred across all age groups with substantial variations between genders. A statistically significant relationship was observed between gender and malaria prevalence ($\chi2 = 181.50$, *d.f* = 1, *P* =0.025. Out of 8449 confirmed malaria cases, 2379 (28.1%) and 6070 (71.9%) were reported in males and females respectively. Statistically significant association was observed between malaria positivity and

Table 1 Showing demographic characteristics of malaria cases

Year	Demographics		Suspected Cases	Confirmed Cases	Prevalence (%) (95% CI)
2011	Gender	Male	1281	266	21 (19.03–22.17)
		Female	2365	673	28 (27.03–30.07)
	Age (years)	0–5	482	83	17 (16.32–19.84)
		6–11	937	185	20 (18.53–22.02)
		12–18	987	254	26 (24.81–28.04)
		>18	1241	417	34 (33.89–37.01)
2012	Gender	Male	986	161	16 (15.05–18.02)
		Female	2130	767	30 (28.25–32.12)
	Age (years)	0–5	474	53	11 (9.74–12.72)
		6–11	718	214	30 (28.76–32.06)
		12–18	871	269	31 (28.91–33.89)
		>18	1053	392	78 (76.05–80.02)
2013	Gender	Male	1228	271	22 (21.04–24.09)
		Female	1527	728	48 (46.26–50.06)
	Age (years)	0–5	341	76	22 (20.89–24.13)
		6–11	672	221	33 (31.87–35.86)
		12–18	824	231	28 (26.54–30.25)
		>18	918	471	52 (50.35–54.52)
2014	Gender	Male	953	421	44 (42.85.–46.05)
		Female	1540	718	47 (45.47–49.06)
	Age (years)	0–5	410	182	44 (42.03–45.98)
		6–11	518	96	19 (17.95–21.25)
		12–18	623	417	70 (68.5–71.75)
		>18	942	444	47 (46.85–48.75)
2015	Gender	Male	1423	186	13 (12.08–15.03)
		Female	2317	841	36 (34.86–38.06)
	Age (years)	0–5	396	78	20 (19.02–21.65)
		6–11	584	176	30 (28.71–32.01)
		12–18	1418	642	45 (43.32–46.45)
		>18	1342	131	10 (9.85–11.35)

(*Continued*)

Table 1 (Continued).

Year	Demographics		Suspected Cases	Confirmed Cases	Prevalence (%) (95% CI)
2016	Gender	Male	1290	510	40 (38.35–42.08)
		Female	2186	577	26 (24.20–28.14)
	Age (years)	0–5	641	238	37 (35.85–38.95)
		6–11	784	242	31 (29.75–32.02)
		12–18	923	228	25 (24.65–27.85)
		>18	1128	379	34 (33.01–36.85)
2017	Gender	Male	974	30	3 (1.84–3.26)
		Female	1489	780	24 (22.65–26.11)
	Age (years)	0–5	640	218	34 (32.05–35.95)
		6–11	618	185	30 (28.86–31.75)
		12–18	423	121	29 (27.45–31.05)
		>18	782	286	37 (35.81–28.25)
2018	Gender	Male	1164	89	8 (6.54–10.06)
		Female	2581	436	17 (16.92–18.31)
	Age (years)	0–5	993	114	12 (10.05–14.24)
		6–11	518	119	23 (21.42–25.75)
		12–18	892	132	15 (13.73–16.08)
		>18	1342	160	12 (11.08–14.95)
2019	Gender	Male	1321	322	17 (13.04–18.27)
		Female	2582	107	12 (10.37–14.55)
	Age (years)	0–5	565	121	21 (19.35–22.96)
		6–11	872	176	20 (18.32–21.08)
		12–18	1048	143	14 (12.01–15.00)
		>18	1418	189	13 (11.75–14.75)
2020	Gender	Male	565	43	8 (6.75–10.37)
		Female	3219	103	47 (46.14–49.03)
	Age (years)	0–5	746	42	6 (5.35–7.87)
		6–11	723	24	3 (1.73–4.05)
		12–18	1343	31	2 (58.25–61.35)
		>18	972	49	5 (3.35–6.08)

(*Continued*)

Table 1 (Continued).

Year	Demographics		Suspected Cases	Confirmed Cases	Prevalence (%) (95% CI)
2021	Gender	Male	381	80	21 (19.85–23.11)
		Female	863	138	16 (14.43–18.21)
	Age (years)	0–5	154	39	25 (23.85–27.09)
		6–11	148	98	66 (63.75–68.05)
		12–18	324	46	14 (12.58–15.07)
		>18	618	35	6 (5.06–7.35)

age sets ($\chi2$ = 442.62, *d.f*= 4, *P* =0.021. Age group of ≥18 years were the most with positive confirmed results, having a prevalence rate of 2953 (35.45%), followed by those of 12–18 years old with prevalence rate of 2468 (29.62%), those between 6–11 years with prevalence rates of 1736 (20.84%) and those between 0–5 years of age with a prevalence rate of 1205 (14.09%), respectively (Table 1).

Total Sub-County Confirmed Malaria Cases

Malaria cases were recorded all years around in all the studied sub counties. In all sub counties, 8449 (22.8%) out of 36,946 patients were positive for malaria. Marani Sub County recorded the largest percentage of 6100 (72.19%), followed by Nyamache with 1100 (13%), Kenyenya with 649 (7.6%) and Bonchari with 600 (7.1%) (Figure 2).

Annual Temporal Malaria Trends

Malaria cases were recorded all year around in all studied sub counties. Despite the fluctuation in malaria cases across years and study areas, there was a general increase in the disease prevalence rates from 2012 to 2015. The highest prevalence rates of 54.3% were recorded in 2014. The proportion of confirmed malaria cases steadily decreased from 2017/2018 to 2020/2021 (Figure 3).
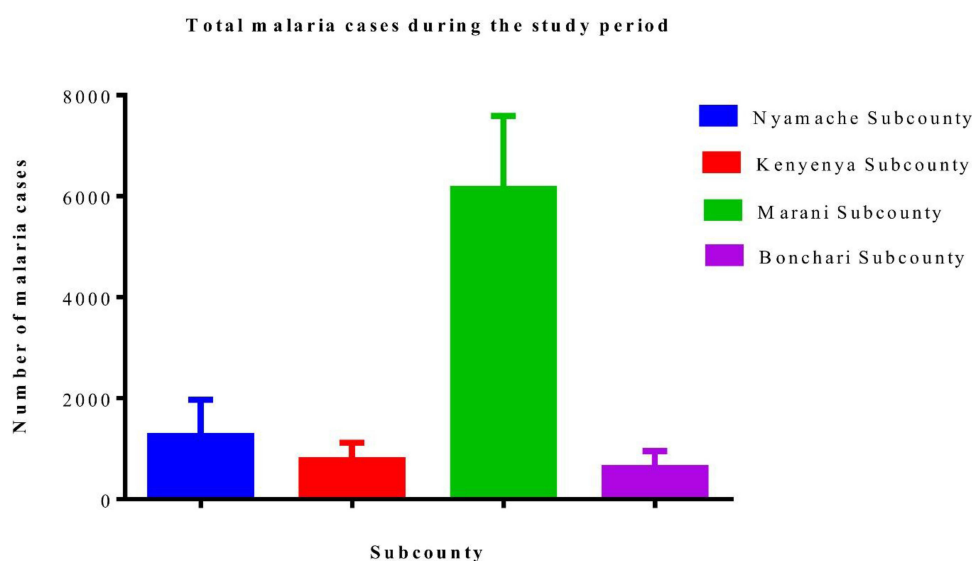

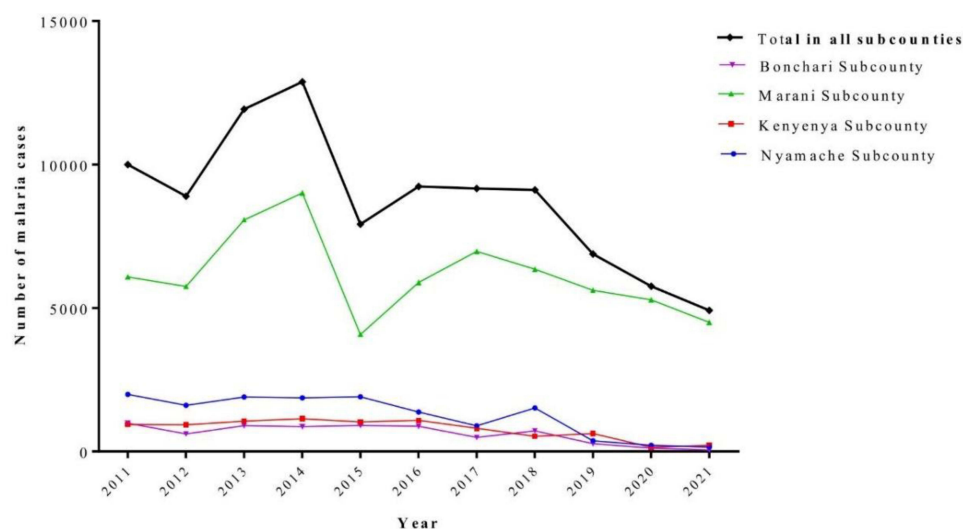**Figure 2** Showing total sub-county confirmed malaria cases.

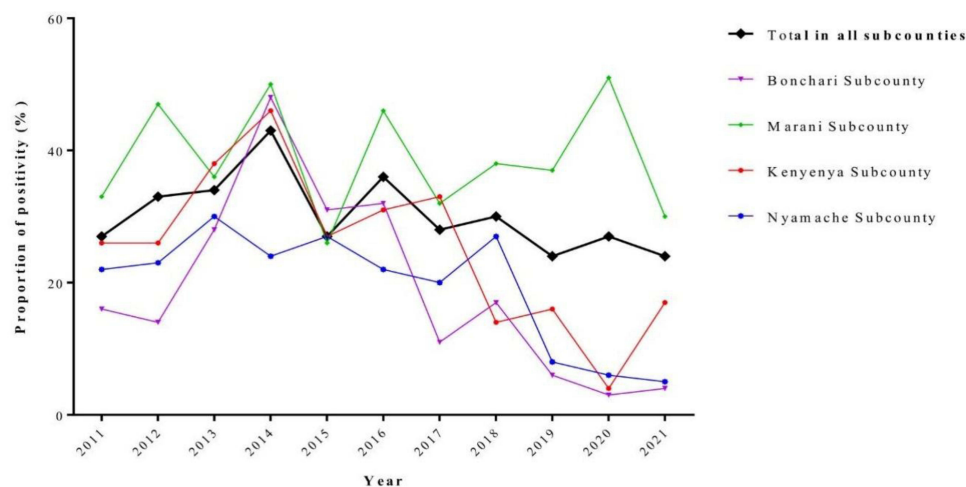**Figure 3** Showing annual temporal malaria trends.

Figure 4 Showing annual malaria sub-county positivity rates.

Annual Malaria Positivity Rate of Each Sub County

Marani Sub County recorded the highest positivity rate of 37.94%, followed by Kenyenya (24.4%), Bonchari (20.8%) and finally Nyamache (9.6%) (Figure 4).

Seasonal Variations of Malaria

Malaria cases fluctuated throughout the year. The months of August and April had the maximum malaria cases of 528 and 434 respectively. Malaria cases were recorded throughout all seasons, however there was an increase in cases between March–April and August–September across all years. There was a sharp reduction of all malaria cases between January–February and June–July across all years (Figure 5).

Discussions

Malaria has been reported previously all over the world with malaria trends varying from one geographical region to another due to different influential factors. Transmission dynamics are crucial for guiding on the proper area specific-interventions. Thus, the goal of this present study was to examine the retrospective temporal trends of malaria prevalence
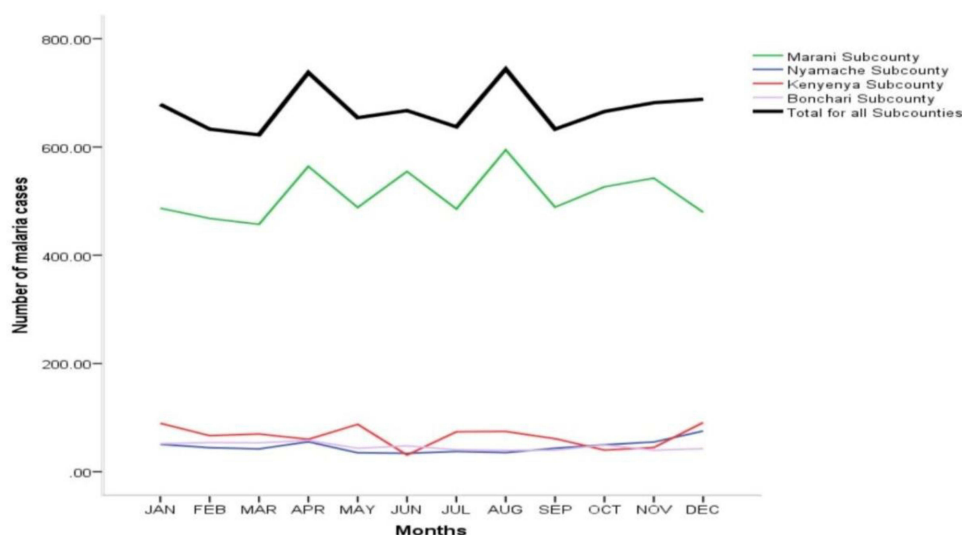
Figure 5 Showing the seasonal Malaria variations.

over the last 11 years in Kisii County, during the time when deployment of ACTs as the drug of choice for malaria treatment was high. Based on these findings, we hereby putatively affirms that Marani Sub County of Kisii County habours large burden of malaria cases, registering 37.94% of all confirmed cases reported. The high prevalence recorded in this sub county may be explained by the proximity with the malaria endemic areas such as Homa-bay County. This proximity may be encouraging the carriage of malaria parasites either by the use of vectors or through human movement. The higher malaria prevalence witnessed in Marani, compared to other Sub Counties may provide evidence of area specific target interventions.

Despite the high positive cases witnessed in Marani Sub County, still the confirmed cases were high compared to the Kenyan national prevalence. This is a worrying situation especially during this season of COVID-19 pandemic where malaria interventions have been compromised as a result of much concentration on COVID-19 pandemic containment. This current study is in agreement to a previous study conducted in different sites in Kenya which reported high malaria prevalence.[6]

Over the 11-year period, all of the sub counties recorded 36,946 patients whose malaria infection status was screened. However the recorded total patients suspected for malaria infection in this study might be lower than expected because most of the suspected cases practice home based self-medication without seeking proper diagnosis from health facilities, which is mediated by several factors such as long distance to health facility and waiting duration for getting services and attitudes toward patient displayed by health care workers. Consequently this study only included malaria cases confirmed by microscopy, thus missing other cases which might have been diagnosed by using malaria rapid diagnostic tests (mRDTs) which is sometimes a diagnostic method commonly used in most of the health facilities in Kenya. This study has confirmed the annual and monthly fluctuations of cases across all sub counties. Generally the current study has reported reduced malaria transmission. The reduced malaria transmission may lead to higher human susceptibility rate due to reduced acquired malaria immunity. In case of such scenario, more drug resistant *Plasmodium* parasites may evolve, hence compromising the gains of control strategies.

The fluctuation of malaria cases observed over the 11-year period of this study might be influenced by factors such as host factors, environmental factors and vector factors. Despite the fluctuation in malaria cases across years and study areas, there was a general increase in the disease prevalence rates from 2012 to 2015. The findings from this study is in agreement with a previous study conducted in Ethiopia which reported the highest malaria cases in 2014.[7] The proportion of confirmed malaria cases steadily decreased from 2018 and 2021. The fluctuations witnessed in this might be as a result of variations on the usage of the malaria interventions such as usage of mosquito nets, indoor residual spraying, chemophylaxis, proper diagnosis of cases and effective treatment of cases by using ACTs. The decline of malaria

cases coincides with the global trends which places Kenya among the countries which have realized substantial malaria interventions such as insecticide treated mosquito nets, indoor residual spraying and wide distribution of ACTs in all government owned health facilities. For instance, currently, the government of Kenya provides free treatment of malaria cases in all government managed health facilities. The artemisinin drug reduces the number of asexual *Plasmodium* parasites exposed to the second drug, thus reducing the chances of evolution of the resistant mutant clones in the population. Some reports suggest that the combination principle may also help in protecting the artemisinin drugs from being destroyed by the enzymes of parasites since they are not exposed alone to the drug. Combination therapies reduce the production of the sexual stages/gametocytes of *Plasmodium* as a result of the rapid reduction of the early stage sexual forms of the parasites.

The high prevalence rate witnessed in 2013–2014 might have been as a result of insufficient vector control interventions due to political unwillingness and bearing in mind that there was transition of health services from the national government to the county government during that specific period of 2013/2014, thus creating malaria control challenges. However the decline in malaria cases witnessed from 2018 to 2021 probably is due to the free malaria health care services provided in all government facilities in Kenya, which includes but not limited to; free diagnosis, free treatment and free distribution of mosquito nets, intermittent preventive treatment in pregnancy and environmental management. Moreover, the country in collaboration with the county government has attained the considerable extension of principal health care facilities that is generally improves the availability of the healthcare services by facilitating early case diagnosis and thus proper management.

This study reported that 35.45% confirmed cases were for those above 18 years and 14.09% of those between 0–5 years. This might be attributed to the activities carried by adults such as agriculture and staying outside shelters up to late night hours, hence serving as risk factors for malaria transmission. The witnessed lower prevalence of malaria in Individuals under 5 years of age might be attributed to their less likely exposure risk to infected mosquito bite owing to good awareness and practices of their care takers or parents Our findings are in support of a recent retrospective study conducted in Tanzania which reported that malaria positive cases were shifting to older age groups.[8] Moreover this study is in agreement with a study conducted in Ethiopia which reported 51.6% adult and 24.5% children confirmed cases.[9] More over another study conducted in Ethiopia also reported that people of age groups of ≥15 years were more prone to malaria infections with a prevalence rate of 60.4%, followed by those in 5–14 years old, and children under five with prevalence rate of 22.6% and 15.9% respectively (Alkadir et al, 2020). It has also been reported that the age prevalence trends observed in our study, where those aged 14 years and above recorded 44.5% of malaria cases, those between 5–14 years recorded 31.9% and those between 0 and 4 years old recording 23.6%.[10] A study conducted in Botswana also indicated a highest incidence rates among the age group > 5 yrs compared to those of the age group of >0–5 yrs.[11] This findings are also supported by a retrospective study conducted previously in Kenya using secondary data from Kenya malaria indicator survey, 2015 also reported same age prevalence witnessed in this current study, with the prevalence of malaria showing an upward trend in terms of age, with the highest prevalence among children aged 10–14 years. Those aged between 10–14 years had a prevalence of 10.22%, whereas those under the age of 5 years reported a prevalence of 4.83%.[12] Our findings are also consistent with previous study in Africa, where malaria prevalence was found to be higher among children aged 5–18 years.[13] In addition, studies conducted previously in Africa have emphasized the shift of malaria incidences to older age categories.[14–16] The study conducted in Zimbabwe revealed that malaria incidences were higher in the >5 age category (95%).[17] The same shift has been reported in Nigeria.[18] Tanzania.[19] Gambia.[20] and Botswana.[11] Studies conducted in Kenya Coast, a high malaria prevalent geographical area points has also pointed to the same trend of shift of malaria cases from younger to older ages.[21–23] Generally the shift in malaria cases from younger to older age is evident in the current study. As malaria cases reduces, older age groups are more susceptible to the disease due to insufficient earlier exposure, leading to reduced acquired immunity. Moreover, more usage of ITNs by young children compared to older age may explain the observed trend.

In contrast, findings from this present study are consistent with previous Global studies which have indicated that children under 5 years of age bears the greatest malaria burden since they have not developed immunity to malaria.[24–26] This group bears the largest malaria burden of approximately 61% of the total malaria deaths globally.[1]

This current study has indicated that gender was a predictor risk factor for malaria cases. The study reported 71.9% in the female and 28.1% in the male gender respectively. The findings from this study are in contrast to previous studies

conducted in Africa which have reported high prevalence of malaria cases in the male gender.[7,27,28] The observed high prevalence of malaria cases in the female gender is attributed to daily activities carried out among the female gender in Kisii County. Usually females are usually engaged in outdoor activities earlier in the morning and later in the night, this puts them at greater risk of contracting the disease.

Malaria incidence rates witnessed here confirmed the seasonal variations in relation to months. The months of August and April had the maximum malaria cases. Malaria cases emerged throughout all seasons, however there was increase in cases between March–April and August–September. There was sharp reduction between January–February and June–July. The months of March, April, August and September correspond with the start and completion of long rain season which runs from March to August each year. These long rains favors malaria transmission since it promotes the breeding and multiplication of malaria vectors. Moreover the months of January, February, June and July are dry in nature, hence discouraging the survival of malaria vectors. Our findings are in support of previous studies which have reported high malaria incidence during the rain seasons.[29–31]

Since this was a retrospective study depended on existing records, this study was faced with some limitations. The study did not classify the malaria cases by using clinical classification viz; asymptomatic, uncomplicated and severe malaria. Health facilities used during this study had a possibility of under reporting malaria cases as a considerable proportion of people might have not presented themselves at the health facilities for treatment of suspected cases due to confounding factors. Moreover, malaria cases might have been missed during stock outs of reagents.

Conclusions

Despite of the Kenyan government embracing malaria interventions with deployment of ACTs as the drug of choice for treatment of malaria cases, the study has demonstrated that malaria still remains a public health burden in the study area with high confirmed cases. This is an important signal that the area needs due malaria interventions attention. Therefore, health policymakers should strengthen evidence-based malaria control and prevention interventions to interfere with disease transmission and total malaria elimination in Kisii County.

Data Sharing Statement

Data in tables and figures used to support the findings of this study are included within the article. Raw materials used in this study can be produced from the corresponding author in request.

Acknowledgments

Author Contributions

This work was conducted in collaboration between all authors. All authors have made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data; took part in drafting the article and revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work.

Disclosure

All authors declare that there are no conflicts of interest existing in regard to this study and publication of the findings.

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