The RTS, S/AS01E Vaccine Uptake and Non-Compliance Risk to Malaria in Children 6-36 Months in Western Kenya

Irine Okanda[1]*, Erick Okuto[1], Emily Abuonji[1], Moses Sadia[1], Patrick Owili[3], Alice Lakati[2] and George Ayodo[1]

[1]Department of Public and Community Health, School of Health Sciences, Jaramogi Oginga Odinga University of Science and Technology, Bondo, Kenya; [2]Amref International University, Nairobi, Kenya, and [3]Africa Population and Health Research Center, Nairobi, Kenya.

***Corresponding author:** Irine Okanda. Email address: ireneokanda1@gmail.com

DOI: https://dx.doi.org/10.4314/ajhs.v36i5.9

Abstract

BACKGROUND

Malaria vaccine provides affordable intervention for malaria in children under 5 years of age. This vaccination is the first to show partial effectiveness in shielding children against malaria. Nonetheless, there remains a scarcity of data regarding the adoption of the vaccine and the likelihood of malaria infection due to non-adherence, which hampers the ability of stakeholders to determine appropriate actions for improving interventions. The study aimed to determine the uptake of the malaria vaccine and the risk of malaria infection due to non-compliance among children aged 6-36 months in Western Kenya.

MATERIALS AND METHODS

The study employed a quantitative cross-sectional design. Data was collected from 319 Caretakers of children 6-36 months in Muhoroni sub-county using ODK. A stratified random sampling method was employed for sample selection. Descriptive statistics and logistic regression were used, and data was analyzed using STATA.

RESULTS

The results showed poor uptake of the RTS, S malaria vaccine as follows 1st dose 72.10%, 2nd 66.68%, 3rd 59.40%, and 4th 31.35% respectively. 67.57% of study participants had a positive malaria result in the past 6 months. Children who had not received the recommended dose were 6 times more likely to be infected by malaria as compared to a fully vaccinated child (COR 5.87, 95% CI 2.25-15.31, P value=<0.001). Unvaccinated children were 3 times more likely to be infected by malaria infection in comparison to children partially vaccinated with a single dose (COR 2.72, 95% CI 1.26-5.88, P value =0.011). older infants 24-36 months were 7 times more likely to get malaria infection as compared to those aged 0-6 months (COR=7, 95%CI=0.09-2.73, P=0.03).

CONCLUSION AND RECOMMENDATIONS

The findings showed low utilization of the malaria vaccine, and non-compliance to the vaccine uptake increases the risk of infection. Age is a risk factor for malaria infection and vaccine uptake. Future efforts should focus on identifying and addressing barriers to malaria vaccine uptake and targeted interventions can be explored to improve the uptake of the 3rd and 4th doses of the malaria vaccine. There is a need for targeted interventions to improve malaria vaccine uptake.

Keywords. *Malaria Vaccine, Malaria Infection, Vaccine Compliance, Vaccine Non-Compliance.*

[***Afr. J.*** *Health Sci*. 2023 36 (5): 568-577]

Introduction

Globally in 2021, there were approximately 247 million cases of malaria in 84 malaria-endemic counties resulting in about 619000 malaria-related deaths(2). World Health Organization (WHO) African region had an estimated 234 million cases which resulted in 593000 deaths, this was estimated to be about 95% of all the global cases(1). Malaria-related deaths in children under the age of 5 were estimated to be 80% of all global deaths (3). In 2020, there were about 27 million cases of malaria in Kenya and 12,600 deaths were attributed to the disease (4). The *Plasmodium falciparum (Pf)* is the leading species causing severe infection resulting in more than 99% of overall malaria infections in the country and approximately 70% of the total population being at risk for malaria (5). In every 1000 live births, 84 die before attaining 5 years in Kenya with malaria being the primary cause of death in malaria endemic regions (6). In all outpatient consultation cases in Kenya, malaria accounts for 19% of all cases (6). In 2015, of all the malaria cases, malaria in children under the age of 5 was approximated to be 70% worldwide and 80% in Kenya (6).

Malaria case data from health facilities and entomology surveillance are basic in informing malaria control strategies in Kenya, they inform risk stratification based on data collected from the two activities (7). Kenya has 4 stratified epidemiological zones based on malaria endemicity (8), Lake and Coastal endemic zones, where malaria is holoendemic with transmission occurring throughout the year, Arid and Semiarid areas with seasonal transmission in the Southern and Northern parts, western highlands which are the malaria epidemic-prone zone with a short period of intense transmission during the rainy seasons and finally Central Kenya highland with a low malaria risk(7, 9). WHO recommends the use of varieties of malaria control tools targeting malaria Plasmodium parasites in humans through case management (CM), the mosquito vector through integrated vector control (IVC), and personal protection (PP) (11,5). Case management is the use of anti-malarial drugs to destroy malaria parasites from the human host to prevent transmission to the mosquito vector during blood meal this helps in preventing new malaria cases (6,11). Integrated Vector Control is the use of adult mosquito killing measures such as indoor adulticide sprays and environmental management to eliminate the mosquito breeding sites, thus lowering the population densities of malaria vectors (11,6). Personal protection measures include insecticide-treated nets(ITNs), indoor residual sprays (IRS), and window and door screens (11). There has been a significant improvement globally in controlling malaria between 2000-2015 with a 62% reduction in malaria-related mortality (12). Current malaria prevention measures in sub-Saharan Africa include chemoprevention in pregnant women and infants, vector control using ITN, and IRS (12). Despite these measures, malaria remains a major cause of mortality in this part of the world especially among children <5 years (7,6).

There have been efforts to develop malaria vaccines to address the huge burden of malaria, European Medicines Agency for the immunization of children against malaria approved the RTS, S/AS01 vaccine in 2015 (13). In April 2017, after several years of clinical trial and research, WHO declared RTS, S to be introduced in a cluster randomized design in some pilot parts of Kenya, Ghana, and Malawi(14). These three countries fall in the region with moderate to high malaria burden, the exercise was done through the National Expanded Programs on Immunization (14,15). In October 2021 WHO recommended the RTS, S malaria vaccine for widespread use on children in malaria-endemic zones of the comprehensive strategy for control of malaria (14). Mosquirix, RTS, S /AS01, or simply RTS, S malaria vaccine is the first vaccine proven to offer partial

protection against malaria (16). This is currently the most clinically advanced malaria vaccine recommended by WHO (17,18). RTS, S /AS01E (GlaxoSmithKline (GSK), Belgium) is a pre-erythrocyte Plasmodium falciparum malaria vaccine developed for routine immunization of young children living in malaria-endemic countries (16). The administration of 4 doses of RTS, S/AS01E to children at age 6 months (1st dose), 7 months (2nd dose), 9 months (3rd dose) and 24(4th dose) reduced clinical malaria by 39%(19), and severe malaria by 29% over 4 years of follow-up as seen in phase III trial (20,21). Additional information showed that vaccination with RTS, S /AS01E was related to a reduction in hospitalizations due to malaria, severe anaemia, and the need for blood transfusion (20, 21). The authority to use RTS, S/AS01E in Kenya was granted on 13 September 2019, and in October 2019 the country rolled out malaria vaccine in some parts of the 8 counties namely Kisumu, Homabay, Migori, Siaya, Vihiga, Kakamega, Bungoma and Busia in western Kenya (21). Studies done on uptake have shown a reduced uptake of RTS, S from the first dose to the 3rd dose(16), particularly in Ghana. A study conducted in 2021 revealed that the uptake of the first dose at 6 months was 94.1%, which decreased to 90.6% for the second dose at 7 months and further declined to 78.1% for the third dose at 9 months. No data was collected for the fourth dose. While the uptake of RTS, S 1 and RTS, S 2 doses met the WHO target of 90%, the uptake of RTS, S 3 fell short. Specifically, the uptake of all RTS, S doses did not achieve the WHO's 90% target (16). Kenya adopted the Global Technical Strategy for Malaria 2016-2030 developed to fasten progress on malaria elimination (10). Global technical strategy for malaria (2016-2030) targets to reduce malaria incidence cases worldwide by at least 90% and to eliminate malaria by 2030 in at least 25 countries, global reductions in disease burden of at least 40% and 75% by 2020 and 2025, and to eliminate malaria by countries in at least 10 in 2020 and 20 in 2025 (10).

To achieve the Global Technical Strategy for Malaria (22), there was a need to identify the current occurrence of malaria infection to inform various interventions towards achieving the same. To achieve the WHO target of 90% uptake of RTS, S doses, there was the need to assess the uptake of the vaccine to inform various decisions on boosting the poor uptake as evidenced by various studies. Muhoroni sub-county in western Kenya is a rural with high Malaria transmission compared to urban settings, this might be due to spatial-temporal variations resulting in a high number of vectors(23). In addition, malaria transmission is determined by knowledge, attitude, socioeconomic factors, and access to healthcare services and preventive interventions (23). This study assessed the uptake of RTS, S and its association with malaria infection in the Muhoroni Sub-County, Kisumu County.

Materials and methods

Study area

This study was carried out in the Muhoroni sub-county in Kisumu County. The sub-county has 41 community units and the major economic activities of the residents are trade and farming. Malaria is holoendemic in this area and transmission occurs throughout the year(24).

Study population

The study population was caretakers of children aged 6-36 months in the Muhoroni sub-county. The information for eligible participants was obtained from the registry of community health assistants with all the data for children under 5 in the community units. The data is collected monthly by community health volunteers (CHVs). Demographic information of the caretakers was collected together with social, economic, and cultural information. All caretakers of children 6-36 months in all the 41 community units in the sub-county were eligible for the study, 319 were selected and all the

caretakers who didn't consent were excluded.

Study design

This was a cross-sectional study employing a quantitative approach. A structured questionnaire was used to collect data on malaria vaccine uptake and information on malaria infection in the last 6 months was abstracted from the Mother Child Health (MCH) booklet.

Sample size determination

The study sample was calculated using the Cochran formula. The formula $n = \frac{Z^2(p)(q)}{e^2}$ Where n=Sample size Z=Standard normal variant for margin of error P=proportion of malaria prevalence q=1-p e=margin of error. Using a malaria proportion of 27%(24) margin of error of 5% and a 5% adjustment for non-response, the sample size was determined as 319.

Sampling

Sampling was done using the Muhoroni sub-county community health strategy data for those under 5, the data was updated on January 2023 by CHVs who handed them over to CHAs. The children's 6-36 months were mapped in their respective households in January 2023. Children were stratified as per the community unit and simple random sampling was used to select 319 children from all the strata based on the number of eligible children. Caretakers of these children were then visited in their households with the guide of Community Health Volunteers to be enrolled in the study.

Data collection procedures

The structured questionnaire was administered to eligible caretakers in February 2023. Uptake of RTS, S vaccine information was abstracted from the Mother Child Health booklet. In cases where the booklet was not available, maternal recall was used. Occurrence of malaria infections was obtained from a review of hospital books for malaria diagnosis and medication in the past 6 months. Data was collected at the household level.

Validity and reliability

Questionnaires were distributed to malaria experts and statisticians for review and critique. Their professional feedback and subsequent revisions were crucial for ensuring the content validity of the data collection instrument. Before commencing the real data-collection process, a test pretest on 32 respondents (10% of the sample) was used to test the reliability of the data-collection tool. The findings indicated a high reliability coefficient of 0.821. Other challenges during the pretesting sessions were thoroughly examined and addressed.

Data management

Before data collection, a 3-day training on the purpose, objectives, and goal of the study, community entry, creating rapport, study procedures, collection of quality data and adherence to ethics in every activity being done for 5 research assistants. Open Data Kit (ODK) software was used to enter data in soft copy this aided data validation and quality check at the entry point. A routine sports check was done during the data collection to ensure research assistants were following the right procedure to collect high-quality data.

Data analysis

Descriptive statistics were used to describe the uptake of the vaccine and episodes of malaria infections. The same was used to describe caregiver sociodemographic, socioeconomic, education status, marital status, religious/cultural information, knowledge and attitude on the vaccine, and distance to the nearest facility. Inferential statistics, in particular, logistic regression and Chi-square were used to establish the association of vaccines with the occurrence of malaria infections. STATA Version 16 was used for analysis.

Ethical considerations

Approval to conduct this study was obtained from both Jaramogi Oginga Odinga University of Science and Technology Ethics

Review Committee (JOOUST/DVC-RIO/ERC/E3) and the National Commission for Science, Technology & Innovation (529996). Permission to conduct the study in Muhoroni was sought from the Ministry of Health in Kisumu County. An informed consent process was administered and the consent forms were signed by willing volunteers. The confidentiality and anonymity of participants were ensured by anonymisation using study codes. All tablets and laptops where study information was password protected and accessible to only the authorised personnel.

Results

Socio-demographic characteristics

Of the 319 caretakers recruited in the study; the majority were female 93.10%, married 86.21%, had primary education 58.93% and the majority were Christians 99.69%. About 50% were aged between 17-29 years and 58% of the children were aged between 24-26 months. Children were grouped into 4 age brackets eligible for the 1st (0-6 months),2nd (7-8 months)3rd (9-23 months), and 4th (24-36 months) dose. See (Table 1).

Distribution of malaria occurrence by sociodemographic characteristics

A Chi-square test of association was done to test the relationship between sociodemographic factors and malaria. Only the child's age showed some statistical significance with a p-value of <0.001.

Over the 6 months of the study, malaria infection was as follows: 33% of children aged 0-6 months tested positive for malaria, while none of those aged 7-8 months were positive. Among children aged 9-23 months, 61% tested positive, and for those aged 24-36 months, the rate increased to 78%. These findings indicate a high prevalence of malaria in the area, with infection rates directly proportional to age as shown in Tables 2 and 3.

Table 1:

Sociodemographic Factors of the Participants

Caretakers			
Category	**Group**	**Frequency**	**%**
Age	>17 to <=29yrs	160	50.16
	>=30 to<=42yrs	127	39.81
	>=43 to <=55yrs	23	7.21
	>=56 to <=68yrs	5	1.57
	>68yrs	4	1.25
Sex	Female	297	93.10
	Male	22	6.90
Marital status	In marriage	275	86.21
	Not in marriage	44	13.79
Education	None	5	1.57
	Primary	188	58.93
	Secondary	104	32.60
	Tertiary	22	6.90
Religion	Christian	318	99.69
	Muslim	1	0.31
Children			
Age in months	0-6	9	2.82
	7-8	12	3.76
	9-23	113	35.42
	24-36	185	57.99
Sex	Female	161	50.47
	Male	158	49.53

Association of age with malaria infection

Bivariate logistic regression was done between malaria infection and the child's age, the result showed that a child in the age category of 9-23 is three times more likely to get malaria infection than a child in the age category of 0-6 months (COR 3.12, 95%CI 0.53-18.32, P=0.21). A child in the age category of 24-36 months is seven times more likely to get malaria infection as compared to a child in the age category of 0- 6 months (COR 7.00,95%CI 0.09-2.73, P=0.03). See Tables 2 and 3.

Uptake of the RTS, S vaccine

The average uptake was 57% and the uptake was reducing as children aged; the 1st, 2nd, 3rd and 4th doses had 72.10%, 66.68%, 59.40% and 31.35% respectively. The first dose is given when a child is in the 6th month, the second at the 7th month, the third at the 9th month and the last at the 24th month. The findings here show that the vaccine uptake reduces as the child's age increases as shown in figure 1.

Association of non-compliance to the RTS, S vaccine with malaria infection

Bivariate analysis was conducted to assess the association between RTS, S uptake and malaria infection. The results indicated that a vaccinated child who had not received the recommended full dose was 6 times more likely to get malaria infection as compared to a child who received the full dosage (COR 5.87, 95% CI 2.25-15.31). A child who had not received any malaria vaccine was 3 times more likely to contract a malaria infection compared to a child who received at least one dose of the vaccine but did not complete the recommended dosage (COR 2.72, 95% CI 1.26-5.88).

Table 2:
Distribution of Malaria Occurrence by Sociodemographic Characteristics.

Test results	C	Prevalence	N	%	95% CI	P value
The child's age in months	0-6	2	6	33.33	7.14-76.47	**<0.001**
	7-8	0	7	0.00	0.00	
	9-23	39	64	60.94	48.38-72.20	
	24-36	84	108	77.78	68.87-84.70	
Sex of the child	Female	61	89	68.54	58.07-77.41	0.79
	Male	64	96	66.67	56.56-75.45	
Caretaker's marital status	In marriage	107	160	66.88	59.15-73.79	0.61
	Not in marriage	18	25	72	51.19-86.31	
Age of the caretaker	>17 to <=29yrs	6	11	54.55	25.53-80.77	0.45
	>=30 to<=42yrs	107	160	66.88	59.15-73.79	
	>=43 to <=55yrs	9	10	90	50.13-98.77	
	>=56 to <=68yrs	2	3	66.67	9.40-97.47	
	>68yrs	1	1	100	.	
Education of the caregiver	None	4	4	100	.	0.33
	Primary	77	115	66.96	57.77-75.01	
	Secondary	39	56	69.64	56.26-80.36	
	tertiary	5	10	50	21.16-78.84	

Table 3:
Association of Age with Malaria Infection.

Test results	Crude Odds ratio	P. value	95%CI
Age of the child			
9_23	3.12	0.21	.53 18.32
24_36	7	0.03	.09 2.73

This shows that the malaria vaccine has a positive association with malaria infection as more infection is seen in children who did not comply with the full recommended dose. See Table 3.

Discussion

This study reported low uptake of RTS, S malaria vaccine, in particular 3rd and 4th doses. We further report that those who have not received the recommended dosage are at increased risk of malaria infection. These study findings are in agreement with a study done in 2021 which assessed factors associated with malaria vaccine uptake in Sunyani Municipality in Ghana, the study showed reduced uptake of RTS, S with subsequent doses, and there was a downward trend from the 1st,2nd and 3rd, uptake as 94.1%,90.6% and 78.1%, respectively. The uptake of the vaccine was reduced as doses increased, no data was collected on the 4th dose uptake (16).

Findings from this study showed that there is a high prevalence of malaria infection which increases with the age of children. This is in agreement with Kenya Malaria Indicator Survey (KMIS 2020) which quoted that Malaria prevalence according to microscopy generally increases with age (9).

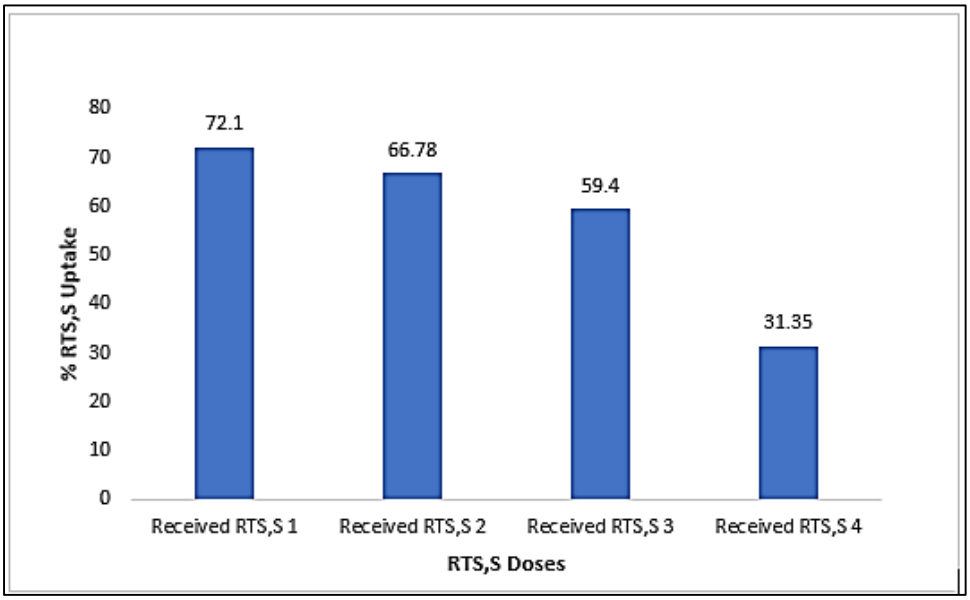

Figure 1:
Uptake of the RTS, S Vaccine in doses

Table:
Association of Uptake of RTS, S vaccine with Malaria Infection

Test results	Cat	Prev	N	% Prev	95%CI	P value	Crude Odds ratio	P value	95%CI
Receive recommended RTS, S dose	Yes	45	89	50.56	40.17-60.90	<0.001	Ref		
	No	36	42	85.71	71.33-93.54		5.87	<0.001	2.25-15.31
Receive at least RTS, S dose	Yes	81	131	61.83	53.15-69.82	0.009	Ref		
	No	44	54	81.48	68.65-89.84		2.72	0.011	1.26-5.88

This finding is consistent with a Ghanaian study on Malaria and anaemia among children in two communities of Kumasi, which revealed that one of the risks for malaria infection was an increase in age(25).

our findings also mirror a study carried out in Nigeria looking at the Prevalence and risk of malaria, anaemia and malnutrition among children in IDP camps in Edo State, Nigeria. The study reported an increased risk of malaria increase with the increase in age of children(26). A study which was looking at the Relationship Between Malaria Status in Under-five Children and Some Household Demographic, Socioeconomic and Environmental Factors Associated with the Disease in Sierra Leone also quoted age as having an association with malaria infection, this is in line with this study's findings(27).

Our findings indicate that the RTS, S vaccine has been effective in decreasing malaria infection rates. Children who did not receive the recommended full dose of the vaccine showed a higher prevalence of positive malaria cases compared to those who received the complete dose. These results align with those observed during the pilot introduction of the vaccine by the World Health Organization (WHO) in Kenya, Ghana, and Malawi. During this pilot, there was a significant decrease in severe malaria cases, as evidenced by a reduction in child hospitalizations and fatalities. (20).

A study done in 2014 that looked at the acceptance of a malaria vaccine by caregivers of sick children in Kenya, found that the reason for low malaria vaccine uptake was a lack of access to vaccine information(18). Another study done on current challenges on proposed solutions to the effective implementation of the RTS, S/ AS01 Malaria Vaccine Program in sub-Saharan Africa in 2018 showed that the main challenges for low uptake of RTS, S were inadequate community engagement due to lack of information about the vaccine and fear of the vaccine's side effects (12). However, this study did not look at the reasons for the low uptake of the malaria vaccines.

This study is unique in that it has shown the level of vaccine uptake per age category in the community. Many studies have shown low uptake of RTS, S vaccine but little has been shown on the level of vaccine compliance based on the age eligibility criteria and the effect the compliance has on malaria infection. Many studies have been done on the uptake of RTS, S vaccines especially on 1st, 2nd and 3rd vaccines but very little has been studied on the 4th uptake. This study looked at the RTS, S uptake from the 1st up to the 4th dose given at two years.

Limitations

This study was done in a single location (Muhoroni sub-county) and hence may not represent the real situation in other parts of western Kenya. This study measured the occurrence of malaria infection for the past 6 months which is a wide range. This may also cause some level of bias for the study participants who lacked medical records and responses based on memory. There is a likelihood of a recall bias. Some age categories had very small sample sizes i.e. 0-6 and 7-8 months with 6 and 7 children respectively, therefore these results might not be representative of this age category in a larger population.

Conclusion

We conclude that there is poor uptake of RTS, S doses, especially the 3rd and 4th doses. Malaria infection in children is high in the Muhoroni sub-county. Full-dose vaccine uptake has a positive impact on malaria prevention and therefore should be adhered to. Age has an association with malaria infection as well as RTS, S uptake. We recommend proper partnership and support to improve RTS, S uptake and to reduce malaria infection in this area. Studies should come up with better ways of improving the utilization of interventions as a child's age increases. Future efforts should focus on

identifying and addressing barriers to malaria vaccine uptake and targeted interventions should be explored to improve the uptake of the 3rd and 4th doses of the malaria vaccine.

Acknowledgements. We are grateful to the European and Developing Country Clinical Trials Partnership (EDCTP) for funding this research. Special thanks to Jaramogi Oginga Odinga University of Science and Technology School of Health Sciences Department of Public and Community Health for their support during this study. We acknowledge the Ministry of Health Kisumu County and Muhoroni sub-county for their assistance during the study, we also thank the research assistants who took part in data collection. This study was also made possible through the help of community health volunteers who introduced us to the community. Lastly, the authors thank all caretakers from the Muhoroni sub-county who actively participated in the study.

Source of funding. This research was supported by the Capacity Development of Applied Epidemiologists in the Eastern Africa Region (CDAE). This project is part of the European and Developing Countries Clinical Trials Partnership II (EDCTP2) Programme supported by the European Union. CDAE is jointly implemented by the African Population and Health Research Center (APHRC), the Amref International University (AMIU) and the Jaramogi Oginga Odinga University of Science and Technology (JOOUST) and funded by the EDCTP2 (grant: CSA2020E-3139).

Conflict of interest. The authors declared no conflict of interest.

References

1. World Malaria Report 2022. 2022.
2. **Oshagbemi OA, Lopez-Romero P, Winnips C, Cermak KR, Su G, Aubrun E.** Estimated distribution of malaria cases among children in sub-Saharan Africa by specified age categories using data from the Global Burden of Diseases 2019. Malar J [Internet]. 2023;22(1):1–7. Available from: https://doi.org/10.1186/s12936-023-04811-z
3. **Hamilton A, Haghpanah F, Hasso-Agopsowicz M, Frost I, Lin G, Schueller E, *et al*.** Modelling of malaria vaccine effectiveness on disease burden and drug resistance in 42 African countries. Commun Med. 2023;3(1):1–10.
4. **Ondeto BM, Wang X, Atieli H, Zhong D, Zhou G, Lee MC, *et al*.** A prospective cohort study of Plasmodium falciparum malaria in three sites of Western Kenya. Parasites and Vectors [Internet]. 2022;15(1):1–14. Available from: https://doi.org/10.1186/s13071-022-05503-4
5. **President US, Initiative M.** President ' S Malaria Initiative Kenya Malaria Operational Plan FY 2019. 2019;
6. **Okoyo C, Githinji E, Muia RW, Masaku J, Mwai J, Nyandieka L, *et al*.** Assessment of malaria infection among pregnant women and children below five years of age attending rural health facilities of Kenya: A cross-sectional survey in two counties of Kenya. PLoS One [Internet]. 2021;16(9 September):1–19. Available from: http://dx.doi.org/10.1371/journal.pone.0257276
7. G**ithure JI, Yewhalaw D, Atieli H, Hemming-Schroeder E, Lee MC, Wang X, *et al*.** Enhancing Malaria Research, Surveillance, and Control in Endemic Areas of Kenya and Ethiopia. Am J Trop Med Hyg. 2022;107(Suppl 4):14–20.
8. **Elnour Z, Grethe H, Siddig K, Munga S.** Malaria control and elimination in Kenya: economy-wide benefits and regional disparities. Malar J [Internet]. 2023;22(1):1–19. Available from: https://doi.org/10.1186/s12936-023-04505-6
9. **Division of National Malaria Programme (DNMP) [Kenya]**, ICF. Kenya Malaria Indicator Survey 2020. Minist Heal. 2021;(September):39.
10. World Health Organization. Global technical strategy for malaria 2016–2030. World Heal Organ [Internet]. 2016;1–35. Available from: https://apps.who.int/iris/bitstream/handle/10665/186671/9789243564999_spa.pdf?sequence=1
11. **Okech BA, Mwobobia IK, Kamau A, Muiruri S, Mutiso N, Nyambura J, *et al*.** Use of integrated malaria management

reduces malaria in Kenya. PLoS One. 2008;3(12):1–9.
12. **Dimala CA, Kika BT, Kadia BM, Blencowe H**. Current challenges and proposed solutions to the effective implementation of the RTS, S/ AS01 Malaria Vaccine Program in sub-Saharan Africa: A systematic review. PLoS One. 2018;13(12):1–11.
13. **Yeboah D, Owusu-Marfo J, Agyeman YN.** Predictors of malaria vaccine uptake among children 6–24 months in the Kassena Nankana Municipality in the Upper East Region of Ghana. Malar J [Internet]. 2022;21(1):1–10. Available from: https://doi.org/10.1186/s12936-022-04378-1
14. **Zavala F**. RTS, S: the first malaria vaccine. J Clin Invest. 2022;132(1).
15. **Adeniji E, Asante KP, Boahen O, Compaor G, Coulibaly B, Kaali S, *et al*.** Estimating Annual Fluctuations in Malaria Transmission Intensity and the Use of Malaria Control Interventions in Five Sub-Saharan African Countries. 2020;103(5):1883–92.
16. **Tabiri D, Ouédraogo JCRP, Nortey PA.** Factors associated with malaria vaccine uptake in Sunyani Municipality, Ghana. Malar J [Internet]. 2021;20(1):1–18. Available from: https://doi.org/10.1186/s12936-021-03857-1
17. **Samuels AM, Ansong D, Kariuki SK, Adjei S, Bollaerts A, Ockenhouse C, *et al*.** Efficacy of RTS, S/AS01E malaria vaccine administered according to different full, fractional, and delayed third or early fourth dose regimens in children aged 5–17 months in Ghana and Kenya: an open-label, phase 2b, randomised controlled trial. Lancet Infect Dis. 2022;22(9):1329–42.
18. **Ojakaa DI, Jarvis JD, Matilu MI, Thiam S.** Acceptance of a malaria vaccine by caregivers of sick children in Kenya. Malar J. 2014;13(1):1–12.
19. **Praet N, Asante KP, Bozonnat MC, Akité EJ.** Assessing the safety, impact and effectiveness of RTS, S / AS01 E malaria vaccine following its introduction in three sub-Saharan African countries : methodological approaches and study set-up. Malar J. 2022;1–12.
20. **Narain K, Rackimuthu S, Nawaz FA, Okonji OC, Ashworth H, Du Plessis SS, *et al*.** Strategies for malaria vaccination during the COVID-19 pandemic in African countries. Bull World Health Organ. 2022;100(10):582-582A.
21. **Praet N, Asante KP, Bozonnat MC, Akité EJ, Ansah PO, Baril L, *et al*.** Assessing the safety, impact and effectiveness of RTS, S/AS01E malaria vaccine following its introduction in three sub-Saharan African countries: methodological approaches and study set-up. Malar J [Internet]. 2022;21(1):1–12. Available from: https://doi.org/10.1186/s12936-022-04144-3
22. **Patouillard E, Griffin J, Bhatt S, Ghani A, Cibulskis R.** Global investment targets for malaria control and elimination between 2016 and 2030. BMJ Glob Heal. 2017;2(2):1–11.
23. **Sultana M, Sheikh N, Mahumud RA, Jahir T, Islam Z, Sarker AR.** Prevalence and associated determinants of malaria parasites among Kenyan children. Trop Med Health. 2017;45(1):1–9.
24. Kenya Malaria Strategy 2019-2023. Kenya malaria strategy.
25. **Ronald LA, Kenny SL, Klinkenberg E, Akoto AO, Boakye I, Barnish G, *et al*.** Malaria and anaemia among children in two communities of Kumasi, Ghana: A cross-sectional survey. Malar J. 2006;5:1–8.
26. **Ajakaye OG, Ibukunoluwa MR.** Prevalence and risk of malaria, anaemia and malnutrition among children in IDPs camp in Edo State, Nigeria. Parasite Epidemiol Control [Internet]. 2020;8:e00127. Available from: https://doi.org/10.1016/j.parepi.2019.e00127
27. **Bah MS.** The Relationship Between Malaria Status in Under-five Children and Some Household Demographic, Socioeconomic and Environmental Factors Associated with the Disease in Sierra Leone. 2020;1–40. Available from: https://doi.org/10.57709/17625877