

RTS, S Malaria Vaccine Uptake and Geographical Disparities among Caregivers in Kisumu County, Kenya: A Cross-Sectional Analysis of Dose Completion (2021–2025)

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ABSTRACT

Malaria remains a leading cause of childhood morbidity and mortality in sub-Saharan Africa. The integration of the RTS, S malaria vaccine into routine immunization schedules represents a milestone in malaria control, but achieving complete and equitable vaccination remains challenging. This study assessed dose-specific uptake and completion of the four-dose RTS, S malaria vaccine schedule among caregivers of children aged 24–36 months in urban and rural healthcare catchment areas of Kisumu County, Kenya. The study used a cross-sectional caregiver survey, with vaccination histories covering children vaccinated during the 2021–2025 implementation period. Thus, the 2021–2025 period describes the vaccination histories represented in the sample and does not constitute a longitudinal follow-up of the same caregivers or children. A sample of 260 eligible caregivers was assessed using child immunization cards and, where documentation was unavailable, structured caregiver recall. Vaccine uptake was operationalized at three levels: dose-specific receipt (Doses 1–4), partial uptake (receipt of 1–3 doses without completion), and full uptake/completion (receipt of all four doses). No uptake was defined as receipt of zero doses. Timeliness of doses was not independently assessed because the available data did not provide a sufficiently documented vaccination date for each dose. Pearson's Chi-Square test was used to examine the association between completion category and geographical classification (urban/rural). Dose 1 uptake was 100.0%, Dose 2 95.8%, Dose 3 80.7%, and Dose 4 49.8%. Overall, 49.6% of children had completed all four doses, 50.0% had partial uptake, and 0.4% had received no dose. Full uptake was higher among urban caregivers (54.8%) than rural caregivers (34.9%), and the observed association between geographical classification and uptake category was statistically significant ($\chi^2 = 9.678$, $df = 2$, $p = 0.008$). The findings demonstrate substantial attrition across the vaccination schedule, particularly before the fourth dose. The observed urban–rural difference should be interpreted as an association rather than a causal effect because the study did not directly measure all facility-, household-, socioeconomic-, supply-, distance-, awareness-, and implementation-level factors that may contribute to geographical variation.

Keywords: Vaccination, immunization, RTS, S malaria vaccine, uptake, dose completion, geographical disparities, caregivers

INTRODUCTION

Malaria is an entirely preventable and treatable disease, yet it continues to exert a devastating disease burden on children under-five years of age in endemic regions such as western Kenya (WHO, 2024; World Bank, 2021; Kolawole, et al. 2023; Oladipo, et al., 2022). In response, global public health bodies have deployed multi-pronged intervention strategies, ranging from vector control (long-lasting insecticidal nets) to seasonal chemo-prevention. The rollout of the RTS, S/AS01 malaria vaccine under the WHO Framework represents a landmark biomedical strategy aimed at reducing severe malaria cases and childhood mortality (WHO, 2021;

UNICEF, 2021).

The operational effectiveness of a vaccination programme depends not only on initial acceptance but also on receipt of subsequent doses and equitable access across geographical settings. The present study therefore distinguishes between dose-specific uptake and completion of the recommended four-dose regimen. For this manuscript, vaccine uptake is operationally defined as receipt of a specified RTS,S dose; overall uptake is categorized as no uptake (0 doses), partial uptake (1–3 doses), or full uptake/completion (all four doses). Completion refers specifically to receipt of all four doses. Timeliness is not treated as a separate outcome because the available study data, as described below, were not designed to establish whether each dose was received within the recommended age window.

The WHO-recommended four-dose regimen is scheduled between approximately 6 and 24 months of age: Dose 1 at 6 months, Dose 2 at 7 months, Dose 3 at 9 months, and Dose 4 at 24 months (WHO, 2021; Maamor, et al., 2024; Price, 2023). The extended interval before the fourth dose may create opportunities for loss to follow-up and missed vaccination.

Kisumu County, a high-endemic malaria zone in western Kenya, provides a relevant setting for examining dose-specific vaccination coverage and geographical variation. The geographical unit examined in this study is the urban versus rural healthcare catchment classification of the sampled caregivers; the study does not attempt to estimate disparities at county, sub-county, ward, facility, or community level beyond this classification.

The study aimed to: (i) describe receipt of each of the four RTS, S vaccine doses among caregivers of eligible children aged 24–36 months; (ii) quantify partial and full regimen completion; and (iii) determine whether completion category was associated with the urban/rural geographical classification of the sampled caregivers. The analysis is cross-sectional. Although vaccination histories relate to the 2021–2025 period, the study does not follow the same children prospectively over that period and therefore does not estimate uptake dynamics or temporal trends.

RESEARCH METHODOLOGY

Study Design, Setting and Population

This study employed a cross-sectional survey design in Kisumu County, Kenya. The sampled caregivers reported vaccination histories for children aged 24–36 months whose vaccination experiences fell within the 2021–2025 period. The reference to 2021–2025 therefore describes the period represented by the vaccination histories in the sample, rather than a longitudinal observation period. The study targeted caregivers with children aged 24–36 months because children in this age range would ordinarily have had an opportunity to receive all four doses of the RTS,S vaccine schedule.

The geographical unit of analysis was the urban versus rural healthcare catchment classification assigned to the sampled caregiver/child. The study did not conduct a sub-county, ward, facility-level, community-level, or spatial GIS analysis. Consequently, the findings should be interpreted as an urban–rural comparison within the sampled population rather than as a comprehensive county-wide spatial disparity analysis.

Sampling and Eligibility

A total sample of 260 caregivers who demonstrated willingness to vaccinate their children was evaluated. In households with multiple children within the 24–36-month window, data were systematically gathered on the youngest child. Most primary respondents were mothers, aligning with local socio-cultural norms surrounding child health tasks (Table 1).

Data Collection and Verification

Vaccination status was primarily verified using official child hospital immunization cards. Where

documentation was unavailable, structured caregiver recall was applied. The principal outcome was vaccination uptake/completion, operationalized as follows:

- a) Dose-specific uptake: receipt of Dose 1, Dose 2, Dose 3, or Dose 4;
- b) No uptake: receipt of zero RTS, S doses;
- c) Partial uptake: receipt of one to three doses, without completion of the four-dose schedule; and
- d) Full uptake/completion: receipt of all four RTS, S doses.

These definitions distinguish initiation and dose-specific coverage from completion of the full regimen. Timeliness of vaccination was not included as a separate outcome because the manuscript's available data are reported primarily as whether each dose was received and do not provide sufficient dose-specific dates to establish adherence to the recommended timing.

Geographical classification was defined as urban versus rural healthcare catchment area. The questionnaire also captured respondents' perceptions of ease of access to malaria immunization services. However, the study did not collect or quantitatively model all potential determinants of geographical disparities, including objective travel distance, facility density, vaccine stock records, household socioeconomic status, vaccine supply continuity, or community-level awareness. These factors are therefore considered possible explanatory factors rather than variables for which causal effects are estimated.

Statistical Analysis

Descriptive statistics (frequencies and percentages) summarized demographic characteristics, dose-specific uptake, overall completion categories, and reported access perceptions. To examine the association between vaccination completion category and geographical classification, a Pearson's Chi-Square test of independence was performed at the stated significance level of $\alpha = 0.05$.

The analysis was designed to identify an association between the categorical variables, not to establish causation. Because the data are cross-sectional and the geographical classification is binary, the analysis does not estimate temporal change or causal effects of rural residence. The manuscript therefore reports the results as geographical differences/associations rather than as explanations of why the differences occur.

No multivariable regression or clustering-adjusted model was undertaken in the supplied analysis. Accordingly, the manuscript does not claim that caregiver characteristics alone explain geographical disparities, and the observed urban–rural association should be interpreted in light of unmeasured household, health-system, access, supply, socioeconomic, and implementation factors.

RESULTS

Those respondents with two or more children were asked to provide information on the uptake of vaccine based on the youngest of the children. Thus, the study considered the 260 sampled caregivers as legible for determination of the level of uptake of malaria vaccine covering the recommended dosage for their children under-five years of age. The distribution of respondents with 1, 2 or 3 children was as shown in Table 1 below

Table 1: Number of Children between 24 and 36 Months

No of Children per Respondent	Frequency	Percent
1	207	79.6

2	52	20.0
3	1	0.4
Total	260	100.0

Those respondents with two or more children were asked to provide information on the uptake of vaccine based on the youngest of the children. Thus, the study considered the 260 sampled caregivers as legible for determination of the level of uptake of malaria vaccine covering the recommended dosage for their children under-five years of age.

Table 2: Adherence to Malaria Vaccine Regimen among Sampled Caregivers

Child received dosage	1 st dose (6 months)	2 nd dose (7 months)	3 rd dose (9 months)	4 th dose (24 months)
Yes (%)	100	95.8	80.7	49.8
No (%)	0	4.2	19.3	50.2
Total	100	100	100	100

Information in Table 2 indicates that Doses 1 and 2 successfully exceeded the WHO 90% coverage benchmark. However, coverage dropped below acceptable targets at Dose 3 (80.7%) and suffered a precipitous decline at Dose 4 (49.8%), where less than half of eligible children completed the dose. This suggests that only the uptake of the first dose at 6 months and the second dose at 7 months of the malaria vaccine met the WHO recommended coverage target standards of 90% (WHO, 2021).

The study summarized and decomposed the levels of uptake of malaria vaccine for the 260 sampled caregivers who expressed willingness to vaccinate. The uptake of the malaria vaccine was measured in three levels using key metrics calculated as the proportion of eligible children receiving each dose namely no uptake (no dose received), partial uptake (received one or more doses but not full regimen), and full uptake/completion (received all the four doses). Table 3 summarizes the level of uptake of malaria vaccine in the study area.

Table 3: Level of Uptake of Malaria Vaccine among Sampled Caregivers

Level	Frequency	Percent
No	1	0.4
Partial	133	51.2
Full/complete	126	48.4
Total	260	100.0

Of the 133 participants classified as having *partial uptake*, 67% ($n = 89$) cited lack of awareness regarding the next appointment date, while 31% ($n = 41$) expressed hesitation or discomfort regarding vaccine safety and systemic side effects. The single caregiver (0.4%) reporting *no uptake* attributed non-vaccination to restrictive religious beliefs and partner/paternal refusal.

The 260 caregivers varied in their ease of access malaria immunization services in their area as summarized in Table 4

Table 4: Ease of Accessing Malaria Immunization

Ease	Frequency	Percent
Very easy	225	86.5
Somewhat easy	13	5
Neutral	17	6.5
Somewhat difficult	5	1.9
Total	260	100

Table 4 indicates that 86.5% (225) of the willing respondents easily accessed malaria immunization services in their area. This suggests that despite the drop in dose completion, structural physical access was rated favourably by the majority of participants. The immunization services were easily available to caregivers who were willing to vaccinate their children.

The study sought to determine whether the levels of uptake varied across geographical areas. The objective had a null hypothesis, which stated that: “there was no statistically significant association between the level of uptake of malaria vaccine and geographical areas (urban and rural) in Kisumu County between the year 2021 and 2025”. The assumption was that the level of uptake of malaria vaccine varies across geographical areas due to difference in the level of accessibility to healthcare facilities. This was done using the non-parametric Pearson’s Chi-Square (χ^2) test as a test of independence (association) by cross tabulating levels of uptake of each dose (no, partial and full) by geographical area (urban and rural). The study used the χ^2 test to compare the frequency of cases as summarized in Table 5.

Table 5: Level of Uptake of Malaria Vaccine across Geographical Area

		Geographical area		Total
		Urban	Rural	
Level of uptake	No	1 (0.6%)	0 (0.0%)	1 (0.4%)
	Partial	79 (44.6%)	54 (65.1%)	130 (51.2%)
	Full/complete	97 (54.8%)	29 (34.9%)	129 (48.5%)
Total		177	83	260

$$\chi^2 = 9.678$$

$$df = 2$$

$$p = 0.008$$

Table 5 indicates that a greater proportion of the sampled caregivers from urban areas (54.8%) recorded full uptake compared to their counterparts from rural areas (34.9%). The study supported these distributions by the χ^2 test value of $\chi^2_{0.05,2} = 9.678$. Since p ($0.008 < 0.05$), which concludes that there was a statistically significant association between the level of uptake of malaria vaccine and geographical areas (urban and rural) in Kisumu County between the year 2021 and 2025. More caregivers from urban areas recorded full/complete uptake of malaria vaccine compared to their rural counterparts. Among the 260 eligible caregivers evaluated, 99.6% reported that their child had received at least one malaria vaccine dose. However, dose-specific receipt declined as the four-dose regimen progressed (Table 2).

Dose-Specific Uptake

Table 2 shows that Dose 1 uptake was 100.0%, Dose 2 uptake was 95.8%, Dose 3 uptake was 80.7%, and Dose 4 uptake was 49.8%. Thus, the largest observed attrition occurred between the third and fourth doses. The first two doses exceeded the 90% benchmark cited in the manuscript, whereas Dose 3 and Dose 4 were below that benchmark.

Overall Uptake and Completion

For this study, overall uptake was classified as no uptake, partial uptake, or full uptake/completion. Of the 260 children, one (0.4%) had received no dose, 130 (50.0%) had received between one and three doses, and 129 (49.6%) had received all four doses (Table 3). The full/completion category therefore represents completion of the four-dose schedule rather than simple initiation of vaccination.

Among the 130 participants classified as having partial uptake, 68.5% cited lack of awareness regarding the next appointment date, while 31.6% expressed hesitation or discomfort regarding vaccine safety and systemic side effects. The single caregiver (0.4%) reporting no uptake attributed non-vaccination to restrictive religious beliefs and partner/paternal refusal. These responses are reported as caregiver-reported reasons and should not be interpreted as independently verified causal determinants.

Reported Access to Immunization Services

The 260 caregivers varied in their reported ease of access to malaria immunization services (Table 4). A total of 225 (86.5%) described access as very easy, 13 (5.0%) as somewhat easy, 17 (6.5%) as neutral, and 5 (1.9%) as somewhat difficult. These responses indicate that most sampled caregivers perceived physical/service access favourably. However, perceived ease of access is not equivalent to objectively measured distance, facility availability, vaccine supply continuity, or service readiness.

Urban–Rural Geographical Association

The geographical analysis compared vaccination uptake categories between urban and rural healthcare catchment areas. The null hypothesis was that there was no statistically significant association between malaria vaccine uptake category and geographical area (urban/rural) among the sampled caregivers in Kisumu County.

Table 5 shows that 97 of 177 urban caregivers (54.8%) were classified as having full/complete uptake, compared with 29 of 83 rural caregivers (34.9%). The Pearson Chi-Square test reported in the manuscript was $\chi^2 = 9.678$, $df = 2$, $p = 0.008$. On the basis of this test, the distribution of uptake categories differed statistically between the urban and rural groups.

This result establishes an association between the observed geographical classification and uptake category in the sample. It does not establish that rural residence caused lower completion, because other potentially relevant determinants were not simultaneously controlled for.

DISCUSSION

The findings demonstrate substantial attrition across the four-dose RTS, S vaccination schedule. Dose 1 uptake was 100.0%, Dose 2 was 95.8%, Dose 3 was 80.7%, and Dose 4 was 49.8%. The pattern indicates that initiation of vaccination was considerably more common than completion of the full regimen. The decline to 49.8% for Dose 4 is consistent with the broader concern that late-stage doses can be missed when there is a prolonged interval between earlier and later appointments (Tabiri et al., 2021; Moturi et al., 2023; Okanda et al., 2023).

The observed reduction between Dose 3 and Dose 4 is important, but the cross-sectional design does not permit the study to describe this pattern as an uptake “dynamic” in the longitudinal sense. Rather, it represents the cumulative dose-specific vaccination status observed among children aged 24–36 months whose

vaccination histories were represented in the 2021–2025 period. The manuscript therefore avoids interpreting the data as a time series or as evidence of change in population coverage from 2021 to 2025.

The study also identified a statistically significant association between geographical classification and overall uptake category. Full completion was reported for 54.8% of sampled urban caregivers compared with 34.9% of sampled rural caregivers. This difference is compatible with the presence of geographical inequalities in vaccination completion within the sampled population. However, the study design does not permit attribution of the difference to any single mechanism.

Several factors may plausibly contribute to geographical variation, including health-facility availability, travel distance, continuity of vaccine supply, household socioeconomic circumstances, awareness of appointments, health-system contact opportunities, and local implementation practices. Some of these issues are reflected in caregiver reports of appointment awareness, vaccine concerns, and ease of access, while others were not directly measured. In particular, the finding that 86.5% of respondents described access as very easy indicates that perceived access alone does not fully account for the observed completion pattern.

The reported reasons for partial uptake—especially lack of awareness of the next appointment and concerns about vaccine safety or side effects—suggest that communication and follow-up may be relevant areas for programme attention. The 15-month interval between Dose 3 and Dose 4 may also create a practical challenge for caregivers. Nevertheless, these observations should be treated as reported associations and possible programme factors rather than causal explanations.

The study's geographical analysis is intentionally limited to the urban/rural healthcare catchment classification. A more detailed assessment of geographical disparities would require location-specific data at facility, ward, sub-county, or community level, together with variables such as distance to vaccination services, facility density, stock-out histories, household socioeconomic indicators, and community-level awareness. Where sufficiently detailed georeferenced data are available, future research could use mapping and spatial analysis to identify finer-scale patterns.

The cross-sectional design also limits inference about temporal change and causality. A retrospective longitudinal analysis or repeated cross-sectional analysis using appropriately structured annual datasets would be required to assess changes in vaccination coverage over 2021–2025. Similarly, multivariable regression, with clustering accounted for where children are nested within facilities or geographical areas, could help identify independent factors associated with completion. Such analyses would complement rather than replace the descriptive urban–rural comparison presented here.

CONCLUSION

The study found high initiation of the RTS, S malaria vaccination schedule but substantial attrition in subsequent doses, with 49.8% of sampled children reported to have received Dose 4 and 49.6% classified as having completed all four doses. A statistically significant urban–rural association in uptake category was observed, with full completion reported more frequently among sampled urban caregivers than rural caregivers.

The findings should be interpreted as cross-sectional evidence of dose-specific uptake and geographical association among the sampled population, not as evidence of longitudinal uptake dynamics between 2021 and 2025. The study also cannot establish that geographical location itself caused the observed difference. Facility availability, travel distance, vaccine supply, household socioeconomic conditions, awareness, healthcare access, and local implementation factors may contribute, but most were not directly measured in the present analysis.

Future studies should use repeated annual or longitudinal datasets to assess temporal trends and should distinguish clearly between initiation, dose-specific coverage, completion, and timeliness. More detailed facility- or community-level location data, together with multivariable and clustering-adjusted analyses, would

strengthen understanding of the determinants of geographical disparities in RTS, S vaccine completion.

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