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Impact of Malaria Rapid Diagnostic Test on the Receipt of Antimalarials Among Children Aged 6-59 Months in Nigeria from 2010 to 2021

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IMPACT OF MALARIA RAPID DIAGNOSTIC TEST ON THE RECEIPT OF ANTIMALARIALS AMONG CHILDREN AGED 6-59 MONTHS IN NIGERIA FROM 2010 TO 2021

by

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ABSTRACT

Background: Nigeria has the highest malaria burden globally, and antimalarials have been commonly used to treat malaria without parasitological confirmation. In 2012, Nigeria implemented RDTs to reduce use of antimalarials for those without malaria and to increase the use of artemisinin-combination therapies (ACTs) for malaria treatment. In this study, we examined trends in antimalarial receipt among children aged 6-59 months during a 12-year period of increasing RDT availability.

Methods: We conducted a cross-sectional analysis using nationally representative Nigeria Malaria Indicator Survey (NMIS) data from 2010 (before RDT implementation), 2015, and 2021. NMIS surveys used histidine-rich protein 2 (HRP2)-based RDTs to test for malaria in children, which remain positive for several weeks after treatment. We assessed trends in malaria prevalence by survey RDT, prevalence of fever in the 2 weeks prior to the survey, and antimalarial/ACT receipt. We used multivariable logistic regression accounting for the complex survey design to examine factors associated with antimalarial receipt, stratified by survey RDT result.

Results: Of a weighted sample of 22,757 children aged 6-59 months, malaria prevalence was 51.2% in 2010, 44.3% in 2015, and 38.5% in 2021 ($p<0.0001$), Fever prevalence remained stable, but population-level antimalarial receipt decreased from 19% in 2010 to 10% in 2021 ($p<0.0001$), accompanied by a slight increase in ACT

receipt (2% in 2010 to 8% in 2021; p<0.0001). Among children who had experienced fever, 30.6% of RDT-positive and 36.1% of RDT negative children received antimalarials. The proportion of antimalarials obtained from the private sector increased from 2010 (61.8%) to 2021 (80.1%) for RDT-positive children; although in 2021 most antimalarials from them were ACTs, 43.2% of non-ACTs were chloroquine. Factors associated with antimalarial receipt for both RDT-negative and RDT-positive children included geographic region, greater household wealth, higher maternal education, and older child age.

Conclusion: From 2010 to 2021 in Nigeria, malaria prevalence and antimalarial receipt among children aged 6-59 months decreased, despite increasing RDT availability. Among children who had prior fever, antimalarial receipt was higher for children with negative survey RDT results. These results indicate persistent challenges in reducing inappropriate use of antimalarials and ensuring that children with malaria receive ACT.

Keywords: Malaria, Rapid Diagnostic Tests, Fever, Antimalarials, Artemisinin-based Combination Therapies.

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LIST OF ABBREVIATIONS

ACT	Artemisinin-based Combination Therapies
AOR	Adjusted Odd Ratios
CI	Confidence Interval
HRP2	Histidine-Rich Protein II
NMIS	Nigeria Malaria Indicator Surveys
RDT	Rapid Diagnostic Tests
WHO	World Health Organization

INTRODUCTION

Nigeria, with a population of over 200 million, had the highest global burden of malaria in 2022, accounting for 27% of global malaria cases, 31% of global malaria deaths, and 38% of global malaria deaths among children under five years of age[1]. The malaria parasite Plasmodium falciparum infects at least 50% of the Nigerian population annually and contributes to over 45% of outpatient visits, 25% of infant mortality, and 30% of childhood mortality[2,3]. Diagnosing and managing malaria has presented significant challenges in malaria-endemic countries including Nigeria due to limited access to diagnostic tests and effective, quality-assured antimalarials. Fevers are often presumed to be malaria-related by patients and healthcare providers and are therefore treated as such, even though many fevers are not caused by malaria[4-8]. Consequently, the overuse of antimalarials without confirming the presence of malaria parasites remains a concern, leading to inappropriate diagnosis, ineffective treatment of non-malarial febrile illnesses, and contributing to the emergence of drug resistance.

In 2010, the World Health Organization (WHO) recommended universal parasitological confirmation of malaria before treatment using either microscopy or rapid diagnostic tests[9,10]. Nigeria, along with other countries, revised its national malaria treatment guidelines in 2011[11] and introduced malaria rapid diagnostic tests (RDTs) in primary healthcare facilities in 2012[12]. RDTs, which utilize lateral flow immunochromatography to identify malaria parasite antigens in under 30 minutes[13], have revolutionized malaria diagnosis, treatment, and surveillance[14], enabling accurate diagnosis and differentiation of malaria from other febrile illnesses. Many Studies

carried out in Sub-Saharan African countries have found that the increasing availability of RDTs improved the prescription of the recommended first line artemisinin-based combination therapies (ACTs), for people with malaria and reduced the rate of empiric treatment for malaria[15-17].

However, despite the widespread availability and accessibility of RDTs, inappropriate use of antimalarials persists. For example, some febrile children who don't have malaria still get antimalarials, while other children with malaria are either not treated or do not promptly receive ACTs[18-20]. Studies have reported varying rates of antimalarial treatment among people without malaria, ranging from 0.1% to 81%[21-23]. Key drivers for this include a lack of confidence in RDTs, preference for presumptive treatment, lack of access to RDTs in both the formal and informal private sectors where many people access antimalarials, limited access to diagnostic tests for non-malarial fevers, and other reasons[20,22,23]. Although population-based surveys routinely report malaria care cascades among children with fever, fewer data are available on the extent of antimalarial receipt among RDT-negative children and which children are most likely to receive antimalarials when they do not have malaria.

Thus, we conducted a secondary analysis leveraging the nationally representative Nigeria Malaria Indicator Survey (NMIS) data from 2010 (prior to RDT implementation in 2012), 2015, and 2021. As part of these NMIS, children aged 6-59 months in sampled households were tested with RDTs detecting histidine-rich protein 2 (HRP II), a protein specific to P. falciparum, which causes about 95% of malaria infections in Nigeria[4]. After successful treatment, HRP2-based RDTs can show persistent positivity for several weeks due to the slow clearance of the HRP2 antigen

from the blood[24,25]. Thus, RDT results at the time of the NMIS surveys provide a unique opportunity to assess self-reported antimalarial use among children who have a negative RDT results and likely did not have malaria, compared to those with positive RDT results (evidence of current or recent infection). The goal of our study was to examine trends in antimalarial use from 2010-2021 to understand how increasing availability of RDTs has influenced the appropriateness of antimalarial prescriptions. We also aimed to describe characteristics of RDT-positive and RDT-negative children aged 6-59 months based on surveys published in 2010, 2015, and 2021. Lastly, we examined the socio-demographic factors associated with the receipt of antimalarial treatment in the prior 2 weeks among both RDT-positive and RDT-negative children.

METHODS

Study Setting and Data

Nigeria is a West African country bordered by Cameroon, Niger, Chad, Benin, and the Atlantic Ocean. Children under five years of age make up 17.1% of Nigeria's population[26]. Urban areas are inhabited by one-third of the population, while the remaining two-thirds reside in rural areas. Malaria is prevalent across Nigeria, spanning diverse ecological zones that transition from south to north. The country is divided into six geopolitical zones—North-East, North-Central, North-West, South-East, South-South, and South-West—which collectively encompass 36 states. Nigeria has distinct climate zones with varying rainfall patterns. In the southern regions, heavy rainfall occurs from March to October, while the central and coastal areas have well-defined rainy seasons. In the north, rainfall mainly occurs from June to September. The dominant species of Anopheles mosquitoes include Anopheles funestus, Anopheles gambiae complex, and Anopheles arabiensis. The NMIS is a cross-sectional household survey conducted approximately every 5 years to provide nationally representative data on malaria epidemiology and control, including insecticide-treated net ownership, fever prevalence and treatment in young children, and malaria prevalence rates[26,27,28]. In a 2-stage sampling process, clusters (census enumeration areas from the Nigeria Population and Housing Census sampling frames) were selected with probability proportional to population size, and a household listing was conducted in selected clusters to form the sampling frame for selection of approximately 25 households per cluster. The 2021 NMIS had a larger sample size, covering 568 clusters compared to the 240 and 333

clusters in the 2010 and 2015 surveys, respectively, including urban and rural areas. The surveys were conducted from October to December during the peak malaria transmission season. We used data collected at all three surveys in this analysis. This analysis was determined to be not Human Subjects Research by the UAB Institutional Review Board (IRB-300010792). The 2010, 2015 and 2021 NMIS protocol were reviewed and approved by the National Health Research and Ethics Committee of Nigeria and the ICF Institutional Review Board for Demographic and Health Surveys.

Study Population

The study population consisted of children aged 6-59 months who were tested with RDTs at the time of the NMIS surveys and their mothers/caregivers. The population included both individuals who tested positive for malaria (RDT-positive) and those who tested negative for malaria (RDT-negative).

List of Variables

The primary outcome of the study was the receipt of any antimalarial (categorized into ACTs and non-ACTs) among children that had fever in the prior 2 weeks before the survey, as reported by the mother/caregiver of the child at the time of the survey. Other variables include the result of the RDT conducted at the survey and data reported by the mother/caregiver of children who got tested. These variables included the child's age and sex, mother/caregiver's age, education, religion, wealth quintile, residential area, region of residence, and whether the child slept under a mosquito bed net the night prior to the survey. Mothers/caregivers were also asked if

their child had fever in 2 weeks prior to the survey, and for all febrile children, variables captured in the care cascade included seeking care from any source, getting tested for malaria, being told they had malaria (regardless of test result), receiving an antimalarial, and receiving an ACT. The sources of antimalarials were classified into two categories: public health facilities (e.g., government hospitals, community health workers, government health facilities) and private health facilities (e.g., private hospitals, pharmacies, private medicine vendors).

Data Management and Analysis

We described the prevalence of malaria by RDT results at the time of the 2010, 2015, and 2021 NMIS survey overall, at each survey and by sociodemographic characteristics of the children tested and their mothers/caregivers. We also examined characteristics of RDT-positive and RDT-negative children by survey year, presenting proportions for categorical variables and median (with IQR) for continuous variables. We assessed trends in the proportions of children with fever, testing positive for malaria by RDT, and receiving antimalarials and ACTs in the two weeks preceding the survey. Logistic regression was used with survey year as a continuous independent variable, and the p-values were presented to assess the significance of the trends. To examine socio-demographic factors associated with the receipt of antimalarial treatment in the prior 2 weeks, we conducted a multivariable logistic regression including all variables listed above using the SAS survey procedures to account for the sampling design and weights. In addition, we examined the proportions of children with fever in the prior 2 weeks for each step of the care-seeking cascade, stratified by the rapid diagnostic test (RDT) result at the time of the survey. Data were analyzed using JMP Pro 16 software

and SAS V 9.4 (SAS Institute, NC) and all significant tests were performed at an alpha level of 0.05. Additionally, we presented the proportions of the RDT-positive and RDT-negative children receiving either ACTs or non-ACTs by year of survey and source of treatment.

RESULTS

Sample Demographics Stratified by RDT Results

The 2010, 2015, and 2021 NMIS included a total sample size of 22,757 children aged 6-59 months who were tested for malaria by RDT at the time of the survey (Table 1 and Supplemental Table 1). The proportion of children testing positive for malaria according to RDT decreased from 51.2% in 2010 to 44.3% in 2015 and 38.5% in 2021 ($p<.0001$). Over the survey years, the proportion of children with a positive RDT increased with age. The highest prevalence was consistently among children in the 48-59 months age group, and this decreased from 57.3% in 2010 to 46.2% in 2021. Malaria prevalence was consistently higher among children residing in rural areas and decreased from 55.3 % in 2010 to 44.2% in 2021. The decline in malaria prevalence over time coincided with the education level of mothers/caregivers. The highest malaria prevalence was observed among children whose mothers or caregivers had no formal education (58.7% in 2010 and 52.4% in 2021). Households classified in the second (poorer) wealth quintile category had the highest malaria prevalence in 2010, with 64.4%. However, in 2015 and 2021, the highest proportions were observed among households classified in the lowest wealth quintile category, with 64.7% and 54.9% respectively. Additionally, there were variations in malaria prevalence across regions, with the South-Western region having the highest prevalence in 2010 (60.2%), the North-Western region in 2015 (58.1%), and the South-Southern region in 2021(51.9%).

Table 1. Characteristics of mothers and children aged 6 to 59 months tested for malaria by year of survey and by RDT status at time of survey (N=22,757)

Variables	Year of Survey					
	2010		2015		2021	
	5498 (row %)		6174 (row %)		11085 (row %)	
	RDT Positive	RDT Negative	RDT Positive	RDT Negative	RDT Positive	RDT Negative
	2816 (51.2)	2682 (48.8)	2737 (44.3)	3437 (55.7)	4273 (38.5)	6812 (61.5)
Child's age in months						
Median (IQR)	34.6 (18.8, 47.3)	28.9 (16.0, 43.4)	36.2 (21.4, 48.3)	29.7 (16.4, 42.9)	37.2 (24.1, 49.1)	30.1 (16.9, 44.3)
6 – 11	268 (43.1)	354 (56.9)	202 (31.3)	444 (68.7)	235 (20.9)	889 (79.1)
12 – 23	564 (47.8)	615 (52.2)	517 (37.8)	850 (62.2)	730 (32.2)	1536 (67.8)
24 – 35	594 (50.0)	595 (50.0)	587 (44.3)	739 (55.7)	967 (39.6)	1474 (60.4)
36 – 47	668 (53.5)	581 (46.5)	691 (48.6)	732 (51.4)	1071 (42.7)	1436 (57.3)
48 – 59	722 (57.3)	537 (42.7)	740 (52.4)	672 (47.6)	1270 (46.2)	1477 (53.8)
Child's sex						
Male	1462 (52.4)	1330 (47.6)	1394 (44.4)	1749 (55.6)	2264 (39.6)	3450 (60.4)
Female	1354 (50.0)	1352 (50.0)	1343 (44.3)	1688 (55.7)	2009 (37.4)	3362 (62.6)
Mother/caregiver's age in years						
Median (IQR)	27.8 (22.8, 34.2)	27.4 (22.4, 33.7)	25.2 (21.0, 31.2)	27.2 (21.9, 32.0)	27.2 (21.3, 33.3)	27.8 (22.2, 33.9)
Residence						
Rural	2335 (55.3)	1887 (44.7)	2255 (55.5)	1805 (44.5)	3556 (44.2)	4485 (55.8)
Urban	481 (37.7)	795 (62.3)	482 (22.8)	1632 (77.2)	717 (23.6)	2327 (76.4)
Mother's education						
No education	1611 (58.7)	1135 (41.3)	1632 (59.9)	1091 (40.1)	2525 (52.4)	2292 (47.6)

Primary education	548 (53.7)	473 (46.3)	466 (43.6)	602 (56.4)	717 (42.2)	981 (57.8)
Secondary education	573 (38.6)	912 (61.4)	582 (30.2)	1347 (69.8)	898 (25.1)	2676 (74.9)
More than secondary education	84 (34.1)	162 (65.9)	57 (12.6)	397 (87.4)	133 (13.4)	863 (86.6)
Religion						
Catholic	1098 (47.6)	1207 (52.4)	957 (36.6)	1658 (63.4)	217 (28.1)	555 (71.9)
Islam	1627 (52.9)	1447 (47.1)	1745 (49.6)	1770 (50.4)	3189 (44.7)	3938 (55.3)
Other religion	91 (76.5)	28 (23.5)	35 (79.5)	9 (20.5)	867 (27.2)	2319 (72.8)
Wealth quintile						
Lowest	652 (57.6)	480 (42.4)	817 (64.7)	446 (35.3)	1317 (54.9)	1082 (45.1)
Second	747 (64.4)	413 (35.6)	877 (62.0)	537 (38.0)	1296 (53.4)	1129 (46.6)
Middle	664 (55.4)	534 (44.6)	565 (48.4)	603 (51.6)	861 (37.8)	1414 (62.2)
Fourth	457 (43.6)	591 (56.4)	335 (29.3)	809 (70.7)	561 (27.3)	1493 (72.7)
Highest	296 (30.8)	664 (69.2)	143 (12.1)	1042 (87.9)	238 (12.3)	1694 (87.7)
Region						
North-Central	400 (44.2)	505 (55.8)	575 (49.9)	577 (50.1)	288 (27.4)	764 (72.6)
North-East	395 (47.3)	440 (52.7)	369 (42.7)	495 (57.3)	605 (38.6)	962 (61.4)
North-West	966 (56.3)	749 (43.7)	1171 (58.1)	843 (41.9)	382 (22.6)	1310 (77.4)
South-East	158 (35.6)	286 (64.4)	157 (29.9)	368 (70.1)	688 (37.0)	1172 (63.0)
South-South	426 (52.2)	390 (47.8)	179 (26.8)	490 (73.2)	1783 (51.9)	1655 (48.1)
South-West	471 (60.2)	312 (39.8)	286 (30.1)	664 (69.9)	527 (35.7)	949 (64.3)
Child slept under mosquito bed net the previous night						
Yes	940 (50.8)	911 (49.2)	1427 (54.7)	1183 (45.3)	2189 (42.6)	2955 (57.4)
No	1876 (51.4)	1771 (48.6)	1310 (36.8)	2254 (63.2)	2084 (35.1)	3857 (64.9)

Malaria Prevalence

Although malaria prevalence by RDT among children aged 6-59 years decreased from 2010 to 2021, the prevalence of fever in the 2 weeks prior to the survey remained generally stable (39% in 2010, 42% 2015, and 38% in 2021) (Figure 1). During this time, Receipt of antimalarials among this population decreased from 19% in 2010 to 17% in 2015 and 10% in 2021 (p<.0001), while receipt of ACTs slightly increased from 2% in 2010 to 6% in 2015 and 8% in 2021 (p<.0001).

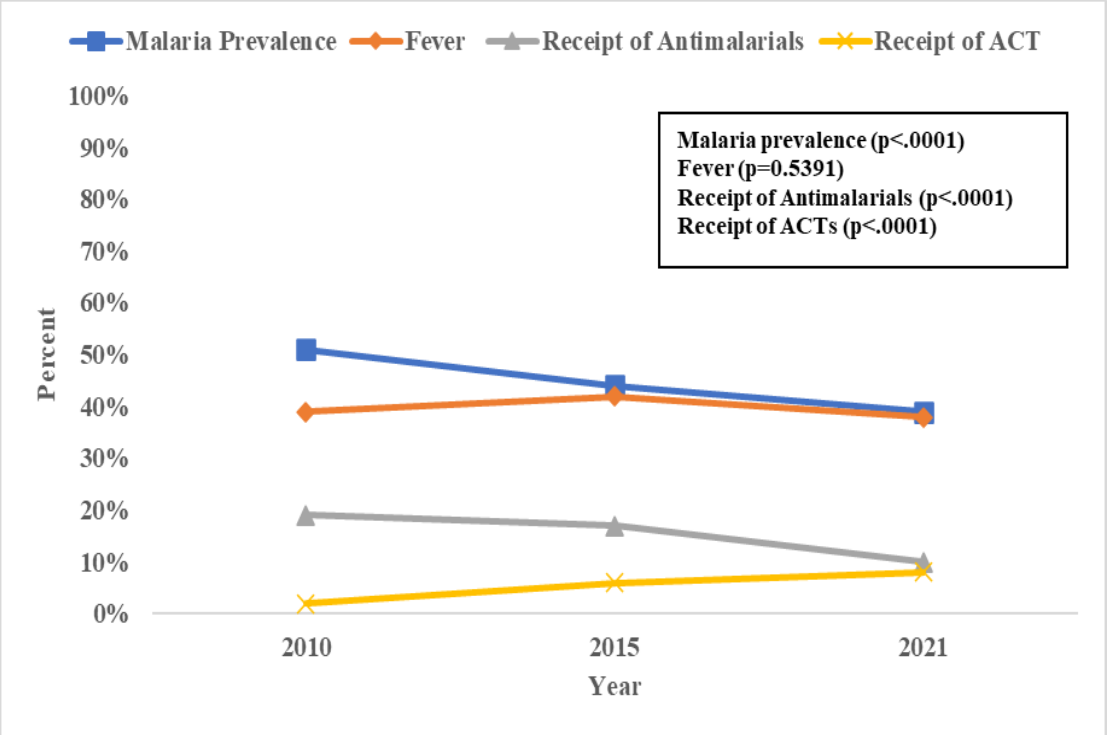

Figure 1. Trends in malaria prevalence by RDT at the time of the survey, report of fever, receipt of antimalarials, and receipt of ACTs in the 2 weeks prior to the survey among children aged 6 to 59 months.

Factors Associated with Antimalarial Receipt

For children with a positive RDT at the time of the survey, factors associated with receipt of an antimalarial in the prior 2 weeks are presented in Table 2A. Children from households in urban areas had 1.34 times higher odds of receiving any antimalarial treatment compared to children from households in rural areas (aOR 1.34 [95% CI: 1.03 - 1.78]). Household wealth quintile was also significantly associated with antimalarial receipt, with children from the fourth and highest wealth quintiles having 1.89 and 2.01 times higher odds of receiving any antimalarial treatment, respectively, compared to children from the lowest wealth quintile (aOR 1.89 [95% CI: 1.29 - 2.78], aOR 2.01 [95% CI: 1.18 – 3.43]) While children from the South-East and South-South regions had lower odds of receiving any antimalarial treatment (aOR 0.50 [95% CI: 0.32 – 0.79], aOR 0.57 [95% CI: 0.36 – 0.92]), children from the North-East and North-West regions had higher odds of receiving any antimalarial treatment (aOR 1.78 [95% CI: 1.14 - 2.78], aOR 2.01 [95% CI: 1.30 – 3.10]) compared to children from the North-Central zone. Moreover, RDT-positive children in 2015 and 2021 had 0.72 and 0.37 times lower odds of receiving any antimalarial treatment in the prior 2 weeks compared to children who tested positive in 2010 (aOR 0.72 [95% CI: 0.53 – 0.97], aOR 0.37 [95% CI: 0.26 – 0.53]). In analyses stratified by year (Supplemental Tables 2A, 3A, and 4A), the association between receipt of antimalarials and geopolitical zone, wealth quintile, and religion were also observed across the different survey years.

For children with a negative RDT at the time of the survey, factors associated with receipt of an antimalarial in the prior 2 weeks are presented in Table 2B. The RDT-negative children had similar factors associated with antimalarial receipt in the prior 2 weeks as the RDT-positive children; however, for this group, child's age and mother's/caregiver's education level were also significantly associated with

antimalarial receipt. Children aged 24-35 months and 48-59 months had 1.44 and 1.51 times higher odds of receiving any antimalarial treatment in the prior 2 weeks compared to younger children aged 6-11 months (aOR 1.44 [95% CI: 1.06 – 1.95], aOR 1.51 [95% CI: 1.10 - 2.08]). Children whose mothers/caregivers had either a secondary or a higher educational qualification had 1.48 and 1.62 times higher odds of receiving any antimalarial treatment than children whose mothers/caregivers had no educational qualification (aOR 1.48 [95% CI: 1.09 – 2.01], aOR 1.62 [95% CI: 1.08 - 2.42]). Similar associations were generally observed across survey years (Supplemental Tables 2B, 3B, and 4B).

Table 2A. Factors associated with antimalarial receipt in the prior 2 weeks among RDT-positive children aged 6 to 59 months from 2010-2021

Variables	Categories	Weighted Frequencies 1395 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	100 (7.2)	1.00	1.00
	12 – 23	258 (18.5)	0.92 (0.64 – 1.33)	1.01 (0.69 – 1.49)
	24 – 35	317 (22.7)	1.02 (0.70 – 1.44)	1.20 (0.82 – 1.75)
	36 – 47	327 (23.4)	0.95 (0.67 – 1.36)	1.15 (0.79 – 1.68)
	48 – 59	393 (28.2)	0.97 (0.68 – 1.38)	1.19 (0.82 – 1.73)
Child's sex	Male	723 (51.8)	1.00	1.00
	Female	672 (48.2)	1.04 (0.86 – 1.26)	1.08 (0.89 – 1.31)
Mother/caregiver's age in years	15 – 20	285 (20.4)	1.00	1.00
	21 – 29	482 (34.6)	1.09 (0.85 – 1.39)	1.01 (0.80 – 1.29)
	30 – 39	457 (32.7)	1.14 (0.87 – 1.48)	1.07 (0.80 – 1.44)
	≥ 40	171 (12.3)	1.20 (0.86 – 1.67)	1.16 (0.81 – 1.67)
Residence	Rural	1097 (78.6)	1.00	1.00
	Urban	298 (21.4)	1.62 (1.16 – 2.27)	1.34 (1.03 – 1.78)
Mother's education	No Education	778 (55.8)	1.00	1.00
	Primary Education	235 (16.8)	1.11 (0.85 – 1.43)	1.08 (0.80 – 1.44)
	Secondary Education	329 (23.6)	1.52 (1.20 – 1.94)	1.30 (0.95 – 1.77)
	More than Secondary Education	53 (3.8)	2.42 (1.44 – 4.05)	1.71 (0.93 – 3.17)

Religion	Catholic	389 (27.9)	1.91 (1.48 – 2.46)	1.89 (1.32 – 2.69)
	Islam	905 (64.9)	1.00	1.00
	Other Religion	101 (7.2)	0.98 (0.67 – 1.43)	1.38 (0.89 – 2.13)
Wealth quintile	Lowest	345 (24.7)	1.00	1.00
	Second	408 (29.2)	1.27 (0.97 – 1.66)	1.32 (0.97 – 1.79)
	Middle	286 (20.5)	1.30 (0.94 – 1.80)	1.16 (0.83 – 1.63)
	Fourth	241 (17.3)	2.10 (1.50 – 2.94)	1.89 (1.29 – 2.78)
	Highest	115 (8.2)	2.79 (1.84 – 4.22)	2.01 (1.18 – 3.43)
Geopolitical zone	North-Central	142 (10.2)	1.00	1.00
	North-East	242 (17.3)	1.16 (0.75 – 1.78)	1.78 (1.14 – 2.78)
	North-West	588 (42.2)	1.50 (1.04 – 2.17)	2.01 (1.30 – 3.10)
	South-East	91 (6.5)	0.40 (0.27 – 0.60)	0.50 (0.32 – 0.79)
	South-South	199 (14.3)	0.41 (0.27 – 0.63)	0.57 (0.36 – 0.92)
	South-West	133 (9.5)	0.75 (0.48 – 1.18)	0.73 (0.44 – 1.22)
Child slept under mosquito	Yes	643 (46.1)	1.00	1.00
bed net the previous night	No	752 (53.9)	1.18 (0.96 – 1.47)	0.89 (0.73 – 1.08)
Year of survey	2010	547 (39.3)	1.00	1.00
	2015	546 (39.1)	0.73 (0.54 – 0.99)	0.72 (0.53 – 0.97)
	2021	302 (21.6)	0.22 (0.16 – 0.30)	0.37 (0.26 – 0.53)

Table 2B. Factors associated with antimalarial receipt in the prior 2 weeks among RDT-negative children aged 6 to 59 months from 2010-2021

Variables	Categories	Weighted Frequencies 1575 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	173 (11.0)	1.00	1.00
	12 – 23	355 (22.5)	1.36 (1.01 – 1.81)	1.21 (0.87 – 1.68)
	24 – 35	358 (22.7)	1.53 (1.16 – 2.01)	1.44 (1.06 – 1.95)
	36 – 47	335 (21.3)	1.48 (1.10 – 1.98)	1.35 (0.97 – 1.86)
	48 – 59	354 (22.5)	1.56 (1.18 – 2.09)	1.51 (1.10 – 2.08)
Child's sex	Male	799 (50.7)	1.00	1.00
	Female	776 (49.3)	0.98 (0.81 – 1.15)	0.93 (0.77 – 1.11)
Mother/caregiver's age in years	15 – 20	297 (18.9)	1.00	1.00
	21 – 29	604 (38.3)	1.20 (0.97 – 1.49)	0.99 (0.78 – 1.26)
	30 – 39	535 (34.0)	1.20 (0.96 – 1.51)	0.99 (0.76 – 1.29)
	≥ 40	139 (8.8)	1.19 (0.87 – 1.62)	0.99 (0.70 – 1.38)
Residence	Rural	966 (61.3)	1.00	1.00
	Urban	609 (38.7)	1.60 (1.25 – 2.02)	1.16 (0.90 – 1.51)
Mother's education	No Education	466 (29.6)	1.00	1.00
	Primary Education	266 (16.9)	1.44 (1.11 – 1.85)	1.32 (0.96 – 1.83)
	Secondary Education	641 (40.7)	1.81 (1.44 – 2.26)	1.48 (1.09 – 2.01)
	More than Secondary Education	202 (12.8)	2.51 (1.81 – 3.49)	1.62 (1.08 – 2.42)
Religion	Catholic	481 (30.5)	2.08 (1.64 – 2.62)	1.41 (1.05 – 1.88)
	Islam	833 (52.9)	1.00	1.00
	Other Religion	261 (16.6)	1.27 (0.96 – 1.67)	1.30 (0.91 – 1.85)

Wealth quintile	Lowest	154 (9.8)	1.00	1.00
	Second	243 (15.4)	1.46 (1.04 – 2.04)	1.65 (1.17 – 2.34)
	Middle	282 (17.9)	1.45 (1.01 – 2.11)	1.36 (0.93 – 1.98)
	Fourth	401 (25.5)	2.37 (1.67 – 3.36)	2.10 (1.41 – 3.14)
	Highest	495 (31.4)	3.60 (2.55 – 5.10)	2.87 (1.84 – 4.47)
Geopolitical zone	North-Central	188 (11.9)	1.00	1.00
	North-East	256 (16.3)	0.91 (0.64 – 1.30)	1.19 (0.82 – 1.73)
	North-West	513 (32.6)	1.33 (0.93 – 1.89)	1.45 (1.02 – 2.11)
	South-East	154 (9.7)	0.36 (0.24 – 0.53)	0.38 (0.25 – 0.56)
	South-South	241 (15.3)	0.52 (0.35 – 0.77)	0.55 (0.36 – 0.84)
	South-West	223 (14.2)	0.98 (0.66 – 1.45)	0.91 (0.61 – 1.36)
Child slept under mosquito bed net the previous night	Yes	662 (42.0)	1.00	1.00
	No	913 (58.0)	1.32 (1.10 – 1.60)	0.92 (0.75 – 1.12)
Year of survey	2010	487 (30.9)	1.00	1.00
	2015	521 (33.1)	0.62 (0.46 – 0.83)	0.57 (0.43 – 0.77)
	2021	567 (36.0)	0.26 (0.20 – 0.34)	0.26 (0.19 – 0.37)

Care-seeking Cascade for Fever

Analyses of the care-seeking cascade for children with fever in the prior 2 weeks are reported in Figures 2A and 2B for children with positive and negative RDT results at the time of the survey. For RDT-positive children with fever in the prior 2 weeks, their numbers increased slightly from 1,181 (41.9%) in 2010 to 1,957 (45.8%) in 2021. However, the proportion of them seeking care from any care provider for fever decreased from 81% in 2010 to 61% in 2021. Malaria testing for this group rose from 4% in 2010 to 24% in 2021, but the proportion of them being told they had malaria irrespective of testing status increased from 13% in 2010 to 46% in 2021. Antimalarial receipt for RDT-positive children with fever in the prior 2 weeks declined from 45% in 2010 to 15% in 2021, while ACT receipt showed a smaller increase, from 6% in 2010 to 12% in 2021. For RDT-negative children with fever in the prior 2 weeks, their numbers rose from 903 (33.7%) in 2010 to 2,280 (43.5%) in 2021. The care-seeking cascade showed similar trends as observed for RDT-positive children. However, a higher proportion of the RDT-negative vs. RDT-positive children with fever in the prior 2 weeks had received antimalarials and ACTs.

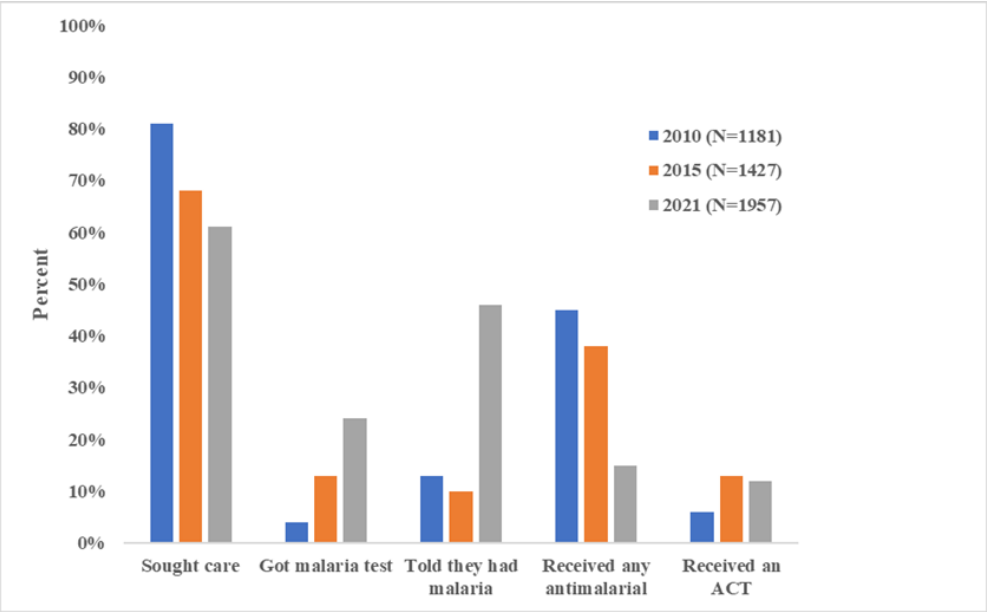

Figure 2A. Care cascade among RDT-positive children aged 6 to 59 months with fever in the prior 2 weeks by survey year.

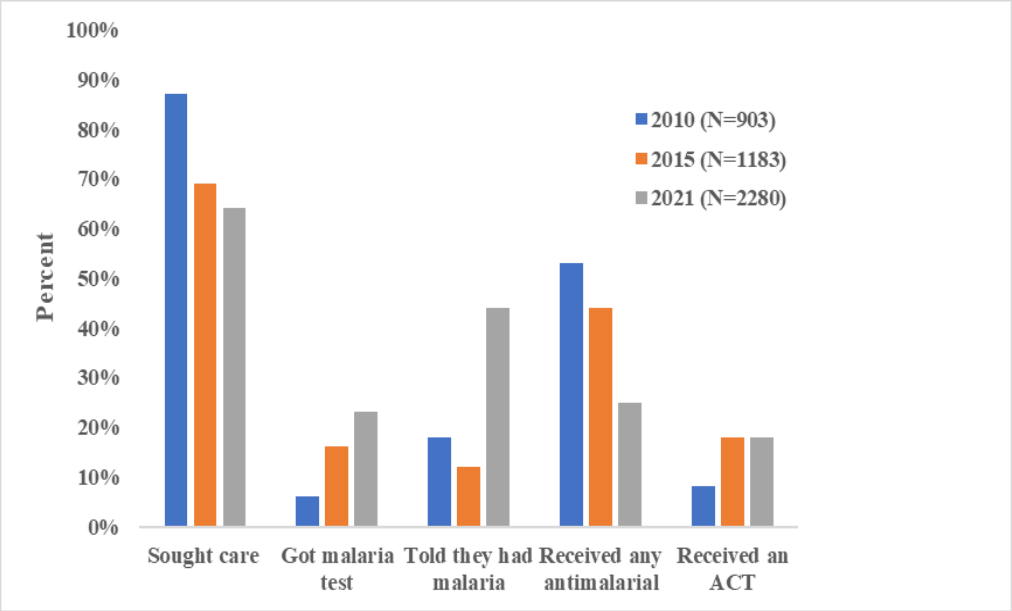

Figure 2B. Care cascade among RDT-negative children aged 6 to 59 months with fever in the prior 2 weeks by survey year.

Source and Type of Antimalarial Medication

The proportions of both RDT-positive and RDT-negative children who received an antimalarial from public health facilities decreased notably over time, while the proportions that received an antimalarial from private health facilities increased. In 2010, 38.2% of the RDT-positive children received antimalarials from public health facilities, but this proportion had decreased to 19.9% in 2021. Similarly, 42.7% of the RDT-negative children received antimalarials from public health facilities in 2010, which decreased to 28.0% in 2021. The proportion of both RDT-positive and RDT-negative children receiving ACTs from either the public or private sectors increased across the years, corresponding to a decrease in the receipt of non-ACT antimalarials. Nonetheless, in 2021, our findings revealed that over 40% of individuals receiving non-ACT antimalarials in the private sector were still prescribed chloroquine. The percentages were notably high, with 43.2% for RDT-positive children and 44.5% for RDT-negative children among those who received the non-ACT antimalarials.

Table 3A. Reported antimalarial medication received in the prior 2 Weeks among RDT-positive children, by survey year and source of treatment (N=1395)

Antimalarials	**Year of Survey**					
	2010		**2015**		**2021**	
	547 (%)		**546 (%)**		**302 (%)**	
	Source of Antimalarial Medication		**Source of Antimalarial Medication**		**Source of Antimalarial Medication**	
	Public	**Private**	**Public**	**Private**	**Public**	**Private**
	209 (38.2)	**338 (61.8)**	**151 (27.7)**	**395 (72.3)**	**60 (19.9)**	**242 (80.1)**
Any ACT	18 (8.6)	38 (11.2)	43 (28.5)	144 (36.5)	49 (81.7)	154 (63.6)

Non-ACT antimalarial	191 (91.4)	300 (88.8)	108 (71.5)	251 (63.5)	11 (18.3)	88 (36.4)
Of which:						
SP/Fansidar	54 (28.3)	65 (21.7)	19 (17.6)	61 (24.3)	3 (27.3)	12 (13.6)
Chloroquine	72 (37.7)	126 (42.0)	32 (29.6)	96 (38.2)	3 (27.3)	38 (43.2)
Amodiaquine	16 (8.4)	30 (10.0)	10 (9.3)	11 (4.4)	2 (18.2)	6 (6.8)
Quinine pills/injection/IV	12 (6.3)	19 (6.3)	3 (2.8)	17 (6.8)	-	2 (2.3)
Artesunate rectal/injection/IV	5 (2.6)	13 (4.3)	27 (25.0)	26 (10.4)	2 (18.2)	5 (5.7)
Other antimalarial	32 (16.7)	47 (15.7)	17 (15.7)	40 (15.9)	1 (9.0)	25 (28.4)

Table 3B. Reported antimalarial medication received in the prior 2 Weeks among RDT-negative children, by survey year and source of treatment (N=1575)

Antimalarials	**Year of Survey**					
	2010		**2015**		**2021**	
	487 (%)		**521 (%)**		**567 (%)**	
	Source of Antimalarial Medication		**Source of Antimalarial Medication**		**Source of Antimalarial Medication**	
	Public	**Private**	**Public**	**Private**	**Public**	**Private**
	208 (42.7)	**279 (57.3)**	**164 (31.5)**	**357 (68.5)**	**159 (28.0)**	**408 (72.0)**
Any ACT	29 (13.9)	43 (15.4)	85 (51.8)	127 (35.6)	118 (74.2)	289 (70.8)
Non-ACT antimalarial	179 (86.1)	236 (84.6)	79 (48.2)	230 (64.4)	41 (25.8)	119 (29.2)
Of which:						
SP/Fansidar	42 (23.5)	56 (23.7)	16 (20.2)	57 (24.8)	7 (17.1)	31 (26.1)

Chloroquine	65 (36.3)	87 (36.9)	26 (32.9)	83 (36.1)	12 (29.3)	53 (44.5)
Amodiaquine	12 (6.7)	25 (10.6)	7 (8.9)	11 (4.8)	4 (9.8)	6 (5.0)
Quinine pills/injection/IV	17 (9.5)	16 (6.8)	3 (3.8)	17 (7.4)	3 (7.3)	2 (1.7)
Artesunate rectal/injection/IV	10 (5.6)	11 (4.6)	15 (19.0)	22 (9.6)	6 (14.6)	7 (5.9)
Other antimalarial	33 (18.4)	41 (17.4)	12 (15.2)	40 (17.3)	9 (21.9)	20 (16.8)

DISCUSSION

Principal Findings

The findings of our study revealed a significant decline in malaria prevalence among children aged 6-59 months in Nigeria during the survey period, spanning from pre-RDT availability in 2010 to the increasing implementation of RDTs in 2015 and 2021. We also observed shifting patterns in antimalarial treatment, with a decreasing likelihood of RDT-positive children receiving antimalarial treatment across the survey years despite the improvements observed with increasing receipt of ACTs and decreasing receipt of other less effective antimalarials. While previous studies have highlighted the issue of a high proportion of children testing positive for malaria not receiving appropriate treatment[16-18], our findings also suggest that certain sociodemographic factors can influence the receipt of antimalarial treatment among these children.

In line with other studies, we also found that the prevalence of malaria increased with the child's age and was highest among children in households classified in the lowest (poorest) or second (poor) wealth quintile categories, as well as children whose mothers or caregivers had no formal education and those residing in rural areas[28, 29]. Moreover, among the RDT-positive children who had experienced fever in the 2 weeks prior to the survey, children who resided in urban areas were more likely to receive antimalarials, as were those from wealthier households. Geopolitical zone, representing regional variations, was also significantly associated with the receipt of antimalarial.

The findings of this study are consistent with a previous study conducted in Uganda[34], which found that certain sociodemographic factors such as caregiver's age and child's age were independently associated with antimalarial use among children with febrile illnesses. The decreasing likelihood of RDT-positive receiving antimalarial treatment raises concerns about the effectiveness of the recommended universal parasitological confirmation in ensuring appropriate and timely treatment for malaria cases.

Furthermore, the RDT-negative children who had experienced fever in the prior 2 weeks exhibited similar levels and trends of antimalarial receipt as RDT-positive children but the proportion of them receiving antimalarial treatment in the prior 2 weeks was notably higher than the proportion of RDT-positive children receiving antimalarial treatment across the years. Similar studies in other Sub-Saharan African countries have reported the use of antimalarials among children in the absence of a positive malaria diagnosis[19, 21, 33]. This observation raises concerns about the potential overuse or inappropriate prescription of antimalarials in the absence of a positive malaria diagnosis among RDT-negative cases. It is possible that factors such as clinical symptoms, healthcare provider practices, or caregiver expectations might contribute to the prescribing patterns. The findings regarding the child's age, mother's higher education, and belonging to a richer household wealth quintile as significant factors influencing inappropriate antimalarial receipt among RDT-negative children have important implications for improving malaria case management[34, 35]. This association can be explained by several factors. First, mothers with higher educational qualifications might have better access to health information and be more proactive in seeking medical care for their children. This leads to a higher likelihood of receiving antimalarial treatment, even without a confirmed malaria diagnosis. Second, wealthier households may have greater access to healthcare services, which could increase the probability of seeking

treatment for febrile illnesses and receiving antimalarial drugs, regardless of a definitive malaria diagnosis.

Additionally, our findings reveal instances of presumptive malaria diagnosis in this population, even in 2015 and 2021 with the wider availability of RDTs, which further contributes to the gap between malaria diagnosis and the provision of proper antimalarial treatment, including ACTs[20,22]. There has also been a notable shift in the preferred source of treatment for children under the age of 5, with private health facilities becoming increasingly favored compared to public facilities. The percentage of children receiving antimalarials from the private sector showed an upward trend across the survey years. The increased preference for private health facilities can be attributed to their higher accessibility and convenience, particularly in urban areas, where they offer shorter waiting times and more flexible operating hours. Caregivers may also choose private facilities due to the perceived higher quality of care, personalized attention, and patient-centered approach they offer, which may be particularly appealing for the treatment of young children. Additionally, the availability of a broader range of antimalarial treatment options and specific medications in private facilities may further influence caregivers' decisions to seek treatment there for their children. Our results lend further support to this factor, showing that a high proportion of children still receive chloroquine as a form of antimalarial treatment in private facilities. This shift is rather concerning, as studies have shown relatively low utilization of RDTs in the private sector in Nigeria[31,35,36]. In the private sector, patients may be reluctant to bear the costs of both diagnostic testing and treatment, potentially hindering the utilization of RDTs as found in a study conducted in Kenya, which noted that the uptake of testing depends, among other factors, on the correlation between the cost of the test and the cost of the ACT[37].

Despite the shift in the preferred source of treatment for children, a greater proportion of both the RDT-positive and RDT-negative children still received ACTs in 2021 compared to prior years. This finding has important implications for malaria treatment in Nigeria, as it suggests that despite the changing landscape of healthcare utilization, there is increasing use of ACTs for malaria treatment[14, 35]. The use of ACTs aligns with global guidelines and underscores the importance of promoting the appropriate treatment of malaria cases[35]. Sustaining and enhancing the effectiveness of the current recommended malaria case management in Nigeria will depend on continued collaboration among stakeholders such as government health departments, healthcare providers, NGOs, private health facilities, community leaders and traditional healers, patent medicine vendors, and community members.

Strengths and Limitations

The strengths of this study include its large nationally representative sample size, allowing for generalizability of the findings to the target population and more reliable conclusions to be drawn. Data from the 3 survey years allowed us to identify trends and assess the changes over time in factors influencing antimalarial receipt. The comparison between the RDT-positive and RDT-negative children provided valuable insights into the specific factors contributing to appropriate or inappropriate antimalarial receipt.

However, it is important to acknowledge limitations: The study relied on self-reported data, which may introduce recall or social desirability biases. Additionally, other potential barriers to RDT utilization were not explored, such as healthcare provider training and regional stockouts of RDTs and ACTs. Future research should

assess RDT availability and utilization in different healthcare settings to better understand their impact on antimalarial receipt. Qualitative research could also shed light on barriers and facilitators of RDT utilization, informing strategies for improving access and utilization in malaria case management.

CONCLUSION

our study revealed a significant decline in malaria prevalence among children aged 6-59 months in Nigeria, accompanied by shifting patterns in antimalarial treatment since the introduction of malaria RDTs. Despite improvements in the receipt of ACTs and decreasing use of less effective antimalarials, there is a concerning discrepancy in the proportion of RDT-positive children not receiving appropriate treatment. We observed a significant decline in antimalarial treatment among RDT-positive children over time, despite the increasing availability and use of RDTs. Moreover, we found that RDT-negative children exhibited similar levels of antimalarial receipt as RDT-positive children, indicating that testing availability has not necessarily deterred inappropriate antimalarial use. Furthermore, the study revealed that sociodemographic factors, such as the mother's education, religion, wealth quintile, and geopolitical zones, influence antimalarial use in both RDT-positive and RDT-negative children. Further studies should focus on investigating the underlying factors leading to the decline in antimalarial treatment rates among RDT-positive children and exploring effective strategies to address this discrepancy in malaria management.

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Table S1. Characteristics of mothers and children aged 6 to 59 months tested for malaria by year of survey and by RDT status at time of survey (N=22,757)

Variables	Year of Survey					
	2010		2015		2021	
	5498 (column %)		6174 (column %)		11085 (column %)	
	RDT Positive 2816 (51.2)	RDT Negative 2682 (48.8)	RDT Positive 2737 (44.3)	RDT Negative 3437 (55.7)	RDT Positive 4273 (38.5)	RDT Negative 6812 (61.5)
Child's age in months						
Median (IQR)	34.6 (18.8, 47.3)	28.9 (16.0, 43.4)	36.2 (21.4, 48.3)	29.7 (16.4, 42.9)	37.2 (24.1, 49.1)	30.1 (16.9, 44.3)
6 – 11	268 (9.5)	354 (13.2)	202 (7.4)	444 (12.9)	235 (5.5)	889 (13.1)
12 – 23	564 (20.0)	615 (22.9)	517 (18.9)	850 (24.7)	730 (17.1)	1536 (22.5)
24 – 35	594 (21.1)	595 (22.2)	587 (21.5)	739 (21.5)	967 (22.6)	1474 (21.6)
36 – 47	668 (23.7)	581 (21.7)	691 (25.2)	732 (21.3)	1071 (25.1)	1436 (21.1)
48 – 59	722 (25.6)	537 (20.0)	740 (27.0)	672 (19.6)	1270 (29.7)	1477 (21.7)
Child's sex						
Male	1462 (51.9)	1330 (49.6)	1394 (50.9)	1749 (50.9)	2264 (53.0)	3450 (50.7)
Female	1354 (48.1)	1352 (50.4)	1343 (49.1)	1688 (49.1)	2009 (47.0)	3362 (49.3)
Mother/caregiver's age in years						
Median (IQR)	27.8 (22.8, 34.2)	27.4 (22.4, 33.7)	25.2 (21.0, 31.2)	27.2 (21.9, 32.0)	27.2 (21.3, 33.3)	27.8 (22.2, 33.9)
Residence						
Rural	2335 (82.9)	1887 (70.4)	2255 (82.4)	1805 (52.5)	3556 (83.2)	4485 (65.8)
Urban	481 (17.1)	795 (29.6)	482 (17.6)	1632 (47.5)	717 (16.8)	2327 (34.2)

Mother's education						
No education	1611 (57.2)	1135 (42.3)	1632 (59.6)	1091 (31.7)	2525 (59.1)	2292 (33.6)
Primary education	548 (19.4)	473 (17.6)	466 (17.0)	602 (17.5)	717 (16.8)	981 (14.4)
Secondary education	573 (20.4)	912 (34.0)	582 (21.3)	1347 (39.2)	898 (21.0)	2676 (39.3)
More than secondary education	84 (3.0)	162 (6.1)	57 (2.1)	397 (11.6)	133 (3.1)	863 (12.7)
Religion						
Catholic	1098 (39.0)	1207 (45.0)	957 (35.0)	1658 (48.2)	217 (5.1)	555 (8.2)
Islam	1627 (57.8)	1447 (54.0)	1745 (63.8)	1770 (51.5)	3189 (74.6)	3938 (57.8)
Other religion	91 (3.2)	28 (1.0)	35 (1.2)	9 (0.3)	867 (20.3)	2319 (34.0)
Wealth quintile						
Lowest	652 (23.2)	480 (17.9)	817 (30.0)	446 (13.0)	1317 (30.8)	1082 (15.9)
Second	747 (26.5)	413 (15.4)	877 (32.0)	537 (15.6)	1296 (30.3)	1129 (16.6)
Middle	664 (23.6)	534 (19.9)	565 (20.6)	603 (17.6)	861 (20.2)	1414 (20.8)
Fourth	457 (16.2)	591 (22.0)	335 (12.2)	809 (23.5)	561 (13.1)	1493 (21.9)
Highest	296 (10.5)	664 (24.8)	143 (5.2)	1042 (30.3)	238 (5.6)	1694 (24.8)
Region						
North-Central	400 (14.2)	505 (18.8)	575 (21.0)	577 (16.8)	288 (6.7)	764 (11.2)
North-East	395 (14.0)	440 (16.4)	369 (13.5)	495 (14.4)	605 (14.2)	962 (14.1)
North-West	966 (34.3)	749 (28.0)	1171 (42.8)	843 (24.5)	382 (9.0)	1310 (19.2)
South-East	158 (5.6)	286 (10.7)	157 (5.7)	368 (10.7)	688 (16.1)	1172 (17.2)
South-South	426 (15.1)	390 (14.5)	179 (6.5)	490 (14.3)	1783 (41.7)	1655 (24.4)
South-West	471 (16.7)	312 (11.6)	286 (10.5)	664 (19.3)	527 (12.3)	949 (13.9)
Child slept under mosquito bed net the previous night						
Yes	940 (33.4)	911 (34.0)	1427 (52.1)	1183 (34.4)	2189 (51.2)	2955 (43.4)
No	1876 (66.6)	1771 (66.0)	1310 (47.9)	2254 (65.6)	2084 (48.8)	3857 (56.6)

Table S2A: Factors associated with receipt of antimalarial in the prior 2 weeks among survey RDT-positive children for survey year 2010

Variables	Categories	Weighted Frequencies 547 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	54 (9.9)	1.00	1.00
	12 – 23	93 (17.0)	0.59 (0.33 – 1.05)	0.58 (0.33 – 1.02)
	24 – 35	119 (21.7)	0.88 (0.50 – 1.58)	0.79 (0.45 – 1.38)
	36 – 47	128 (23.4)	0.93 (0.51 – 1.68)	0.82 (0.45 – 1.49)
	48 – 59	153 (28.0)	0.90 (0.51 – 1.57)	0.84 (0.48 – 1.48)
Child's sex	Male	278 (50.8)	1.00	1.00
	Female	269 (49.2)	1.23 (0.82 – 1.85)	1.21 (0.82 – 1.78)
Mother/caregiver's age in years	15 – 20	96 (17.6)	1.00	1.00
	21 – 29	209 (38.2)	0.98 (0.64 – 1.51)	0.93 (0.59 – 1.46)
	30 – 39	169 (30.9)	0.75 (0.42 – 1.35)	0.73 (0.39 – 1.37)
	≥ 40	73 (13.3)	1.06 (0.57 – 1.98)	0.90 (0.50 – 1.64)
Residence	Rural	420 (76.8)	1.00	1.00
	Urban	127 (23.3)	1.54 (0.84 – 2.82)	1.61 (0.97 – 2.68)
Mother's education	No education	356 (65.1)	1.00	1.00
	Primary education	75 (13.7)	0.51 (0.31 – 0.84)	0.74 (0.40 – 1.39)
	Secondary education	97 (17.7)	0.73 (0.47 – 1.15)	1.05 (0.54 – 2.02)
	More than secondary education	19 (3.5)	1.14 (0.44 – 2.92)	1.34 (0.40 – 4.48)
Religion	Catholic	145 (26.5)	0.58 (0.38 – 0.88)	1.72 (0.84 – 3.50)
	Islam	397 (72.6)	1.00	1.00
	Other religion	5 (0.9)	0.17 (0.03 – 1.11)	0.58 (0.10 – 3.26)
Wealth quintile	Lowest	133 (24.3)	1.00	1.00

	Second	153 (28.0)	1.17 (0.61 – 2.24)	1.46 (0.77 – 2.78)
	Middle	102 (18.6)	0.61 (0.33 – 1.13)	0.88 (0.44 – 1.78)
	Fourth	106 (19.4)	1.18 (0.63 – 2.21)	2.51 (1.10 – 5.75)
	Highest	53 (9.7)	1.20 (0.58 – 2.47)	2.30 (0.75 – 7.11)
Geopolitical zone	North-Central	29 (5.3)	1.00	1.00
	North-East	99 (18.1)	2.77 (1.11 – 6.89)	3.66 (1.20 – 11.15)
	North-West	291 (53.2)	2.62 (1.23 – 5.59)	3.96 (1.44 – 10.87)
	South-East	17 (3.1)	0.73 (0.31 – 1.75)	0.48 (0.16 – 1.42)
	South-South	82 (15.0)	1.82 (0.82 – 4.05)	1.08 (0.38 – 3.04)
	South-West	29 (5.3)	0.59 (0.22 – 1.61)	0.50 (0.19 – 1.33)
Child slept under mosquito bed net	Yes	205 (37.5)	1.00	1.00
the previous night	No	342 (62.5)	0.70 (0.46 – 1.09)	0.82 (0.55 – 1.22)

Table S3A: Factors associated with receipt of antimalarial in the prior 2 weeks among survey RDT-positive children for survey year 2015

Variables	Categories	Weighted Frequencies 546 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	37 (6.8)	1.00	1.00
	12 – 23	114 (20.9)	1.28 (0.68 – 2.42)	1.27 (0.64 – 2.53)
	24 – 35	121 (22.1)	1.35 (0.73 – 2.52)	1.41 (0.72 – 2.77)
	36 – 47	136 (24.9)	1.36 (0.71 – 2.63)	1.43 (0.71 – 2.90)
	48 – 59	138 (25.3)	1.23 (0.64 – 2.34)	1.23 (0.59 – 2.54)
Child's sex	Male	290 (53.1)	1.00	1.00
	Female	256 (46.9)	0.93 (0.71 – 1.20)	0.93 (0.72 – 1.21)
Mother/caregiver's age in years	15 – 20	138 (25.3)	1.00	1.00
	21 – 29	180 (33.0)	1.03 (0.71 – 1.43)	0.92 (0.63 – 1.34)
	30 – 39	171 (31.3)	1.22 (0.85 – 1.77)	1.11 (0.74 – 1.66)
	≥ 40	57 (10.4)	1.03 (0.62 – 1.71)	0.97 (0.55 – 1.71)
Residence	Rural	432 (79.1)	1.00	1.00
	Urban	114 (20.9)	1.89 (1.35 – 2.63)	1.42 (0.91 – 2.22)
Mother's education	No education	296 (54.2)	1.00	1.00
	Primary education	102 (18.7)	1.52 (1.05 – 2.20)	1.41 (0.92 – 2.17)
	Secondary education	133 (24.4)	1.86 (1.33 – 2.60)	1.42 (0.89 – 2.25)
	More than secondary education	15 (2.7)	3.65 (1.55 – 8.61)	2.50 (0.99 – 6.31)
Religion	Catholic	198 (36.3)	1.48 (1.07 – 2.05)	1.32 (0.78 – 2.24)
	Islam	343 (62.8)	1.00	1.00
	Other religion	5 (0.9)	0.82 (0.30 – 2.25)	0.83 (0.30 – 2.28)

Wealth quintile	Lowest	155 (28.4)	1.00	1.00
	Second	177 (32.4)	1.20 (0.83 – 1.74)	1.27 (0.86 – 1.88)
	Middle	106 (19.4)	1.24 (0.79 – 1.94)	1.14 (0.71 – 1.83)
	Fourth	75 (13.7)	2.05 (1.23 – 3.42)	1.81 (0.98 – 3.35)
	Highest	33 (6.1)	2.63 (1.45 – 4.77)	1.91 (0.81 – 4.49)
Geopolitical zone	North-Central	71 (13.0)	1.00	1.00
	North-East	104 (19.1)	1.86 (1.11 – 3.13)	2.27 (1.30 – 3.95)
	North-West	243 (44.5)	1.17 (0.74 – 1.86)	1.57 (0.92 – 2.67)
	South-East	42 (7.6)	2.51 (1.39 – 4.51)	1.31 (0.64 – 2.68)
	South-South	43 (7.9)	1.35 (0.80 – 2.28)	0.83 (0.44 – 1.57)
	South-West	43 (7.9)	1.79 (0.85 – 3.75)	1.20 (0.55 – 2.61)
Child slept under mosquito bed net the previous night	Yes	291 (53.3)	1.00	1.00
	No	255 (46.7)	1.08 (0.82 – 1.42)	0.96 (0.70 – 1.31)

Table S4A: Factors associated with receipt of antimalarial in the prior 2 weeks among survey RDT-positive children for survey year 2021

Variables	Categories	Weighted Frequencies 302 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	8 (2.7)	1.00	1.00
	12 – 23	52 (17.2)	1.99 (0.92 – 4.27)	1.70 (0.75 – 3.86)
	24 – 35	76 (25.2)	2.14 (0.99 – 4.61)	2.05 (0.89 – 4.70)
	36 – 47	63 (20.8)	1.62 (0.81 – 3.23)	1.51 (0.71 – 3.23)
	48 – 59	103 (34.1)	2.22 (1.09 – 4.47)	2.00 (0.93 – 4.30)
Child's sex	Male	155 (51.3)	1.00	1.00
	Female	147 (48.7)	1.04 (0.78 – 1.41)	1.14 (0.81 – 1.61)
Mother/caregiver's age in years	15 – 20	51 (16.9)	1.00	1.00
	21 – 29	94 (31.1)	1.19 (0.70 – 2.03)	0.97 (0.54 – 1.36)
	30 – 39	116 (38.4)	1.63 (0.98 – 2.70)	1.33 (0.73 – 2.43)
	≥ 40	41 (13.6)	1.62 (0.87 – 3.02)	1.65 (0.79 – 3.48)
Residence	Rural	245 (81.1)	1.00	1.00
	Urban	57 (18.9)	1.35 (0.85 – 2.15)	0.86 (0.54 – 1.36)
Mother's education	No education	126 (41.7)	1.00	1.00
	Primary education	58 (19.2)	1.82 (1.22 – 2.71)	1.15 (0.73 – 1.82)
	Secondary education	98 (32.5)	2.94 (2.01 – 4.29)	1.08 (0.63 – 1.84)
	More than secondary education	20 (6.6)	5.11 (2.42 – 10.77)	1.56 (0.61 – 3.98)
Religion	Catholic	45 (14.9)	7.70 (4.00 – 10.83)	3.41 (1.70 – 6.87)
	Islam	165 (54.6)	1.00	1.00
	Other religion	92 (30.5)	3.23 (2.11 – 4.94)	1.32 (0.76 – 2.31)

Wealth quintile	Lowest	56 (18.5)	1.00	1.00
	Second	78 (25.8)	1.53 (0.80 – 2.96)	1.25 (0.61 – 2.58)
	Middle	78 (25.8)	2.63 (1.49 – 4.66)	1.60 (0.85 – 3.02)
	Fourth	60 (20.0)	3.58 (2.05 – 6.27)	1.64 (0.88 – 3.05)
	Highest	30 (9.9)	6.13 (3.07 – 10.26)	2.27 (0.91 – 5.68)
Geopolitical zone	North-Central	42 (13.9)	1.00	1.00
	North-East	38 (12.6)	0.26 (0.12 – 0.55)	0.39 (0.18 – 0.83)
	North-West	53 (17.6)	1.09 (0.51 – 2.30)	1.06 (0.53 – 2.13)
	South-East	32 (10.6)	0.13 (0.06 – 0.25)	0.19 (0.09 – 0.37)
	South-South	75 (24.8)	0.14 (0.06 – 0.30)	0.22 (0.11 – 0.46)
	South-West	62 (20.5)	0.47 (0.22 – 0.96)	0.46 (0.24 – 0.91)
Child slept under mosquito bed net the previous night	Yes	146 (48.3)	1.00	1.00
	No	156 (51.7)	1.34 (0.98 – 1.83)	0.76 (0.56 – 1.04)

Table S2B: Factors associated with receipt of antimalarial in the prior 2 weeks among survey RDT-negative children for survey year 2010

Variables	Categories	Weighted Frequencies 487 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	47 (9.7)	1.00	1.00
	12 – 23	137 (28.1)	2.05 (1.03 – 4.08)	2.22 (1.04 – 4.74)
	24 – 35	101 (20.7)	1.23 (0.71 – 2.12)	1.46 (0.79 – 2.71)
	36 – 47	93 (19.1)	1.61 (0.89 – 2.93)	1.96 (1.04 – 3.82)
	48 – 59	109 (22.4)	1.36 (0.72 – 2.57)	1.52 (0.73 – 3.16)
Child's sex	Male	242 (49.7)	1.00	1.00
	Female	245 (50.3)	0.86 (0.60 – 1.24)	0.84 (0.58 – 1.21)
Mother/caregiver's age in years	15 – 20	87 (17.9)	1.00	1.00
	21 – 29	197 (40.4)	1.11 (0.69 – 1.79)	0.88 (0.52 – 1.47)
	30 – 39	150 (30.8)	0.95 (0.57 – 1.59)	0.85 (0.46 – 1.55)
	≥ 40	53 (10.9)	1.14 (0.56 – 2.37)	0.92 (0.41 – 2.06)
Residence	Rural	343 (70.4)	1.00	1.00
	Urban	144 (29.6)	2.01 (1.22 – 3.31)	1.73 (0.98 – 3.07)
Mother's education	No education	223 (45.8)	1.00	1.00
	Primary education	72 (14.8)	0.81 (0.52 – 1.26)	1.05 (0.54 – 2.02)
	Secondary education	150 (30.8)	1.09 (0.70 – 1.68)	1.31 (0.63 – 2.74)
	More than secondary education	42 (8.6)	2.69 (1.19 – 6.08)	2.59 (0.85 – 7.89)
Religion	Catholic	179 (36.8)	0.70 (0.45 – 1.08)	0.70 (0.31 – 1.61)
	Islam	297 (61.0)	1.00	1.00
	Other religion	11 (2.2)	1.52 (0.15 – 5.14)	3.09 (0.22 – 3.85)
Wealth quintile	Lowest	56 (11.5)	1.00	1.00

	Second	77 (15.8)	2.04 (1.01 – 4.13)	2.20 (1.06 – 4.57)
	Middle	101 (20.7)	1.30 (0.66 – 2.56)	1.43 (0.70 – 2.95)
	Fourth	125 (25.7)	1.94 (0.96 – 3.91)	2.70 (1.15 – 6.33)
	Highest	128 (26.3)	3.08 (1.63 – 5.81)	4.26 (1.75 – 10.38)
Geopolitical zone	North-Central	35 (7.2)	1.00	1.00
	North-East	65 (13.4)	1.75 (0.74 – 4.17)	2.23 (0.77 – 6.49)
	North-West	206 (42.3)	2.24 (1.12 – 4.47)	2.54 (1.01 – 6.45)
	South-East	47 (9.6)	1.30 (0.63 – 2.67)	0.98 (0.40 – 2.41)
	South-South	81 (16.6)	1.49 (0.70 – 3.20)	1.10 (0.44 – 2.78)
	South-West	53 (10.9)	2.58 (1.03 – 6.47)	1.33 (0.49 – 3.59)
Child slept under mosquito bed net	Yes	186 (38.2)	1.00	1.00
the previous night	No	301 (61.8)	0.68 (0.45 – 1.02)	0.70 (0.46 – 1.08)

Table S3B: Factors associated with receipt of antimalarial in the prior 2 weeks among survey RDT-negative children for survey year 2015

Variables	Categories	Weighted Frequencies 521 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	64 (12.3)	1.00	1.00
	12 – 23	107 (20.5)	1.03 (0.66 – 1.61)	0.86 (0.54 – 1.37)
	24 – 35	125 (24.0)	1.63 (1.05 – 2.64)	1.43 (0.87 – 2.33)
	36 – 47	119 (22.8)	1.43 (0.91 – 2.24)	1.11 (0.69 – 1.79)
	48 – 59	106 (20.4)	1.53 (0.96 – 2.45)	1.39 (0.85 – 2.29)
Child's sex	Male	248 (47.6)	1.00	1.00
	Female	273 (52.4)	1.16 (0.87 – 1.55)	1.03 (0.78 – 1.37)
Mother/caregiver's age in years	15 – 20	114 (21.9)	1.00	1.00
	21 – 29	185 (35.5)	0.96 (0.66 – 1.39)	0.82 (0.56 – 1.21)
	30 – 39	177 (34.0)	1.16 (0.83 – 1.62)	0.92 (0.65 – 1.31)
	≥ 40	45 (8.6)	1.30 (0.81 – 2.09)	1.08 (0.63 – 1.84)
Residence	Rural	273 (52.4)	1.00	1.00
	Urban	248 (47.6)	2.07 (1.47 – 2.91)	1.25 (0.77 – 2.02)
Mother's education	No education	154 (29.6)	1.00	1.00
	Primary education	99 (19.0)	1.35 (0.91 – 2.01)	1.17 (0.75 – 1.83)
	Secondary education	196 (37.6)	1.76 (1.22 – 2.56)	1.25 (0.76 – 2.04)
	More than secondary education	72 (13.8)	3.02 (1.75 – 5.22)	1.63 (0.80 – 3.32)
Religion	Catholic	241 (46.3)	1.36 (0.97 – 1.90)	1.31 (0.85 – 2.04)
	Islam	270 (51.8)	1.00	1.00
	Other religion	10 (1.9)	1.14 (0.22 – 3.82)	0.80 (0.18 – 3.60)

Wealth quintile	Lowest	66 (12.7)	1.00	1.00
	Second	89 (17.1)	1.31 (0.81 – 2.11)	1.29 (0.78 – 2.13)
	Middle	88 (16.9)	1.18 (0.66 – 2.12)	1.13 (0.62 – 2.07)
	Fourth	117 (22.4)	1.77 (1.07 – 2.95)	1.73 (0.95 – 3.14)
	Highest	161 (30.9)	3.64 (2.15 – 6.18)	3.25 (1.48 – 7.13)
Geopolitical zone	North-Central	48 (9.2)	1.00	1.00
	North-East	104 (20.0)	1.80 (1.11 – 2.91)	2.12 (1.28 – 3.49)
	North-West	150 (28.8)	1.27 (0.76 – 2.13)	1.59 (0.93 – 2.73)
	South-East	54 (10.4)	1.50 (0.80 – 2.79)	0.77 (0.39 – 1.52)
	South-South	90 (17.2)	1.68 (0.94 – 2.98)	1.02 (0.54 – 194)
	South-West	75 (14.4)	2.48 (1.51 – 4.07)	0.99 (0.58 – 1.69)
Child slept under mosquito bed net the previous night	Yes	244 (46.8)	1.00	1.00
	No	277 (53.2)	1.23 (0.91 – 1.66)	1.06 (0.76 – 1.49)

Table S4B: Factors associated with receipt of antimalarial in the prior 2 weeks among survey RDT-negative children for survey year 2015

Variables	Categories	Weighted Frequencies 567 (%)	Crude Odds Ratios (95% CI)	Adjusted Odds Ratios (95% CI)
Child's age in months	6 – 11	61 (10.8)	1.00	1.00
	12 – 23	111 (19.6)	1.22 (0.74 – 2.00)	1.11 (0.64 – 1.94)
	24 – 35	132 (23.3)	1.60 (0.99 – 2.59)	1.53 (0.90 – 2.59)
	36 – 47	123 (21.7)	1.50 (0.91 – 2.46)	1.44 (0.84 – 2.47)
	48 – 59	140 (24.6)	1.72 (1.08 – 2.74)	1.71 (1.02 – 2.86)
Child's sex	Male	309 (54.5)	1.00	1.00
	Female	258 (45.5)	0.84 (0.65 – 1.10)	0.89 (0.66 – 1.19)
Mother/caregiver's age in years	15 – 20	96 (16.9)	1.00	1.00
	21 – 29	223 (39.3)	1.42 (1.02 – 1.98)	0.99 (0.68 – 1.44)
	30 – 39	209 (36.9)	1.44 (0.98 – 2.13)	0.90 (0.59 – 1.39)
	≥ 40	39 (6.9)	1.02 (0.61 – 1.72)	0.73 (0.41 – 1.30)
Residence	Rural	350 (61.7)	1.00	1.00
	Urban	217 (38.3)	1.45 (1.06 – 1.99)	1.05 (0.72 – 1.52)
Mother's education	No education	89 (15.7)	1.00	1.00
	Primary education	95 (16.8)	2.91 (1.82 – 4.66)	1.89 (1.12 – 3.19)
	Secondary education	295 (52.0)	4.10 (2.88 – 5.83)	1.88 (1.19 – 2.97)
	More than secondary education	88 (15.5)	4.84 (3.06 – 7.67)	1.83 (1.03 – 3.26)
Religion	Catholic	61 (10.8)	3.99 (2.45 – 6.50)	1.94 (1.15 – 3.28)
	Islam	256 (45.1)	1.00	1.00
	Other religion	250 (44.1)	2.68 (1.93 – 3.71)	1.25 (0.84 – 1.86)
Wealth quintile	Lowest	32 (5.6)	1.00	1.00

	Second	77 (13.6)	2.00 (1.09 – 3.65)	1.72 (0.95 – 3.14)
	Middle	92 (16.2)	2.25 (1.25 – 4.08)	1.31 (0.69 – 2.47)
	Fourth	159 (28.0)	4.42 (2.56 – 7.62)	1.93 (0.99 – 3.76)
	Highest	207 (36.5)	6.30 (3.67 – 10.80)	2.03 (1.01 – 4.10)
Geopolitical zone	North-Central	105 (18.5)	1.00	1.00
	North-East	87 (15.3)	0.44 (0.27 – 0.73)	0.52 (0.31 – 0.87)
	North-West	157 (27.7)	0.98 (0.60 – 1.62)	0.92 (0.55 – 1.53)
	South-East	52 (9.2)	0.13 (0.08 – 0.22)	0.18 (0.10 – 0.31)
	South-South	71 (12.5)	0.17 (0.10 – 0.32)	0.29 (0.16 – 0.54)
	South-West	95 (16.8)	0.47 (0.27 – 0.83)	0.49 (0.28 – 0.84)
Child slept under mosquito bed net	Yes	233 (41.1)	1.00	1.00
the previous night	No	334 (58.9)	1.57 (1.16 – 2.13)	0.94 (0.67 – 1.30)

APPENDIX

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM
Office of the Institutional Review Board for Human Use

470 Administration Building
701 20th Street South
Birmingham, AL 35294-0104
205.934.3789 | Fax 205.934.1301 |
irb@uab.edu

NHSR DETERMINATION

TO: Olisakwe, Sandra

FROM: University of Alabama at Birmingham Institutional Review Board
Federalwide Assurance # FWA00005960
IORG Registration # IRB00000196 (IRB 01)
IORG Registration # IRB00000726 (IRB 02)
IORG Registration # IRB00012550 (IRB 03)

DATE: 15-Mar-2023

RE: IRB-300010792
Malaria care-seeking behavior for children 6-59 months having NMFI using DHS and MIS data from Nigeria

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The Office of the IRB has reviewed your Application for Not Human Subjects Research Designation for the above referenced project.

The reviewer has determined this project is not subject to FDA regulations and is not Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.

if you have questions or concerns, please contact the Office of the IRB at 205-934-3789.

Additional Comments:

De-identified publicly available data from https://www.dhsprogram.com/data/dataset_admin/login_main.cfm

ICF DATA AUTHORIZATION LETTER

Jan 03, 2023

Sandra Olisakwe
University of Alabama at Birmingham
United States
Request Date: 01/03/2023

Dear Sandra Olisakwe:

This is to confirm that you are approved to use the following Survey Datasets for your registered research paper titled: "Care-seeking behavior for non-malarial febrile illness for children under age 5 using the DHS 2018-21 Nigerian dataset":

Nigeria

To access the datasets, please login at: https://www.dhsprogram.com/data/dataset_admin/login_main.cfm. The user name is the registered email address, and the password is the one selected during registration.

The IRB-approved procedures for DHS public-use datasets do not in any way allow respondents, households, or sample communities to be identified. There are no names of individuals or household addresses in the data files. The geographic identifiers only go down to the regional level (where regions are typically very large geographical areas encompassing several states/provinces). Each enumeration area (Primary Sampling Unit) has a PSU number in the data file, but the PSU numbers do not have any labels to indicate their names or locations. In surveys that collect GIS coordinates in the field, the coordinates are only for the enumeration area (EA) as a whole, and not for individual households, and the measured coordinates are randomly displaced within a large geographic area so that specific enumeration areas cannot be identified.

The DHS Data may be used only for the purpose of statistical reporting and analysis, and only for your registered research. To use the data for another purpose, a new research project must be registered. All DHS data should be treated as confidential, and no effort should be made to identify any household or individual respondent interviewed in the survey. Also, be aware that re-distribution of any DHS micro-level data, either directly or within any tool/dashboard, is not permitted. Please reference the complete terms of use at: https://dhsprogram.com/Data/terms-of-use.cfm.

The data must not be passed on to other researchers without the written consent of DHS. However, if you have coresearchers registered in your account for this research paper, you are authorized to share the data with them. All data users are required to submit an electronic copy (pdf) of any reports/publications resulting from using the DHS data files to: references@dhsprogram.com.

Sincerely,

Bridgette Wellington

Bridgette Wellington
Data Archivist
The Demographic and Health Surveys (DHS) Program