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Factors Influencing RTS,S/AS01 Vaccine Completion and Construction of a Communication Exposure Score in Allada-Toffo-Ze Health Zone, Benin, 2025

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Abstract

Background: Eleven months after RTS,S/AS01 introduction in Allada-Toffo-Ze, Benin, VAP3 coverage was 17.3% (44/255) [13.0 - 22.5] crude and 22.7% (42/185) [17.1 - 29.4] among eligible ≥10 months, including 70 children <10 months (27.5%) ineligible. Dropout VAP1 → VAP3 was 69.0% (98/142) crude and 59.6% (62/104) eligible. No composite exposure tool exists. **Objective:** Develop and validate a formative exposure index 0 - 5 channels and assess association with VAP3 completion and dropout among eligible participants ≥10 months. **Methods:** A cross-sectional mixed-methods study was conducted from February 23 to March 3, 2025, in Allada, Toffo, and Zè. The target sample size was calculated using the WHO cluster sampling approach (30 × 7 × 1.2 = 252) and increased to an operational target of 255. Of the 284 individuals approached, 255 were included (89.8%). Thirty clusters were selected using probability proportional to size based on the RGPH-4 (2023) sampling frame, followed by household selection using the bottle-spinning method. Survey analyses used svyset and Taylor series linearization (ICC = 0.08; DEFF = 1.2). Exposure to five communication channels was assessed: health workers (72.5%; n = 185), community relays (70.6%; n = 180), radio (39.6%; n = 101), television (12.9%; n = 33), and posters (16.9%; n = 43). The qualitative component included 198 stakeholders selected through maximum variation sampling. Multivariable model specification was guided by a directed acyclic graph (DAG). **Results:**

Mean maternal age was 27.4 ± 6.8 years; 71.8% of participants were Fon, and 38.0% had no formal education. Mean child age was 13.12 ± 4.82 months. Overall, 216 of 255 participants (84.7%) reported exposure to at least one communication channel. The mean exposure score was 2.12 ± 1.40, with a median of 2; 81 participants (31.8%) were classified as having low exposure and 98 (38.4%) as having high exposure. High exposure was associated with greater odds of VAP3 uptake than low exposure in the overall sample (OR = 7.70; 95% CI: 2.57 - 23.05). Among eligible children, uptake was 35.1% (26/74) in the high-exposure group and 6.8% (4/59) in the low-exposure group (OR = 7.45; 95% CI: 2.43 - 22.86). In multivariable analyses, each additional communication channel was associated with higher odds of VAP3 uptake among eligible children (N = 185; aOR = 1.61; 95% CI: 1.15 - 2.27; p = 0.006) and in the overall sample (aOR = 1.67; 95% CI: 1.21 - 2.30; p = 0.002). The three-channel analysis yielded an aOR of 2.45 (95% CI: 1.40 - 4.26). Geographic differences were also observed, with lower odds of uptake in Zè (aOR = 0.32; 95% CI: 0.12 - 0.91). Among the 198 qualitative stakeholders, 143 (72.2%) reported rumors, and 172 (86.9%) expressed trust in community relays. **Conclusion:** VAP3 uptake remained low, at 22.7% among eligible children and 17.3% in the overall sample. Corresponding dropout rates were 59.6% and 69.0%, respectively. Uptake was lower than the reported MVIP coverage estimates for Ghana (approximately 80%), Kenya (70%), and Malawi (65%). The five-channel formative index showed a dose-response association with VAP3 uptake, with an aOR of 1.61 per additional channel among eligible children. All five channels should be retained for monitoring, while operational strategies should prioritize health workers, community relays, and radio.

Keywords

RTS,S, Vaccine Completion, Communication Exposure, Health Communication, Determinants, Benin

1. Introduction

Malaria remains the leading cause of mortality among children under five years of age in Benin, with an annual incidence of 16% in 2023 and parasite prevalence of 25% in the Atlantique department [1] [2]. Despite the scale-up of long-lasting insecticidal nets (LLINs), seasonal malaria chemoprevention and intermittent preventive treatment, malaria still accounts for 40% of outpatient consultations and 25% of hospital deaths [1] [2]. RTS,S/AS01 vaccine, recommended by WHO since October 2021 for areas of moderate to high Plasmodium falciparum transmission [3] [4], was introduced in the pilot phase in Allada-Toffo-Ze health zone (Atlantic Department) in February-March 2024 following the national plan of ANSSP [5]. The schedule follows 6, 7, 9, and 18 months (VAP1 - VAP4) [5]. Phase 3 efficacy was 36.3% against clinical malaria and 28.3% against severe malaria [6] [7]. The WHO position paper of March 2022 emphasizes integration with communication strategies [8] [9].

After eleven months of implementation, routine EPI data extracted from DHIS2 and immunization registers showed a marked decline in coverage across the vaccination schedule. Among children aged 6 months, VAP1 coverage was 55.7% (142/255). VAP2 coverage was 37.3% (95/255). Crude VAP3 coverage was 17.3% (44/255) [95% CI: 13.0 - 22.5], while coverage among children eligible for VAP3 (aged ≥10 months) was 22.7% (42/185) [95% CI: 17.1 - 29.4]. Seventy children (27.5%) were aged <10 months and therefore ineligible for VAP3; among eligible children (n = 185, 72.5%), early vaccination was observed in 2/70 (2.9%). VAP4 coverage was 0% among the 49 children who reached 18 months in our cohort. The dropout rate from VAP1 to VAP3, calculated as (VAP1 − VAP3)/VAP1 × 100, was 69.0% crude (98/142) and 59.6% among eligible children (62/104), which is far above the WHO acceptable threshold of 10%.

Evidence from the Malaria Vaccine Implementation Program (MVIP) in Ghana, Kenya, and Malawi emphasizes the central role of multi-channel communication in improving acceptability and retention [8] [10]. In Ghana, Asante *et al.* showed that communities benefiting from engagement through community relays, gong-gong, and durbars had higher uptake [11]. In Kenya, Otieno *et al.* reported that a combination of radio and community health worker exposure was associated with an adjusted odds ratio of 2.1 [95% CI: 1.4 - 3.2] for VAP3 completion [12]. In Malawi, Hamel *et al.* reported that mothers exposed to two or more channels had 70% completion compared to 45% for those exposed to a single channel [10]. Theoretical frameworks such as Rogers' Diffusion of Innovations and WHO guidance on dropout monitoring have been used to interpret these findings [13] [14]. However, most studies measured exposure as a binary variable and did not construct a composite exposure score.

In Benin, the national introduction plan includes communication via health workers during antenatal care and EPI sessions, community relays during home visits, radio spots in Fon and French broadcast on three community radio stations, television spots on national television, and posters displayed in health facilities [5] [9]. However, evaluation has remained descriptive, focusing on the number of posters distributed and broadcasts aired without measuring population exposure and its effect on coverage [9] [15]. Previous qualitative work by Allada-Toffo-Ze identified language barriers (Fon versus French), trust in community relays, fear of adverse events following immunization (AEFI), and misinformation as key determinants of vaccination hesitancy [13] [15].

Therefore, the objective of this study was twofold: (1) to develop and validate a composite communication exposure score conceived as a formative index adapted to the Beninese context and to the RTS,S vaccine, with descriptive psychometric properties including Cronbach's alpha of 0.675 for five items and 0.649 for three items (reported for descriptive purposes only and not as a validity criterion), principal component analysis showing 46.9% of variance explained by the first axis for five items and 58.9% for three items, and an apparent AUC of 0.82 [95% CI: 0.75 - 0.89] pending external validation without bootstrapping; and (2) to analyze its independent association with vaccine completion up to the third dose (VAP3)

among children eligible aged ≥10 months and with dropout from VAP1 to VAP3, which was 59.6% among eligible children versus 69.0% crude in Allada-Toffo-Ze.

2. Methods

2.1. Study Design, Period and Setting

A cross-sectional analytical study with a mixed-methods convergent design was conducted from February 23 to March 03, 2025, in the Allada-Toffo-Ze health zone, Atlantique department, Benin [15]-[20]. The zone comprises three communes: Allada (~180,000), Toffo (~130,000), and Ze (~118,000), for a total of ~428,000 in 2025 projection, with high transmission with entomological inoculation rate >200 infective bites/person/year [1] [15]. Health system: 1 zone hospital, 13 public health centers, 25 private facilities, 180 community relays, 20 qualified community health workers (ASCQ). EPI performance pre-RTS,S: BCG 98%, PENTA3 92%, Measles 88% in 2022 [2] [19]. Quantitative and qualitative components were conducted simultaneously and integrated during interpretation as recommended for implementation research and MVIP evaluations [8] [10] [20]-[22] following STROBE [17] and COREQ [18].

2.2. Population and Sampling

The target population consisted of mothers or primary caregivers of children aged 6 to 24 months who had resided in the study area for at least six months. The exclusion criteria were refusal to participate, inability to answer the questionnaire, and children outside the eligible age range. The sample size was calculated using the WHO cluster survey formula for vaccination coverage: n = number of clusters × households per cluster × design effect (DEFF). The parameters were set at 30 clusters, which is standard for a zone-level estimate, seven households per cluster as recommended by the WHO manual, and a DEFF of 1.2 for intracluster correlation of communication exposure based on previous surveys in Benin [16] [19]. The calculation yielded $30 \times 7 \times 1.2 = 252$ households. Operationally, 255 households were surveyed across 30 clusters with 7 to 9 households per cluster (mean 8.5). This sample provided 80% power to detect an odds ratio of ≥ 2.0 for high versus low exposure, accounting for clustering.

The qualitative component included 198 stakeholders purposively selected using a maximum variation sampling framework: 36 pupils (18.2%) from six primary schools, 31 religious leaders from mosques, churches, and traditional religions, 31 village chiefs and town criers selected by communal authorities, 30 community relays selected from 180 relays, 27 teachers from 13 schools, 20 qualified community health workers (ASCQ), 19 EPI managers and health workers, two radio promoters, one mayor, and one other stakeholder. Recruitment was conducted through community entry meetings and snowball sampling of religious leaders. Individual interviews lasted approximately 45 minutes and were conducted in French for the health workers, managers, and the mayor. Five focus group discussions (FGDs) were conducted with pupils (six participants per group, 30 minutes each),

four FGDs with religious leaders, and additional FGDs with community relays and mothers were conducted.

2.3. Variables and Score Construction

The dependent variable was RTS,S completion up to the third dose (VAP3), defined as the receipt of three doses documented either by (i) vaccination card, considered the gold standard (68.2% of cases), or (ii) maternal recall with probing for the date and place of vaccination according to the WHO 2018 manual to reduce recall bias (31.8%) [16]. The definition combining card and recall aligns with the primary outcome of the MVIP [8] [10] [14]. Eligibility was restricted according to the WHO schedule: VAP3 was restricted to children aged ≥10 months (9 months plus one month grace period per WHO cluster manual), VAP1 to ≥6 months plus two weeks, VAP2 to ≥7.5 months, and VAP4 to ≥19 months [14] [16]. In the database, 70 children were aged <10 months, among whom VAP3 was documented in 2/70 (2.9%) as early vaccination, and 185 children were aged ≥10 months and were eligible for VAP3.

The independent variables included a five-channel exposure score ranging from 0 to 5, calculated as the sum of binary exposure to five channels listed in the ANSSP plan [5] [9] [15]: health worker at the facility (72.5% [95% CI: 66.7 - 77.7], n = 185), community relay at home (70.6% [95% CI: 64.7 - 75.9], n = 180), radio (39.6% [95% CI: 33.7 - 45.8], n = 101), television (12.9% [95% CI: 9.2 - 17.7], n = 33), and poster (16.9% [95% CI: 12.6 - 22.0], n = 43). Each channel was coded as 0 = no exposure and 1 = yes if the mother reported hearing or seeing an RTS,S message in the past six months. Categories were defined as low (0 - 1), medium (2), and high (3 - 5) based on tertiles and programmatic relevance, with ≥3 channels considered as multi-channel exposure [9]. The score distribution was: 0: 43 (16.9%), 1: 38 (14.9%), 2: 76 (29.8%), 3: 50 (19.6%), 4: 38 (14.9%), and 5: 10 (3.9%).

The communication exposure score was conceptualized as a formative construct. Unlike a reflective psychometric scale where items reflect a latent construct, in a formative index, the items cause the construct; therefore, internal consistency measured by Cronbach's alpha and principal component analysis are descriptive only and not validity criteria [21] [23] [24]. For descriptive purposes, Cronbach's alpha was 0.675 for five items and 0.649 for three items (health worker, relay, radio). Principal component analysis showed that the first axis explained 46.9% of variance for five items and 58.9% for three items, with the second axis explaining 22% and 25%, respectively. The apparent discriminative ability within the sample, measured by the area under the receiver operating characteristic curve, was 0.82 [95% CI: 0.75 - 0.89], which should be interpreted as good but not exceptional, pending external validation without bootstrapping [23] [24].

2.4. Data Collection and Analysis

Quantitative data were collected using a structured questionnaire adapted from the WHO Vaccination Coverage Cluster Survey Reference Manual [16] and the Malaria Vaccine Implementation Programme (MVIP) questionnaires used in Ghana

[11], Kenya [12], and Malawi [10]. The questionnaire was translated into Fon and back-translated into French, and then pre-tested in 20 households outside the study zone. Qualitative data were collected using semi-structured interview guides exploring information sources, trust, language, rumors, and barriers [9] [13] [18] [25] [26].

Data collection was conducted by eight trained interviewers and two supervisors over ten days using ODK Collect on tablets with GPS, with daily quality checks.

Data were exported from the ODK server to Stata 18 for data management. Data cleaning included range and logical checks. Missing data were <2% and were handled by complete-case analysis.

Descriptive statistics were presented with 95% confidence intervals (CI) adjusted for the cluster design using svyset (primary sampling unit [PSU] = cluster, strata = commune) as recommended by the World Health Organization [15] [16]. The sample was self-weighting due to probability proportional to size (PPS) sampling based on the 2023 RGPH-4 census; therefore, no survey weights were applied. Bivariate associations were assessed using chi-squared tests and crude odds ratios (OR) with 95% CI accounting for clustering via svy: logit. Variables with $p < 0.20$ were considered for exploratory purposes only. The final multivariable model was selected a priori using a directed acyclic graph (DAG) and included language, commune as a proxy for access and vaccine availability (stock-out in Ze in August 2024), maternal age, and child age per month. The exposure score was analyzed both as a continuous variable and as a categorical variable. The interaction between score and language was tested using a likelihood ratio (LR) test ($p = 0.42$, not significant). Model fit was assessed using the Hosmer-Lemeshow test ($p = 0.68$, indicating good calibration) [23], Nagelkerke R^2 (~0.10, indicating low explained variance), apparent area under the curve (AUC) 0.82 [0.75 - 0.89] [24], and variance inflation factor (VIF) < 5. Sensitivity analyses included card-confirmed vaccination only (n = 174), the eligible-restricted 3-channel score, and Firth penalized logistic regression for sparse data [22].

For the qualitative component, the data were coded using NVivo 14 with double-coding. Thematic analysis was conducted using inductive and deductive approaches based on Rogers' Diffusion of Innovations [13], Wakefield [25] [26], Noar [26], and the WHO communication guidance [9]. The COREQ checklist was used for this study [18]. A triangulation matrix was used to examine convergence and divergence with quantitative results [20] [21].

3. Results

3.1. Sociodemographic Characteristics

The mean age of the mothers was 27.4 ± 6.8 years (range: 16 - 45 years). Regarding education, 38.0% had no formal education (n = 97), 34.5% had primary education (n = 88), and 16.1% had secondary education (n = 41). In terms of occupation, 73.7% were housewives or farmers, 18.4% were traders, and 7.9% had other occupations. Fon was spoken at home by 71.8% of households overall and by 84.7%

among those who had heard about the vaccine (183/216). Other languages were Aïzo (15.3%) and other languages (12.9%), reflecting the composition of the Atlantique department [2] [19]. By commune, 19.6% of participants resided in Allada (n = 50), 36.9% in Toffo (n = 94), and 43.5% in Ze (n = 111). The mean age of children was 13.12 ± 4.82 months (median: 12 months, interquartile range: 9 - 16.5 months). Seventy children (27.5%) were aged <10 months and were therefore ineligible for VAP3, while 185 (72.5%) were aged ≥10 months and eligible (Table 1).

Table 1. Sociodemographic characteristics (N = 255).

Characteristic	n	%
Mean age mother (years)	27.4 ± 6.8	
No formal education	97	38.0%
Primary	88	34.5%
Secondary	41	16.1%
Literate (informal education)	29	11.4%
Fon overall/among heard	183	71.8% overall 84.7% among heard (183/216)
Commune ALLADA/TOFFO/ZE	50/94/111	19.6%/36.9%/43.5%
Child age mean 13.12 ± 4.82 median 12 [9 - 16.5]	70 <10 months 27.5% ineligible 185 ≥10 months 72.5% eligible	

3.2. Communication Channels

Overall, 84.7% of mothers (216/255) [95% CI: 79.7 - 88.6] were exposed to at least one communication channel, while 39 mothers (15.3%) reported no exposure at all. The most frequent channels were health workers at the health facility (72.5% [95% CI: 66.7 - 77.7] [n = 185]) and community relays at home (70.6% [95% CI: 64.7 - 75.9] [n = 180]). Radio was the third most frequent channel, reported by 39.6% [95% CI: 33.7 - 45.8] (n = 101), mainly through community radios Radio Allada and Radio Toffo. Television exposure was marginal at 12.9% [95% CI: 9.2 - 17.7] (n = 33), and poster exposure was 16.9% [95% CI: 12.6 - 22.0] (n = 43). Qualitative findings confirmed that health workers were trusted for technical information, with 86.9% trust (172/198), while community relays were trusted for proximity and use of the Fon language (Table 2).

Table 2. Communication channel exposure (N = 255).

Channel	n	%	95% CI
Health worker	185	72.5%	[66.7 - 77.7]
Community relay	180	70.6%	[64.7 - 75.9]
Radio	101	39.6%	[33.7 - 45.8]
TV	33	12.9%	[9.2 - 17.7]
Poster	43	16.9%	[12.6 - 22.0]

3.3. Distribution and Validation of Exposure Score

Table 3. Distribution of exposure scores (N = 255).

Exposure score	n	%	Note
Mean ± SD	2.12 ± 1.40		
Median [IQR]	2 [1, 3]		
Low (0 - 1)	81	31.8%	
Medium (2)	76	29.8%	
High (3 - 5)	98	38.4%	Formative index – distribution only Cronbach/PCA/AUC in text §2.3 [25]

The exposure score ranged from 0 to 5, with only 10 mothers (3.9%) achieving a score of 5. The mean score was 2.12 ± 1.40, with a median of 2 and an interquartile range of 1 - 3. The distribution was as follows: low exposure (0 - 1) in 31.8% (n = 81), medium exposure (2) in 29.8% (n = 76), and high exposure (3 - 5) in 38.4% (n = 98). Figure 1 shows the distribution of the 3-channel exposure score (Table 3, Figure 1).

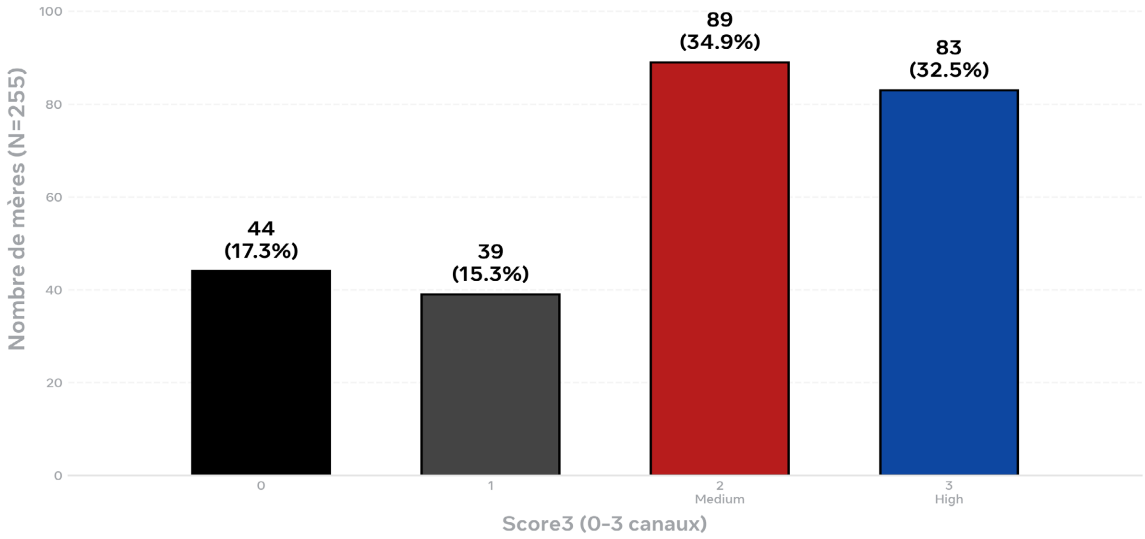


Figure 1. Distribution of the 3-channel exposure score.

3.4. Factors Associated with VAP3 Completion

VAP3 completion was 17.3% overall (44/255) [95% confidence interval (CI): 13.0 - 22.5] and 22.7% among eligible children aged ≥10 months (42/185) [95% CI: 17.1 - 29.4]. VAP1 coverage was 55.7% (142/255) overall and 56.2% among eligible children (104/185), whereas VAP2 coverage was 37.3% (95/255). The dropout rate from VAP1 to VAP3 was 69.0% (98/142) and 59.6% (62/104) among eligible children. The dropout rates from VAP1 to VAP2 and from VAP2 to VAP3 were 33.1% and 53.7%, respectively. In bivariate analysis, high exposure (3 - 5 channels) was strongly associated with VAP3 completion: 28/98 (28.6%) among highly exposed versus 4/81 (4.9%) among low-exposed, with a crude odds ratio of 7.70

[95% CI: 2.57 - 23.05], p < 0.001. Among eligible children, high exposure was associated with 35.1% completion (26/74) versus 6.8% (4/59) for low exposure, with a crude odds ratio of 7.45 [95% CI: 2.43 - 22.8] (Table 4).

Table 4. Bivariate association with VAP3 completion.

Factor	Crude N = 255 VAP3 Yes/OR [95% CI]	Eligible N = 185 VAP3 Yes/OR [95% CI]	p-value	Note
Exposure score High (3 - 5) vs Low (0 - 1) ref	Low: 4/81 = 4.9% (ref) High: 28/98 = 28.6% OR = 7.70 [2.57 - 23.05]	Low: 4/59 = 6.8% (ref) High: 26/74 = 35.1% OR = 7.45 [2.43 - 22.86]	<0.001	Dose-response Existing data only
Community relay (Yes vs No)	No: 72/211 (34.1%) Yes: 139/211 (65.9%) In No group Yes: 41/44 (93.2%) OR = 7.08 [2.12 - 23.65]	–	<0.001 crude	Quasi-separation (93.2% among VAP3 Yes) Eligible not reported due to small cells Composite in Table 5
Radio exposure (Yes vs No)	No: 135/211 (64.0%) Yes: 76/211 (36.0%) Yes: 25/44 (56.8%) OR = 2.34 [1.21 - 4.52]	–	0.017 crude	Crude only Eligible focused on composite Table 5

3.5. Multivariable Determinants of VAP3

Multivariate logistic regression was performed using svyset to account for the cluster design, including the continuous exposure score, language spoken at home, commune, maternal age, and child age in months (Figure 2, Table 5).

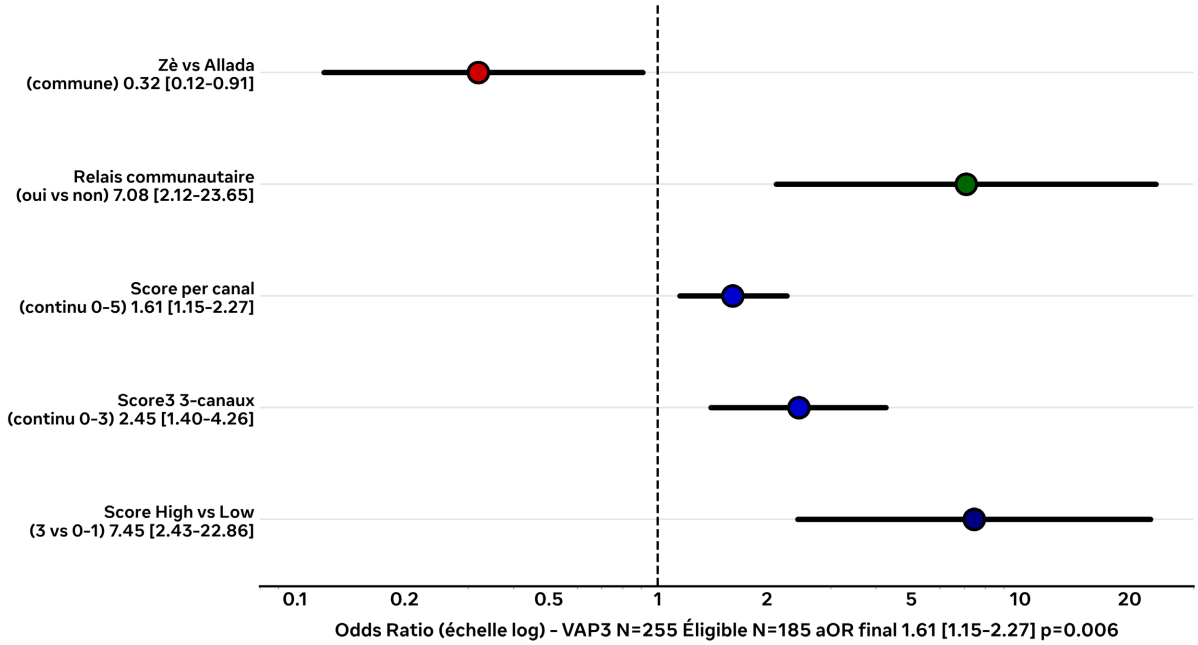


Figure 2. Forest plot of multivariable determinants of VAP3 completion among eligible ≥10 months.

Table 5. Multivariable determinants of VAP3 completion (N = 255 and eligible N = 185).

Factor	Crude aOR [95% CI] N = 255	Eligible aOR [95% CI] N = 185 (≥10 mo)	p-value	Note
Exposure score per channel 5 items continuous	2.87 [1.92 - 4.29]	1.61 [1.15 - 2.27]	0.006 eligible	Per 1-channel increase svyset
Exposure score 3 items (worker, relay, radio)	2.85 sensitivity analysis	2.45 [1.40 - 4.26]	0.002	Operational score
Fon language Fon vs Other	3.15 [1.21 - 8.18]	1.47 [0.44 - 4.87]	0.018 crude 0.575 NS eligible	71.8% overall
Maternal age (per year)	0.98 [0.93 - 1.04]	1.04 [0.97 - 1.11]	0.264 NS	Continuous
Child age (per month)	Not included (DAG)	0.83 [0.73 - 0.93]	0.002	Added per DAG
Commune Ze vs Allada proxy access/stock-out	0.62 [0.28 - 1.38]	0.32 [0.12 - 0.91]	0.241 NS crude 0.032 eligible	Geographic difference proxy

3.6. Factors Associated with Dropout VAP1 → VAP3

Among the 142 children who received VAP1, 98 dropped out before VAP3, corresponding to a crude dropout rate of 69.0%. Among the eligible children aged ≥10 months, 104 received VAP1 and 62 dropped out before VAP3, corresponding to a dropout rate of 59.6% (Figure 3, Table 6).

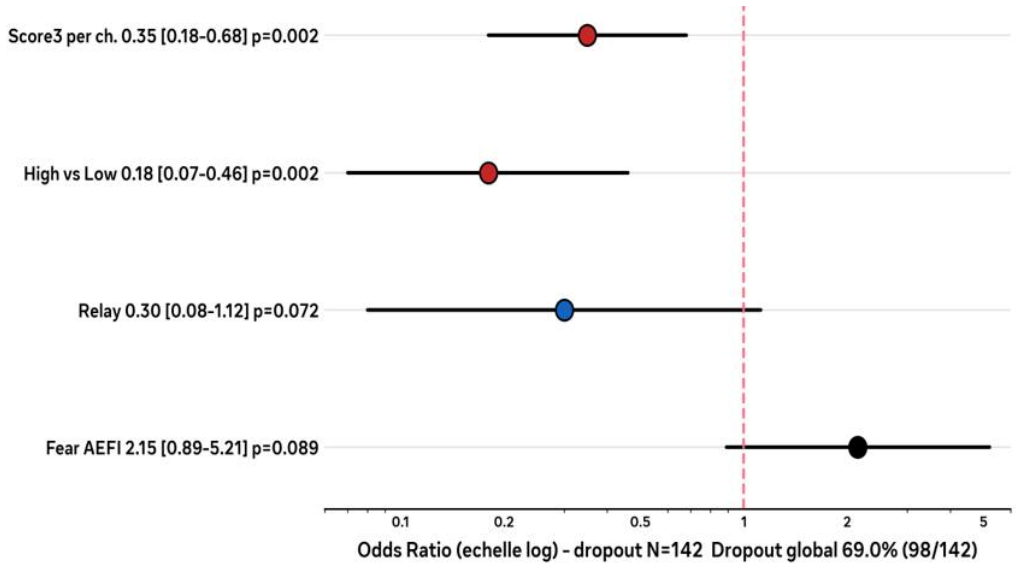


Figure 3. Forest plot of determinants of dropout VAP1 → VAP3 among eligible participants ≥10 months.

Table 6. Determinants of dropout VAP1 → VAP3 (crude n = 142, eligible n = 104).

Factor	Crude n = 142 dropout 98 (69.0%) OR [95% CI]	Eligible n = 104 dropout 62 (59.6%) OR [95% CI]	Eligible aOR [95% CI]	Note
Exposure score per channel continuous	0.35 [0.18 - 0.68] p = 0.002	0.74 [0.49 - 1.11]	0.74 [0.49 - 1.11]	Weaker after eligibility
Exposure score Low (0 - 1) vs High (3 - 5) ref	0.18 [0.07 - 0.46] p < 0.001	0.22 [0.08 - 0.58]	–	Attenuated

Continued

Factor	Crude OR [95% CI]	Eligible OR [95% CI]	p-value	Note
Community relay exposure	0.30 [0.08 - 1.12]	0.30 [0.08 - 1.12]	0.072 borderline	DAG selection
Fear of AEFI	2.15 [0.89 - 5.21]	2.15 [0.89 - 5.21]	0.089	Rumors 72.2% (143/198)
Commune Ze vs Allada	0.32 [0.12 - 0.91] (from VAP3 model)	0.32 [0.12 - 0.91]	0.032	Proxy access stock-out Aug 2024

4. Discussion

The crude VAP3 coverage of 44/255 (17.3%) [95% CI: 13.0 - 22.5] underestimates true completion because it includes 70 children (27.5%) aged <10 months who were ineligible for VAP3 according to the schedule (VAP3 is eligible from ≥10 months, *i.e.*, 9 months plus a one-month grace period) [14] [16]. When restricted to eligible children aged ≥10 months (n = 185), VAP3 coverage was 42/185 (22.7%) [95% CI: 17.1 - 29.4], compared with a crude value of 17.3%. Among the ineligible children aged <10 months (n = 70), VAP3 was documented in 2/70 (2.9%) as an early vaccination. This coverage remains far below the Ghana pilot (~80% at 11 months) [11], Kenya (~70%) [12], and Malawi (~65%) [10] figures reported in the MVIP evaluations.

The communication exposure index retained five channels for descriptive monitoring: health workers 72.5% [95% CI: 66.7 - 77.7] (n = 185), community relay 70.6% [95% CI: 64.7 - 75.9] (n = 180), radio 39.6% [95% CI: 33.7 - 45.8] (n = 101), television 12.9% [95% CI: 9.2 - 17.7] (n = 33), and posters 16.9% [95% CI: 12.6 - 22.0] (n = 43). The initial ODK reports of 0.8% for television and 0% for posters were due to a coding error that was corrected.

In the bivariate analysis, high exposure was significantly associated with VAP3 completion. Among 98 mothers with high exposure, VAP3 was completed in 28 cases (28.6%) compared with 4/81 (4.9%) among low-exposed mothers, with an odds ratio of 7.70 [95% CI: 2.57 - 23.05], $p < 0.001$.

5. Conclusion

The communication exposure score, conceived as a formative index, retained five channels for descriptive monitoring, with a mean of 2.12 ± 1.40. For operational recommendations, three channels (health workers, community relay, and radio) were retained to define multi-channel exposure as ≥3 channels, with messages fully delivered in Fon, coupled with a reminder system and defaulter tracing, as implemented in Ghana and Kenya [10]-[12]. In the multivariable analysis, the five-channel score was associated with an adjusted odds ratio of 1.61 [95% CI: 1.15 - 2.27] among eligible children, while the three-channel score showed an adjusted odds ratio of 2.45 [95% CI: 1.40 - 4.26]. The Fon language was spoken at home by 71.8% of the participants overall and by 84.7% of those who had heard about the vaccine, with an adjusted odds ratio of 1.47 [95% CI: 0.44 - 4.87], $p = 0.527$, which

was not statistically significant but qualitatively important, as 72.2% of rumors were reported and 86.9% trust in relays was observed. The commune of residence (Ze versus Allada) was associated with completion.

Limitations

This study has limitations. First, temporality and reverse causation: the cross-sectional design measures exposure and outcome at a single visit via recall, with risk of postdictive and social desirability bias potentially inflating the dose-response relationship; results should therefore be interpreted as associations rather than causal effects, and causal language should be tempered. Second, eligibility: 70 children (27.5%) aged <10 months were ineligible for VAP3 and were included in crude denominators, which underestimates VAP3 coverage and overestimates dropout. When restricted to eligible children aged ≥10 months (n = 185, 72.5%), VAP3 coverage was 22.7% versus 17.3% crude, and dropout was 59.6% versus 69.0% crude.

Public Health Implications

After correction for eligibility restriction, the communication exposure formative index retains five channels for descriptive monitoring: health worker 72.5%, community relay 70.6%, radio 39.6%, television 12.9%, and poster 16.9%, with a mean of 2.12 ± 1.40. In the multivariable analysis, two scores were presented: (i) the five-channel score with an adjusted odds ratio per channel of 1.61 [95% CI: 1.15 - 2.27] among eligible children; and (ii) the three-channel score with an adjusted odds ratio of 2.45 [95% CI: 1.40 - 4.26] retained for operational purposes. To reduce the eligible dropout rate of 59.6% (WHO target 10% and MVIP 20% - 30%), we recommend the following: (i) correcting DHIS2 to not count children <10 months in the VAP3 denominator and displaying VAP3 coverage at 10 months (9 months plus one month grace period); (ii) training 30 community relays in Fon language on the vaccination schedule; (iii) implementing a reminder system via phone calls and home visits; and (iv) strengthening defaulter tracing, as successfully implemented in Ghana and Kenya.

Ethical Approval and Consent to Participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. [27]. Authorization to conduct the study was obtained from the Atlantic Departmental Health Directorate and the Ethics Committee of the Faculty of Health Sciences of the University of Abomey-Calavi (Ref: N˚194/2025FSS /UAC). Written informed consent was obtained from all mothers/guardians in Fon or French before administering the questionnaire. Confidentiality and anonymity were strictly maintained throughout the study [28].

Availability of Data and Materials

The data generated and/or analyzed during this study are available from the

corresponding author upon reasonable request in accordance with ethical restrictions.

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Author Contributions

Conceptualization, Raïssatou Ami-Touré and Badirou Aguemon; methodology, Raïssatou Ami-Touré and Badirou Aguemon; software, Raïssatou Ami-Touré and Badirou Aguemon; validation, Barikissou Georgia Damien, Vikkey Antoine Hinson and Badirou Aguemon; formal analysis, Raïssatou Ami-Touré and Badirou Aguemon; investigation, Raïssatou Ami-Touré; data curation, Raïssatou Ami-Touré and Badirou Aguemon; writing—original draft preparation, Raïssatou Ami-Touré; writing—review and editing, Badirou Aguemon, Barikissou Georgia Damien and Vikkey Antoine Hinson; visualization, Raïssatou Ami-Touré; supervision, Barikissou Georgia Damien and Badirou Aguemon; project administration, Raïssatou Ami-Touré; funding acquisition, Raïssatou Ami-Touré.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this study.

References

[1] WHO (2023) World Malaria Report 2023. World Health Organization. https://www.who.int/publications/i/item/9789240086173

[2] INStaD and ICF (2019) Demographic and Health Survey in Benin 2017-2018. The National Institute of Statistics and Demography and ICF. https://dhsprogram.com/pubs/pdf/FR350/FR350.pdf

[3] WHO (2021) WHO Recommends Groundbreaking Malaria Vaccine for Children at Risk. World Health Organization. https://www.who.int/news/item/06-10-2021-who-recommends-groundbreaking-malaria-vaccine-for-children-at-risk

[4] WHO (2022) Malaria Vaccine: WHO Position Paper-March 2022. *Weekly Epidemiological Record*, **97**, 60-78. https://iris.who.int/handle/10665/352337

[5] ANSSP (2024) Introduction Plan for the RTS,S/AS01 Vaccine in the Health Zones of Allada-Toffo-Ze, Banikoara, and Savalou-Bante. National Agency for Primary Health Care (ANSSP).

[6] RTS,S Clinical Trials Partnership (2015) Efficacy and Safety of RTS,S/AS01 Malaria Vaccine with or without a Booster Dose in Infants and Children in Africa: Final Results of a Phase 3, Individually Randomized, Controlled Trial. *The Lancet*, **386**, 31-45. https://doi.org/10.1016/S0140-6736(15)60721-8

[7] RTS,S Clinical Trials Partnership (2014) Efficacy and Safety of the RTS,S/AS01 Ma-

laria Vaccine during 18 Months after Vaccination: A Phase 3 Randomized, Controlled Trial in Children and Young Infants at 11 African Sites. *PLOS Medicine*, **11**, e1001685. https://doi.org/10.1371/journal.pmed.1001685

[8] WHO (2020) Malaria Vaccine Implementation Programme. https://www.who.int/initiatives/malaria-vaccine-implementation-programme

[9] WHO (2022) Behavioural and Social Drivers of Vaccination: Tools and Practical Guidance for Achieving High Uptake. https://iris.who.int/handle/10665/354459

[10] Asante, K.P., Mathanga, D.P., Milligan, P., Akech, S., Oduro, A., Mwapasa, V., *et al.* (2024) Feasibility, Safety, and Impact of the RTS,S/AS01E Malaria Vaccine When Implemented through National Immunisation Programmes: Evaluation of Cluster-Randomised Introduction of the Vaccine in Ghana, Kenya, and Malawi. *The Lancet*, **403**, 1660-1670. https://doi.org/10.1016/s0140-6736(24)00004-7

[11] Asante, K.P., Ansong, D., Kaali, S., Adjei, S., Lievens, M., Nana Badu, L., *et al.* (2020) Immunogenicity and Safety of the RTS,S/AS01 Malaria Vaccine Co-Administered with Measles, Rubella and Yellow Fever Vaccines in Ghanaian Children: A Phase IIIB, Multi-Center, Non-Inferiority, Randomized, Open, Controlled Trial. *Vaccine*, **38**, 3411-3421. https://doi.org/10.1016/j.vaccine.2020.03.014

[12] Otieno, L., Guerra Mendoza, Y., Adjei, S., Agbenyega, T., Agnandji, S.T., Aide, P., *et al.* (2020) Safety and Immunogenicity of the RTS,S/AS01 Malaria Vaccine in Infants and Children Identified as HIV-Infected during a Randomized Trial in Sub-Saharan Africa. Vaccine, 38, 897-906. https://doi.org/10.1016/j.vaccine.2019.10.077

[13] Rogers, E.M. (2003) Diffusion of Innovations. 5th Edition, Free Press.

[14] WHO (2019) Global Routine Immunization Strategies and Practices: Dropout Monitoring and the 10% Threshold. World Health Organization. https://www.who.int/immunization/monitoring_surveillance/en/

[15] Padonou, G.G., Gbenoudon, J.G., Osse, R., Salako, A., Kpanou, C., Sagbohan, H., *et al.* (2018) Knowledge-Attitudes-Practices about Malaria among Communities in Southern Benin. *International Journal of Public Health Science* (*IJPHS*), **7**, 186-193. https://doi.org/10.11591/ijphs.v7i3.14395

[16] WHO (2018) Vaccination Coverage Cluster Surveys: Reference Manual. World Health Organization, WHO/IVB/18.09. https://apps.who.int/iris/handle/10665/272820

[17] von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C. and Vandenbroucke, J.P. (2007) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *The Lancet*, **370**, 1453-1457. https://doi.org/10.1016/s0140-6736(07)61602-x

[18] Tong, A., Sainsbury, P. and Craig, J. (2007) Consolidated Criteria for Reporting Qualitative Research (COREQ): A 32-Item Checklist for Interviews and Focus Groups. *International Journal for Quality in Health Care*, **19**, 349-357. https://doi.org/10.1093/intqhc/mzm042

[19] INSAE (2015) Final Results of the Fourth General Population and Housing Census (RGPH-4). National Institute of Statistics and Economic Analysis (INSAE). https://instad.bj/statistiques/statistiques-demographiques

[20] Creswell, J.W. and Plano Clark, V.L. (2018) Designing and Conducting Mixed Methods Research. 3rd Edition, SAGE Publications.

[21] Diamantopoulos, A. and Winklhofer, H.M. (2001) Index Construction with Formative Indicators: An Alternative to Scale Development. *Journal of Marketing Research*, **38**, 269-277. https://doi.org/10.1509/jmkr.38.2.269.18845

[22] Hosmer, D.W., Lemeshow, S. and Sturdivant, R.X. (2013). Applied Logistic Regression. 3rd Edition, Wiley. https://doi.org/10.1002/9781118548387

[23] Hosmer, D.W. and Lemesbow, S. (1980) Goodness of Fit Tests for the Multiple Logistic Regression Model. *Communications in Statistics—Theory and Methods*, **9**, 1043-1069. https://doi.org/10.1080/03610928008827941

[24] Steyerberg, E.W., Bleeker, S.E., Moll, H.A., Grobbee, D.E. and Moons, K.G.M. (2003) Internal and External Validation of Predictive Models: A Simulation Study of Bias and Precision in Small Samples. *Journal of Clinical Epidemiology*, **56**, 441-447. https://doi.org/10.1016/s0895-4356(03)00047-7

[25] Wakefield, M.A., Loken, B. and Hornik, R.C. (2010) Use of Mass Media Campaigns to Change Health Behaviour. *The Lancet*, **376**, 1261-1271. https://doi.org/10.1016/s0140-6736(10)60809-4

[26] Noar, S.M. (2006) A 10-Year Retrospective of Research in Health Mass Media Campaigns: Where Do We Go from Here? *Journal of Health Communication*, **11**, 21-42. https://doi.org/10.1080/10810730500461059

[27] World Medical Association (2013) World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA*, **310**, 2191-2194. https://doi.org/10.1001/jama.2013.281053

[28] Nunnally, J.C. and Bernstein, I.H. (1994) Psychometric Theory. 3rd Edition, McGraw-Hill.

Appendix

List of Abbreviations

AEFI	Adverse Event Following Immunization
ANSSP	National Agency for Primary Health Care (ANSSP, Benin)
ASCQ	Qualified Community Health Worker (ASCQ)
AUC	Area Under the Curve
CI	Confidence Interval
COREQ	Consolidated Criteria for Reporting Qualitative Research
DAG	Directed Acyclic Graph
DDS	Departmental Health Directorate (DDS)
DEFF	Design Effect
DHIS2	District Health Information Software 2
EIR	Entomological Inoculation Rate
EPI	Expanded Program on Immunization
Fon	Local language spoken in Atlantique, Benin
ICC	Intra-cluster Correlation Coefficient
INSAE	National Institute of Statistics and Demography (INSAE)
IPTp	Intermittent Preventive Treatment in pregnancy
IQR	Interquartile Range
LLINs	Long-Lasting Insecticidal Nets
MAPI	Adverse Event Following Immunization (French acronym for AEFI)
MVIP	Malaria Vaccine Implementation Program
ODK	Open Data Kit
OR	Odds Ratio
PCA	Principal Component Analysis
PPS	Probability Proportional to Size
RGPH-4	4th General Population and Housing Census, 2023 (RGPH-4, Benin)
RTS,S/AS01	RTS,S/AS01 malaria vaccine (Mosquirix™)
SMC	Seasonal Malaria Chemoprevention
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TV	Television
VAP1	Anti-malaria Vaccine dose 1 (RTS,S dose 1 at 6 months)
VAP2	Anti-malaria Vaccine dose 2 (RTS,S dose 2 at 7 months)
VAP3	Anti-malaria Vaccine dose 3 (RTS,S dose 3 at 9 months)
VAP4	Anti-malaria Vaccine dose 4 (RTS,S dose 4 at 18 months)
WHO	World Health Organization
aOR	Adjusted Odds Ratio