

Effectiveness of a Short Message Service (SMS)-Based Mobile Health Intervention on Routine Childhood Vaccination Uptake In Keffi Local Government Area, Nasarawa State, Nigeria: A Quasi-Experimental Study

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ABSTRACT

Missed and delayed childhood vaccinations remain a challenge in low-resource settings, including Nigeria. Mobile health (mHealth) interventions, particularly Short Message Service (SMS) reminders, may offer an affordable and practical way to help caregivers keep children's vaccinations on schedule. This study assessed the effect of an SMS-based intervention on routine childhood vaccination uptake in Keffi Local Government Area, Nasarawa State, Nigeria. A quasi-experimental, non-randomized, two-group study was conducted among 423 caregivers of children aged 0–23 months from urban and rural wards in Keffi. Caregivers were allocated sequentially to either the SMS group (n = 223), which received scheduled vaccination reminders for 12 weeks, or the comparison group (n = 200), which received routine services without SMS reminders. The study assessed immunization schedule completion, antigen-specific coverage, and dropout rates. Among caregivers in the SMS group, message delivery, engagement, and acceptability were also assessed. Data were analysed using chi-square tests, with statistical significance set at $p < 0.05$. The two groups had broadly similar sociodemographic characteristics. Completion of the routine immunization schedule was significantly higher in the SMS group than in the comparison group (78.0% vs. 42.5%; $p < 0.001$). Coverage was higher in the SMS group for all antigens assessed, with statistically significant differences for OPV3, Penta-3, PCV3, and measles-containing vaccine, but not for BCG. Dropout in the SMS group declined from 22.1% at baseline to 6.4% at endline ($p < 0.001$), whereas dropout in the comparison group changed only slightly, from 20.5% to 18.9%. Of all SMS reminders sent, 91.9% were successfully delivered, and 87.0% of caregivers reported that the reminders helped them keep their children's vaccinations on schedule. SMS reminders were associated with higher routine childhood vaccination completion and lower dropout rates compared with routine care alone. Integrating SMS reminders into routine immunization services may help improve vaccination uptake in similar low-resource settings.

Keywords: mHealth, SMS reminders, childhood immunization, vaccination uptake, Nigeria

INTRODUCTION

Childhood immunization is a cost-effective public health intervention that protects children from vaccine-preventable diseases such as measles, poliomyelitis, diphtheria, and tuberculosis, thereby reducing childhood illness and deaths globally [1]. However, immunization coverage remains uneven worldwide. High-income countries generally achieve better coverage because of stronger health systems and easier access to services, whereas many low- and middle-income countries, particularly in sub-Saharan Africa, continue to experience low vaccination uptake [1]. The COVID-19 pandemic further disrupted routine immunization services across the

region, leading to declines in vaccination coverage and leaving many children under-immunized [2]. Despite efforts through the Expanded Programme on Immunization and regional immunization strategies, vaccination coverage in the WHO African Region remains below global targets, showing that important gaps still need to be addressed fifty years after the programme began [3].

Nigeria continues to experience low and uneven childhood immunization coverage across different geographical areas. According to the 2018 Nigeria Demographic and Health Survey, only 31% of children aged 12–23 months had received all basic vaccines, while 19% had not received any basic vaccine [4]. Factors contributing to incomplete immunization include missed appointments, caregiver forgetfulness, long distances to health facilities, financial difficulties, and weak systems for identifying and following up children who miss scheduled vaccination visits [5,6]. Children are more likely to miss vaccines that require several doses, particularly those given later in infancy, such as measles-containing vaccines. This is because each additional clinic visit creates another opportunity for a caregiver to miss the scheduled vaccination [7–9].

Mobile health (mHealth) interventions, particularly SMS reminders, may provide a low-cost and scalable way to address these gaps. By reminding caregivers about upcoming vaccination appointments, SMS messages can help reduce missed visits caused by forgetfulness [10]. Studies from Kenya, Zimbabwe, Ethiopia, Guatemala, and Pakistan have shown that SMS reminders can improve the timely receipt and completion of childhood vaccinations, particularly for vaccines that require multiple doses and repeated clinic visits [11–14,25,26,30]. A Cochrane review of interventions to improve childhood immunization coverage in low- and middle-income countries found that reminder- and information-based approaches, including SMS reminders, may help improve vaccination uptake. However, the effect of these interventions may vary according to the setting, message design, and level of support within the health system [10,27].

In Nigeria, evidence on the use of mHealth interventions to support routine childhood immunization remains limited, particularly at the local government level, where gaps in service delivery and caregiver follow-up are often most apparent [9,16]. Available studies in Nigeria suggest that caregivers generally accept SMS reminders for their children's immunization appointments [28,29]. Keffi LGA in Nasarawa State is a semi-urban area comprising both urban and rural communities. The area faces challenges that may affect routine childhood immunization, including vaccine stock-outs, inconsistent caregiver follow-up, and gaps in vaccination coverage [5,6]. The widespread use of mobile phones in the area provides an opportunity to assess whether SMS reminders can support routine immunization services and improve caregiver follow-up [16]. This study assessed the effectiveness of a structured, facility-supported SMS reminder intervention in improving routine childhood vaccination uptake among children aged 0–23 months in Keffi LGA. The study compared vaccination outcomes between caregivers who received SMS reminders and those who did not. Specifically, it aimed to determine baseline vaccination coverage, implement and monitor an SMS reminder system, assess its effect on vaccination completion and dropout, identify barriers and facilitators influencing caregivers' response to the reminders, and evaluate the acceptability and feasibility of integrating SMS reminders into routine immunization service delivery.

METHODS

Study design and setting

This study used a quasi-experimental, non-randomized, two-group design to compare routine childhood vaccination outcomes among caregivers who received SMS vaccination reminders and those who did not. The intervention was implemented over a 12-week period. A quasi-experimental design was considered appropriate because the study was conducted within routine, facility-based immunization services, where individual randomization was not feasible [17]. The study was conducted in Keffi Local Government Area (LGA), Nasarawa State, North Central Nigeria, near the Federal Capital Territory, Abuja. Keffi LGA includes urban and

peri-urban communities with varying access to health services. Routine immunization services are provided through the Federal Medical Centre, General Hospital Keffi, primary healthcare centres, and private health facilities operating under Nigeria's Expanded Programme on Immunization. The availability of mobile phones among eligible caregivers provided an opportunity to assess the use of SMS reminders in supporting routine immunization services.

Participants

Eligible participants were primary caregivers of children aged 0–23 months who lived in Keffi LGA, owned or had reliable access to a mobile phone that could receive SMS messages, and provided informed consent. Caregivers were excluded if they were not permanent residents of Keffi LGA, were unable to communicate effectively because of illness or cognitive impairment, or had children who had already completed the national routine immunization schedule.

Sample size and sampling

The minimum sample size was calculated using the Cochran formula for an unknown population proportion ($Z=1.96$, $p=0.5$, $d=0.05$), yielding a minimum of 384 participants; a 10% allowance for non-response and attrition brought the target sample to 423 caregivers.

Using my stated values:

$$n = \frac{(1.96)^2(0.5)(1 - 0.5)}{(0.05)^2} = 384.16$$

The minimum required sample is conventionally rounded to **384**; increasing this by 10% gives approximately **422.4**, which rounds to **423 caregivers**.

A multistage sampling approach was used: wards in Keffi LGA were first stratified into urban and rural strata, after which health facilities providing immunization services were randomly selected from each stratum, yielding a common pool of facilities in which both study groups were subsequently enrolled.

Group allocation

Facility selection and group allocation were carried out in two stages. First, health facilities were randomly selected from the urban and rural strata to serve as study sites. Both the SMS and comparison groups were recruited from the same selected facilities. This approach helped to reduce the influence of differences in staffing, service quality, or other facility-level factors between study sites.

Second, eligible caregivers attending immunization clinics at the selected facilities were enrolled consecutively according to the order in which they presented. Participants were assigned alternately to the SMS intervention group or comparison group using sequential allocation. Caregivers did not choose their study group. Recruitment continued until the target sample size for each group was reached (223 SMS, 200 comparison).

This allocation method was neither facility-based nor individually randomized. Instead, caregivers were assigned to the SMS or comparison group using a fixed alternating sequence at the point of enrolment. Although this approach prevented caregivers from selecting their preferred study group and was practical to implement during routine clinic activities, it was not equivalent to true randomization.

Because the allocation sequence was predictable, enrolling staff may have been aware of the next group assignment. In addition, a fixed sequence may not ensure that unmeasured characteristics that changed during the recruitment period, such as seasonal patterns of clinic attendance or changes in the caregivers attending the facilities, were equally distributed between the two groups. These issues may have introduced bias and are considered further in the Discussion and Limitations section.

Intervention

Caregivers in the SMS group received scheduled text-message reminders before their child's next routine immunization appointment over the 12-week study period. The reminders were generated from facility immunization records and timed according to the national routine immunization schedule. Caregivers in the comparison group did not receive SMS reminders and continued to access routine immunization services as usual during the same period.

The primary outcome was completion of the routine immunization schedule appropriate for the child's age at the end of the 12-week study period. Secondary outcomes included coverage for Bacillus Calmette-Guérin (BCG), the third dose of oral polio vaccine (OPV3), the third dose of pentavalent vaccine (Penta-3), the third dose of pneumococcal conjugate vaccine (PCV3), and measles-containing vaccine. Immunization dropout rates were also assessed in both study groups. Among caregivers in the SMS group, additional process indicators were assessed. These included successful message delivery, whether SMS messages were read, caregiver replies or acknowledgements, attendance at a health facility after receiving a reminder, reported barriers and facilitators, and the acceptability and feasibility of the SMS reminder system.

Statistical analysis

Data were analysed using IBM SPSS Statistics version 29. Sociodemographic characteristics and intervention process indicators were summarised using frequencies, percentages, means, and standard deviations. Pearson chi-square tests were used to compare vaccination completion, antigen-specific coverage, and dropout rates between the SMS and comparison groups. All expected cell counts were greater than 5, and statistical significance was set at $p < 0.05$.

Risk differences, risk ratios, odds ratios, and 95% confidence intervals were calculated for the primary outcome, antigen-specific coverage, and dropout comparisons. These measures were used to show the magnitude and precision of the observed associations in addition to the p-values.

Multivariable analysis adjusting for sociodemographic covariates was not conducted because individual-level data were not available for re-analysis at the time of revision. Since the groups were broadly comparable in the sociodemographic characteristics shown in Table 1, unadjusted estimates were retained to describe the association between SMS reminders and vaccination outcomes. However, future studies that collect individual-level data prospectively should conduct adjusted analyses to account for possible confounding.

Ethical considerations

Ethical approval was obtained from the Institutional Review Board of the Nasarawa State Ministry of Health. The study was conducted in accordance with the ethical principles outlined in the 2024 revision of the Declaration of Helsinki [18]. Written informed consent was obtained from all participating caregivers before enrolment. To protect confidentiality, unique identification codes were used instead of participant names. All study records were stored in password-protected databases that were accessible only to the research team.

RESULTS

Sociodemographic characteristic

The SMS and comparison groups had similar sociodemographic characteristics, as shown in Table 1. In both groups, just over half of the caregivers were aged 25–34 years (53.8% in the SMS group and 51.0% in the comparison group). The mean age was 31.68 ± 7.14 years in the SMS group and 31.85 ± 7.39 years in the comparison group. Educational level, religion, occupation, and the number of children under five years were also broadly similar between the two groups

Table 1. Sociodemographic characteristics of caregivers by study group

Characteristic	Comparison group (n=200)	SMS group (n=223)
Age 25–34 years	51.0%	53.8%
Age 35–44 years	23.5%	22.4%
Age <25 years	19.0%	17.9%
Age ≥ 45 years	6.5%	5.8%
Mean age, years (SD)	31.85 (7.39)	31.68 (7.14)
Secondary education	39.0%	41.3%
Primary education	27.0%	26.0%
Tertiary education	21.0%	23.3%
No formal education	13.0%	9.4%
Christian	66.0%	67.3%
Traders (occupation)	34.0%	33.2%
1–2 children under five	47.5%	51.1%

Source: Field survey.

Vaccination completion and antigen-specific coverage

At the end of the 12-week study period, full completion of the routine immunization schedule was significantly higher in the SMS group than in the comparison group (78.0% [174/223] vs. 42.5% [85/200], respectively; $\chi^2(1) = 56.06, P < .001$).

Antigen-specific vaccination coverage was higher in the SMS group than in the comparison group for all five vaccines assessed (Table 2). The between-group differences were statistically significant for OPV3 $\chi^2(1) = 10.08, P = .002$, Penta-3 $\chi^2(1) = 14.47, P < .001$, PCV3 $\chi^2(1) = 13.62, P < .001$, and the measles-containing vaccine $\chi^2(1) = 18.38, P < .001$. Coverage for the measles-containing vaccine showed the largest

absolute difference between groups (72.6% in the SMS group vs. 52.5% in the comparison group; difference, 20.1 percentage points). Although BCG coverage was also higher in the SMS group (86.1% vs. 79.0%; difference, 7.1 percentage points), the between-group difference was not statistically significant $\chi^2(1) = 3.72, P = .054$. Because BCG is a single-dose vaccine typically administered at birth, there is less opportunity for reminder messages to influence its uptake than for vaccines that require multiple scheduled visits. The larger and statistically significant differences observed for multi-dose antigens may therefore reflect the greater potential for SMS reminders to reduce missed or delayed follow-up immunization visits [12–14,25,30].

For full routine immunization completion, the SMS group had a 35.5-percentage-point higher completion rate than the comparison group (95% CI, 26.8–44.3 percentage points). This corresponded to a risk ratio of 1.84 (95% CI, 1.54–2.19) and an odds ratio of 4.80 (95% CI, 3.15–7.34). The number needed to treat was approximately 3, indicating that provision of SMS reminders to about three caregivers was associated with one additional child achieving full schedule completion over the 12-week study period.

For antigen-specific coverage, risk differences ranged from 7.1 percentage points for BCG (95% CI, –0.1 to 14.3 percentage points; risk ratio, 1.09; 95% CI, 1.00–1.19) to 20.1 percentage points for measles-containing vaccine (95% CI, 11.1–29.2 percentage points; risk ratio, 1.38; 95% CI, 1.19–1.61). OPV3, Penta-3, and PCV3 had intermediate absolute differences of 14–17 percentage points, with risk ratios ranging from 1.23 to 1.29; the 95% confidence intervals for these estimates excluded the null value. The BCG estimate was the only antigen-specific comparison for which the confidence interval included the null value, consistent with the non-significant between-group test. Dropout in the SMS group decreased by 15.7 percentage points from baseline to endline (95% CI, 9.4–22.0 percentage points), whereas the comparison group showed a non-significant decrease of 1.6 percentage points (95% CI, –6.2 to 9.4 percentage points). Among the 223 caregivers in the SMS group, 1,785 reminder messages were sent during the intervention period, of which 1,640 (91.9%) were successfully delivered. Most caregivers reported opening or reading the reminders (84.3%), while 56.5% reported replying to or acknowledging a message. In addition, 77.1% reported attending a health facility after receiving an SMS reminder (Table 4).

Table 2. Antigen-specific vaccination coverage by study group

Vaccine	Comparison (n=200)	SMS (n=223)	χ^2 (df=1)	p-value
BCG	79.0%	86.1%	3.72	0.054
OPV3	62.0%	76.2%	10.08	0.0015
Penta-3	60.0%	77.1%	14.47	<0.001
PCV3	59.0%	75.8%	13.62	<0.001
Measles	52.5%	72.6%	18.38	<0.001

Source: Field survey. Pearson chi-square tests, 1 degree of freedom for each comparison.

Schedule dropout differed between the study groups (Table 3). In the SMS group, the dropout rate decreased from 22.1% at baseline to 6.4% at endline, representing a statistically significant reduction $\chi^2(1) = 22.64, P < .001$. In contrast, dropout in the comparison group changed minimally, from 20.5% at baseline to 18.9% at endline, and this change was not statistically significant $\chi^2(1) = 0.14, P = .706$ [31].

Table 3. Change in schedule dropout rate within each group over the 12-week study period

Group	Baseline dropout	Endline dropout	χ^2 (df=1)	p-value
SMS (n=223)	22.1%	6.4%	22.64	<0.001
Comparison (n=200)	20.5%	18.9%	0.14	0.706

Source: Field survey. Pearson chi-square tests comparing baseline and endline dropout proportions within each group.

SMS delivery, engagement, and feasibility

Among the 223 caregivers in the SMS group, 1,785 reminder messages were sent during the intervention period, of which 1,640 (91.9%) were successfully delivered. Most caregivers reported opening or reading the reminders (84.3%), while 56.5% reported replying to or acknowledging a message. In addition, 77.1% reported attending a health facility after receiving an SMS reminder (Table 4).

Table 4. SMS delivery, engagement, acceptability, and feasibility indicators (SMS group, n=223)

Indicator	Value
Reminders sent	1,785
Successfully delivered	1,640 (91.9%)
Opened/read the SMS	188 (84.3%)
Replied to/acknowledged SMS	126 (56.5%)
Attended facility after SMS	172 (77.1%)
Agreed reminders helped keep vaccinations on schedule	87.0%
Found messages easy to understand	84.3%
Preferred SMS to phone calls	74.0%
Would recommend SMS to others	81.2%

Source: Field survey.

Barriers and facilitator

The most frequently reported barriers to caregiver response to SMS reminders were poor mobile network coverage (18.8%), phone unavailability (16.1%), competing household responsibilities (13.5%), forgetfulness despite receiving reminders (12.1%), and transport costs (11.2%). The most frequently reported facilitators of SMS-reminder use were the reminders serving as clear prompts for immunization visits (78.9%), ease of understanding the message content (74.0%), improved awareness of vaccination dates and schedule completion

(64.1%), encouragement from health workers (54.3%), and the convenience of receiving information directly on a personal mobile phone (52.5%) [33,34].

DISCUSSION

This study found that a facility-supported SMS-reminder intervention was associated with substantially higher completion of the routine childhood immunization schedule and lower schedule dropout than a concurrent comparison group that received no reminders. Higher coverage in the SMS group was particularly apparent for multi-dose antigens, including OPV3, Penta-3, PCV3, and measles-containing vaccine [11–13]. Similar improvements in childhood immunization completion and timeliness have been reported in randomized studies in Ethiopia, Guatemala, and Pakistan. Collectively, these findings suggest that SMS reminders can support adherence to multi-visit childhood immunization schedules across diverse low- and middle-income settings, although the magnitude of benefit varies according to baseline coverage, vaccine availability, message design, and local health-system conditions [25,26,30]. The smallest between-group difference was observed for BCG, a single-dose vaccine generally administered at birth. This finding may reflect the more limited opportunity for SMS reminders to influence uptake of a vaccine that does not require subsequent caregiver return visits. In contrast, vaccines administered over multiple scheduled visits may provide greater opportunity for reminder-based interventions to support timely attendance and schedule completion [9,14].

The intervention demonstrated high operational feasibility, with 91.9% of reminder messages successfully delivered and 84.3% of caregivers reporting that they opened or read the messages. These findings indicate that the SMS platform achieved substantial reach and caregiver engagement within the study population [19,20]. The delivery and self-reported reading rates observed in this study were broadly comparable with those reported in other African mHealth immunization studies. For example, a randomized trial in northwest Ethiopia reported successful delivery of 89.7% of automated SMS reminders, and telephone follow-up indicated that 87.3% of delivered messages had been seen by participants. A Nigerian implementation study in Bauchi State reported successful delivery of 96.8% of automated SMS notifications, although that intervention targeted health workers' immunization data reporting rather than caregivers' childhood vaccination attendance [36].

Caregiver acceptability of the SMS-reminder intervention was high, with most participants describing the messages as helpful, easy to understand, and preferable to phone calls. These findings indicate that text-message reminders were an acceptable mode of communicating routine immunization information in the study population. [20,21,34]. The high acceptability observed in this study is broadly consistent with evidence from low- and middle-income settings, where caregivers commonly report that SMS reminders are convenient and acceptable. However, preferences for SMS versus phone calls may vary by literacy, language, network access, phone sharing, and caregiver familiarity with text messaging. Therefore, the reported preference for SMS in this study should be interpreted as specific to the participating caregivers rather than assumed to apply universally [28,29].

Nonetheless, several contextual barriers were identified that could limit the effectiveness of the intervention if it were implemented at scale. Poor mobile network coverage and inconsistent access to mobile phones were the most commonly reported challenges. These barriers may prevent reminders from being received, read, or acted upon, thereby reducing the reach and potential effectiveness of the intervention [16]. The identified barriers are consistent with evidence from resource-limited settings, where unreliable network connectivity, limited phone access, intermittent electricity, device-sharing, and affordability constraints can impede mHealth implementation. In Nigeria, experts assessing the integration of mobile health into routine immunization services similarly identified poor mobile networks and inconsistent electricity supply as important threats to successful implementation [37].

Caregiver literacy and message clarity also emerged as important implementation considerations. These findings underscore the need for SMS reminders to use simple, concise, and culturally appropriate language, particularly in communities with mixed literacy levels [21,22].

Message content should be developed and tested with intended users to ensure that it is understandable, relevant, culturally acceptable, and delivered in a language caregivers can read. Where literacy or language barriers may limit the usefulness of text messages, programmes should consider complementary approaches, such as voice calls or voice messages, health-worker counselling, and community-based reminders.

Importantly, an SMS-only strategy may not reach caregivers who do not have reliable access to a personal mobile phone. This raises equity concerns because caregivers who are already disadvantaged by poverty, rural residence, gender-related disparities in phone ownership or control, limited connectivity, or low literacy may be less likely to receive or act on SMS reminders. Complementary non-phone-based outreach strategies are therefore needed to prevent SMS programmes from inadvertently widening existing immunization gaps [13,23].

A recent Cochrane review of interventions to improve childhood immunization coverage in low- and middle-income countries found that several strategies, including caregiver health education, home-based records, community-leader and health-provider interventions, integrated services, and immunization outreach, may improve vaccine uptake. The review found low-certainty evidence that phone calls or SMS reminders may produce little or no improvement in DTP3/Penta-3 uptake, highlighting uncertainty and variation in effects across interventions and settings [27]. This heterogeneity underscores the importance of context-specific evaluations, such as the present study, to assess whether findings from other countries and regions are applicable and associated with comparable benefits within a Nigerian local-government setting.

These findings should be interpreted in light of the study's non-randomized, quasi-experimental design. Participants were allocated using a fixed alternating sequence at enrolment rather than random assignment. Although caregivers did not select their own study group, alternating allocation is not equivalent to randomization.

Because enrolling staff were aware of the allocation sequence, allocation concealment was not possible. This may have introduced selection bias if the timing or order in which eligible caregivers were approached was consciously or unconsciously influenced. In addition, alternating allocation does not ensure that characteristics varying during the enrolment period, such as changes in clinic attendance, seasonal patterns, or shifts in the population of caregivers attending the facility, were equally distributed between groups.

Although the groups were broadly comparable with respect to measured sociodemographic characteristics (Table 1), residual confounding from unmeasured or unevenly distributed factors cannot be excluded. Therefore, the observed effect estimates should be interpreted as associations consistent with a beneficial effect of SMS reminders, rather than definitive evidence that the intervention caused the observed differences in immunization outcomes

Future studies should use designs that provide stronger protection against allocation bias. Cluster-randomized trials could randomize facilities, clinic sessions, or comparable service-delivery units to intervention or control conditions, particularly where individual randomization may lead to contamination between groups. Alternatively, individually randomized trials should use a truly random, computer-generated allocation sequence and conceal allocation from enrolling staff until eligibility has been confirmed and enrolment is complete.

These approaches would strengthen causal inference by making allocation unpredictable and reducing the potential for selection bias associated with a fixed alternating sequence. Cluster-randomized studies should also account for clustering in sample-size estimation and statistical analysis and should incorporate measures to minimize recruitment bias after clusters have been assigned.

Future research should recruit larger and more geographically diverse samples across multiple local government areas and states to improve statistical precision and assess the applicability of findings beyond a single semi-urban local-government area. Mixed-methods studies could additionally examine how message timing, content,

language, literacy, phone access, health-worker support, and health-service accessibility influence caregiver engagement and immunization attendance [24].

In addition, outcomes were assessed only at the end of the 12-week intervention period. It is therefore unknown whether the observed improvements in schedule completion and reductions in dropout would persist after active SMS reminders ceased. Future evaluations should include longer-term follow-up beyond the intervention period to assess the durability of any observed effects and to determine whether continued reminder delivery is required to maintain improved immunization attendance.

CONCLUSIONS

In this quasi-experimental study conducted in Keffi Local Government Area, Nasarawa State, a facility-supported SMS reminder intervention was associated with higher routine childhood immunization completion and lower schedule dropout than a concurrent comparison group that received no reminders. The intervention also demonstrated high caregiver acceptability and operational feasibility among participating caregivers.

Integrating SMS reminders into routine immunization service delivery may be a practical approach to support vaccination attendance in Keffi LGA and similar settings. However, scale-up should address network reliability, equitable phone access, caregiver literacy and language needs, data privacy, and linkage with routine facility workflows. SMS reminders should complement, not replace, reliable immunization services and non-digital outreach for caregivers who cannot be reached by mobile phone.

Declarations

Ethics approval and consent to participate: This study received ethical approval from the Institutional Review Board of the Nasarawa State Ministry of Health and was conducted in accordance with the ethical principles of the 2024 revision of the World Medical Association Declaration of Helsinki [18]. Written informed consent was obtained from all participating caregivers before enrolment.

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions: **Mbamalu Onyinye Benjamin:** Conceptualization, data collection, formal analysis, and writing the original draft. **Akyala I. A.:** Study design, supervision, writing, review, and editing. **Aremu Stephen Olaide:** Study implementation, writing, review, and editing. **Gyar Sunday Silas:** Study implementation and writing, review, and editing.

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