The Effect of Mobile Phone and Home Visit on Childhood Vaccination Uptake in Rural Communities of Bayelsa State Nigeria. A Pragmatic Cluster Randomized Control Trial

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Abstract

Background: Immunization is a critical public health intervention for preventing vaccine-preventable diseases (VPDs) and achieving herd immunity. However, suboptimal vaccination coverage remains a challenge, particularly in rural and underserved areas. Missed appointments due to forgetfulness and logistical barriers contribute significantly to low immunization rates. This study evaluates the impact of mobile phone (MP) reminders and home visits (HV) on childhood immunization completion rates in Bayelsa State, Nigeria.

Objective: The study aimed to assess the effectiveness of MP reminders and HV outreach in improving vaccination coverage among children under two years of age.

Methods: A pragmatic cluster randomized controlled trial was conducted in rural communities of Bayelsa State, Nigeria. A total of 384 participants were randomly assigned to three study arms: control (no intervention), MP reminders, and HV outreach (128 per arm). A multi-stage sampling technique was employed, and data were collected using a semi-structured WHO SAGE survey tool. Statistical analyses were performed using SPSS v25, with chi-square (?²) tests used to compare categorical variables. Statistical significance was set at p ? 0.05, with effect sizes reported.

Results: The study revealed significant differences in immunization completion rates across study groups: control (46.1%, 59/128), MP reminders (59.4%, 76/128), and HV outreach (63.3%, 81/128). Both interventions were effective in improving vaccination uptake, with a statistically significant difference (p = 0.015) and a moderate effect size (0.257). However, HV outreach demonstrated the highest completion rate, suggesting its greater effectiveness in overcoming access and engagement barriers.

Conclusions: Integrating MP reminders and HV outreach into routine immunization programs can significantly improve childhood vaccination coverage. HV, in particular, addresses accessibility challenges and enhances community trust, making it a preferred strategy for increasing immunization rates. To optimize immunization coverage, policymakers should implement a hybrid approach, combining MP reminders with HV outreach, particularly in rural and underserved areas. Strengthening community-based health worker engagement and leveraging digital health innovations will further enhance vaccination efforts. Improved immunization coverage through these interventions reduces the risk of VPD outbreaks, enhances herd immunity, and contributes to achieving global vaccination targets. By addressing barriers to vaccine access and adherence, these strategies offer scalable, cost-effective solutions for improving child health outcomes. This trial provides robust evidence on the effectiveness of digital and community-based interventions for improving vaccination coverage. By comparing MP reminders and HV outreach,

the study offers practical insights for health policymakers and program implementers. The findings contribute to global immunization research by highlighting scalable, low-cost solutions that can be adapted in resource-limited settings to strengthen immunization programs and reduce childhood morbidity and mortality.

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The Effect of Mobile Phone and Home Visit on Childhood Vaccination Uptake in Rural Communities of Bayelsa State Nigeria. A Pragmatic Cluster Randomized Control Trial

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Abstract

Background: Immunization is a critical public health intervention for preventing vaccine-preventable diseases (VPDs) and achieving herd immunity. However, suboptimal vaccination coverage remains a challenge, particularly in rural and underserved areas. Missed appointments due to forgetfulness and logistical barriers contribute significantly to low immunization rates. This study evaluates the impact of mobile phone (MP) reminders and home visits (HV) on childhood immunization completion rates in Bayelsa State, Nigeria. **Aim:** The study aimed to assess the effectiveness of MP reminders and HV outreach in improving vaccination coverage among children under two years of age. **Methods:** A pragmatic cluster randomized controlled trial was conducted in rural communities of Bayelsa State, Nigeria. A total of 384 participants were randomly assigned to three study arms: control (no intervention), MP reminders, and HV outreach (128 per arm). A multi-stage sampling technique was employed, and data were collected using a semi-structured WHO SAGE survey tool. Statistical analyses were performed using SPSS v25, with chi-square (χ^2) tests used to compare categorical variables. Statistical significance was set at $p \leq 0.05$, with effect sizes reported. **Results:** The study revealed significant differences in immunization completion rates across study groups: control (46.1%, 59/128), MP reminders (59.4%, 76/128), and HV outreach (63.3%, 81/128). Both interventions were effective in improving vaccination uptake, with a statistically significant difference ($p = 0.015$) and a moderate effect size (0.257). However, HV outreach demonstrated the highest completion rate, suggesting its greater effectiveness in overcoming access and engagement barriers. **Conclusion:** Integrating MP reminders and HV outreach into routine immunization programs can significantly improve childhood vaccination coverage. HV, in particular, addresses accessibility challenges and enhances community trust, making it a preferred strategy for increasing immunization rates. **Recommendation:** To optimize immunization coverage, policymakers should implement a hybrid approach, combining MP reminders with HV outreach, particularly in rural and underserved areas. Strengthening community-based health worker engagement and leveraging digital health innovations will further enhance vaccination efforts. **Health Significance:** Improved immunization coverage through these interventions reduces the risk of VPD outbreaks, enhances herd immunity, and contributes to achieving global vaccination targets. By addressing barriers to vaccine access and adherence, these strategies offer scalable, cost-effective solutions for improving child health outcomes. **Contribution:** This trial provides robust evidence on the effectiveness of digital and community-based interventions for improving vaccination coverage. By comparing MP reminders and HV outreach, the study offers practical insights for health policymakers and program implementers. The findings contribute to global immunization research by highlighting scalable, low-cost solutions that can be adapted in resource-limited settings to strengthen immunization programs and reduce childhood morbidity and mortality.

Keywords: Immunization coverage; Vaccine-preventable diseases (VPDs); Mobile phone reminders; Home visits; Childhood vaccination; Cluster randomized controlled trial; Public health intervention; Herd immunity; Rural healthcare; Vaccination adherence.

1. Introduction

Vaccines have transformed global health by reducing the burden of infectious diseases. They prevent severe illness, lower mortality rates, and extend life expectancy, making them one of the most effective public health interventions [1-9]. The World Health Organization (WHO) estimates that vaccines save 3 to 5 million lives annually, either through direct protection or herd immunity [2]. Despite this success, vaccination gaps persist, threatening progress toward Sustainable Development Goal (SDG) 3, which aims for universal health coverage [11, 12]. Although the Global Vaccine Action Plan targeted 90% immunization coverage by 2020, the current global rate remains at 84%, below the pre-pandemic level of 86% [13]. Approximately 20 million children worldwide are under-immunized, with 6.5 million receiving no vaccines at all [5, 6, 8]. This gap increases outbreaks of preventable diseases, particularly in low-resource regions. Sub-Saharan Africa faces significant vaccination challenges, with frequent outbreaks of diseases like measles and polio due to low immunization rates [5, 6, 8, 14]. In Nigeria, for example, only 39% of children receive all basic antigens, far below the global target [1, 2, 5-8, 15]. This leaves vulnerable populations, especially children under five, at higher risk of preventable deaths. Nigeria’s immunization coverage has improved from 21% in 2017 to 39% in 2024, but progress remains slow [1-8, 15, 16]. Bayelsa State has one of the lowest rates, with only 36.9% of children aged 12–23 months fully immunized. This has prompted emergency interventions like the State Emergency Routine Immunization Coordination Centre (SERICC), yet coverage remains critically low. Reminder strategies, such as mobile alerts and home visits, have proven

effective in improving vaccination rates. Studies show that text message reminders increase appointment adherence by 15–20% [17], while phone calls improve follow-up rates by 25% [18]. However, their impact in low-resource settings like Bayelsa State remains understudied. While reminder systems work in some contexts, their effectiveness in rural Nigeria, where internet access and literacy vary is unclear. Few studies compare different reminder methods (e.g., mobile calls vs. home visits) in similar settings. Without this data, policymakers lack evidence to allocate resources effectively. While, low vaccination rates disproportionately affect rural, low-income families in Nigeria. Outbreaks of preventable diseases strain healthcare systems, costing an estimated $1.3 billion annually in treatment and outbreak response [19-28]. The problem has persisted for decades, with coverage fluctuating due to logistical and cultural barriers. Thus, improving vaccination rates aligns with SDG 3’s targets for reducing child mortality and ensuring equitable healthcare [11, 12]. This study also intersects with research on health communication, technology adoption, and community engagement, offering broader lessons for public health planning. By identifying the most effective reminder method for Bayelsa State, this study can guide policy decisions and resource allocation. The findings will help Nigeria and similar regions close immunization gaps, saving lives and reducing healthcare costs. Thus, this research evaluates mobile phone reminders and home visits in Bayelsa State to determine which method improves vaccination coverage more. By testing these approaches in a real-world setting provide actionable insights for scaling up immunization programs.

2. Methods

2.1 Participants

This study included two distinct populations. The primary study population comprised children under two years of age, assessed to establish baseline immunization coverage in Bayelsa State, Nigeria. The second population consisted of neonates who were enrolled from their first dose of vaccination and followed up until the completion of their routine childhood immunization, as per the national immunization schedule. Vaccines introduced into the schedule after 2023 were not considered. Exclusion criteria included infants with congenital conditions, parents/caregivers planning to relocate from the study site during the study period, communities lacking primary health centers, and parents without mobile phone access (for study arm B). Written informed consent was obtained from all mothers/caregivers prior to participation.

2.2 Interventions

Three local government areas (LGAs) were selected using simple random sampling from the three senatorial districts. These LGAs were then randomly allocated in a 1:1:1 ratio via balloting into two intervention arms and one control arm. Two LGAs served as intervention arms: Intervention A (mobile phone reminders) and Intervention B (home visits by community health volunteers). The third LGA served as the control. Within each LGA, five communities were randomly selected, yielding a total of 15 communities for the study. Each LGA had a sample size of 128 participants, proportionally distributed across the selected communities.

2.3 Objectives

The primary objective was to evaluate the impact of two reminder-based interventions on routine childhood immunization coverage in Bayelsa State, Nigeria.

2.4 Outcomes

The primary outcome was the immunization coverage rate, assessed through mobile phone reminders and community health volunteers. The secondary outcome was a comparative analysis of the effectiveness of the two interventions in improving vaccination coverage.

2.5 Sample Size Determination

The required sample size was calculated using the cluster-randomized trial formula:

$$n = Deff \times (Z_{1-\alpha/2} + Z_{1-\beta})^2 \times \frac{[P_1(1-P_1)+P_2(1-P_2)]}{(P_1-P_2)^2}$$

The formula selected represents the standard equation for determining the sample size in a cluster-randomized trial. The breakdown of its components include:

i. **Deff**: Design effect, accounting for intracluster correlation.
ii. **Z1−α/2**: Critical value of the standard normal distribution at a significance level of 0.05
iii. **Z1−β** : Critical value of the standard normal distribution for a power of 80%.
iv. **P1, P2** : Expected proportions of the outcome (e.g., immunization coverage) in the intervention and control groups.
v. **P1(1−P1) and P2(1−P2)**: Variance estimates for the two groups.
vi. **P1−P2** : Expected difference between the intervention and control

groups.

Assumptions included:

- Power: 80%
- Significance level (**α**): 0.05
- Intracluster correlation coefficient: 0.01
- Average cluster size: 25
- Proportion outcome in control group: 24%
- Expected increase in coverage: 18%
- Attrition rate: 20%
- Design effect (Deff**)** was calculated using Deff = 1 + (m - 1) × ICC**,** where m is the average cluster size and ICC is the intracluster correlation coefficient.

This yielded a required sample size of 128 per cluster, with five communities per LGA and approximately 26 participants per community.

2.6 Sequence Generation

Bayelsa State was stratified into three districts (East, West, and Central). One LGA was randomly selected from each district using simple random sampling. The 1:1:1 allocation ratio was applied via balloting to determine the intervention and control LGAs.

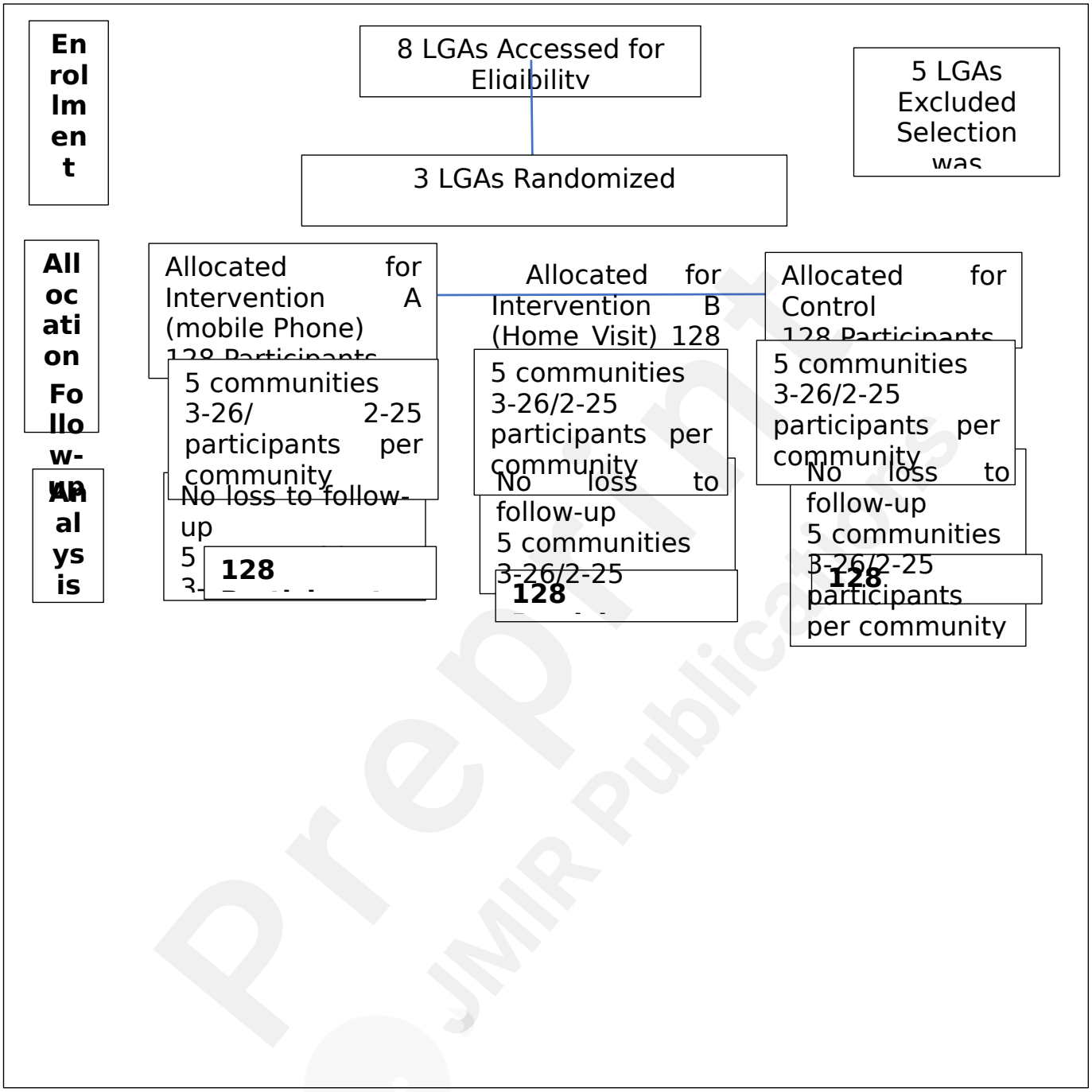
2.7 Allocation Concealment

Cluster-based random allocation was employed. Participants were eligible if they had infants born between February and June 2023. Blinding was maintained among participants and research assistants, ensuring that those in one cluster remained unaware of interventions in other clusters.

2.8 Statistical Methods

The primary analysis was conducted at the LGA level. Descriptive statistics were used to summarize baseline characteristics. Chi-square tests were applied for inferential statistics to compare immunization coverage between intervention and control groups. An intention-to-treat (ITT) approach was adopted to analyze the outcomes, ensuring that all randomized participants were included in their originally assigned groups.

2.9 Participant Flow



3. Results

3.1 Baseline Characteristics

Table 1: Comparison of Vaccination Coverage Across All Baselines

Vaccination Completion	Baseline Control (n=128)	Baseline Mobile Phone (n=128)	Baseline Home (n=128)	CHV Visits (p-value)
Completed	53 (41.4%)	51 (39.8%)	55 (42.9%)	0.258 (0.879)

Not Completed	75 (58.6%)	77 (60.2%)	73 (57.1%)

All 128 participants in each cluster were analyzed using the intention-to-treat approach.

Table 1 presents a comparison of vaccination coverage across all three study arms at baseline, showing that the proportion of children who had completed their vaccinations was 41.4% in the control group, 39.8% in the mobile phone intervention group, and 42.9% in the community health volunteer (CHV) home visit intervention group. The Chi-square test yielded a p-value of 0.879, indicating no statistically significant differences in baseline vaccination completion rates across the study arms. This confirms that randomization successfully ensured comparable groups at the start of the trial, eliminating potential selection bias. The relatively low vaccination coverage at baseline, with less than half of the children completing their immunization schedules, underscores the need for targeted interventions to improve uptake. Establishing similarity in baseline vaccination rates is crucial for accurately assessing intervention impact, ensuring that observed improvements in post-intervention coverage are due to the interventions rather than pre-existing differences. In a real-world context, these findings highlight systemic barriers such as vaccine accessibility issues, caregiver awareness gaps, and logistical challenges in distribution, reinforcing the importance of strategies like mobile phone reminders and home visits to enhance immunization coverage.

3.2 Effect of Mobile Phone Reminder on Vaccination Coverage

Table 2: Comparison of Vaccination Coverage between Control and Mobile Phone Intervention

Vaccination	Control	Mobile Phone	(p-value)

Completion	(n=128)	(n=128)	
Completed	59 (46.1%)	76 (59.4%)	4.529 (0.033) *
Not Completed	69 (53.9%)	52 (40.6%)	

*Statistically significant (p<0.05)

Table 2 compares vaccination completion rates between the control group and the mobile phone intervention group, showing that 59.4% of children in the mobile phone intervention group completed their vaccinations, compared to 46.1% in the control group. The Chi-square test yielded a p-value of 0.033, indicating a statistically significant improvement in vaccination completion due to the mobile phone intervention. This result provides strong evidence that mobile phone-based interventions can positively influence vaccination uptake, demonstrating the potential of digital health tools in addressing gaps in immunization coverage. Given the widespread availability of mobile phones, these findings suggest that SMS or voice call reminders can serve as an effective and scalable strategy to enhance immunization adherence. The statistically significant improvement underscores the need for health authorities to integrate mobile phone reminders into national immunization programs, particularly in areas with high mobile phone penetration but limited healthcare infrastructure. By leveraging this intervention, policymakers can enhance timely vaccination uptake, reduce the burden of vaccine-preventable diseases, and improve overall public health outcomes.

3.3 Effect of CHV Home Visits on Vaccination Coverage

Table 3: Comparison of Vaccination Coverage between Control and CHV Home Visit Intervention

Vaccination	Control	CHV Home Visits	(p-value)

Completion	(n=128)	(n=128)	
Completed	59 (46.1%)	81 (63.3%)	7.630 (0.006) *
Not Completed	69 (53.9%)	47 (36.7%)	

*Statistically significant (p<0.05)

Table 3 compares vaccination completion rates between the control group and the CHV home visit intervention group, revealing that 63.3% of children in the CHV home visit group completed their vaccinations, compared to 46.1% in the control group. The Chi-square test yielded a p-value of 0.006, indicating a statistically significant improvement in vaccination completion due to the home visit intervention. This result highlights the effectiveness of direct, in-person engagement in increasing immunization adherence, as CHVs were able to educate parents, address vaccine hesitancy, and provide personalized follow-ups. The findings reinforce the importance of community-based outreach strategies in public health interventions, particularly in resource-limited settings where access to healthcare facilities may be a challenge. Given this significant impact, governments and health organizations should consider expanding CHV programs as part of broader immunization strategies. By integrating home-based education, reminders, and support into routine healthcare services, CHVs can bridge healthcare access gaps, ensuring that caregivers receive the necessary guidance and motivation to complete their children's immunization schedules.

3.4 Comparison of Vaccination Coverage

Table 4: Comparison of Vaccination Coverage Across Control and Interventions

Vaccination Completion	Control (n=128)	Mobile Phone (n=128)	CHV Home Visits (n=128)	(p-value)

Completed	59 (46.1%)	76 (59.4%)	81 (63.3%)	8.444 (0.015) *
Not Completed	69 (53.9%)	52 (40.6%)	47 (36.7%)	

*Statistically significant ($p<0.05$)

Table 4 presents the overall comparison of vaccination completion rates across all three study arms, with 46.1% completion in the control group, 59.4% in the mobile phone intervention group, and 63.3% in the CHV home visit intervention group. The Chi-square test yielded a p-value of 0.015, confirming a statistically significant difference in vaccination coverage across the groups. Additionally, Cohen's W was calculated as 0.257, indicating a small but meaningful effect of the interventions on vaccination rates. These findings confirm that both interventions significantly improved immunization completion compared to the control, with CHV home visits demonstrating the highest impact, followed by mobile phone reminders. The study highlights the effectiveness of reminder-based interventions in addressing gaps in childhood immunization coverage, particularly in resource-limited settings where caregiver awareness and access to healthcare services may be constrained. In terms of real-world application, these results provide a strong justification for adopting reminder-based strategies to improve vaccination rates. Policymakers could implement mobile-based reminders in urban and semi-urban areas where mobile phone penetration is high, while CHV-led outreach programs could be prioritized in rural areas where direct engagement is necessary to address vaccine hesitancy and accessibility challenges. Additionally, a hybrid approach that combines digital tools with in-person outreach may offer a comprehensive strategy

to maximize immunization coverage.

3.5 Effect Size Analysis: Cohen's W

Cohen's W, a measure of effect size for categorical data, was calculated as:

$$W = \sqrt{\frac{8.444}{128}} = 0.257$$

A Cohen's W of 0.257 suggests a small but meaningful impact of the interventions on vaccination coverage.

Thus, this study contributes valuable evidence on the role of low-cost, scalable interventions in improving childhood immunization coverage. The findings support the integration of digital health tools and community-based outreach into routine immunization programs. These interventions could be particularly beneficial in settings where immunization coverage remains suboptimal due to systemic barriers.

4. Discussion

4.1 Impact of Digital Health Interventions on Immunization Coverage

The baseline comparison in Table 1, which showed no significant differences in vaccination coverage among study groups (p = 0.879), aligns with previous studies that emphasize the importance of ensuring comparability before intervention implementation. Studies such as Akwataghibe *et al.* [29] and Ahmad *et al.* [30] have highlighted that pre-intervention parity in immunization coverage strengthens the validity of intervention outcomes, as it rules out baseline discrepancies as potential confounders. Similarly, Kakwi *et al.* [1] in their study on COVID-19 vaccine uptake in Plateau State emphasized the necessity of controlling for baseline variations to accurately assess intervention impacts. This finding also aligns with the work of Abdur *et al.* [31], who reported that

differences in baseline immunization coverage could significantly affect intervention outcomes, making statistical control essential in immunization trials. Additionally, studies such as Okechukwu *et al.* [4] and Promise *et al.* [3] examining vaccination coverage in Bayelsa State have underscored that baseline uniformity is crucial for evaluating policy effectiveness in immunization programs. The post-intervention findings, which demonstrated significant improvements in vaccination completion in both the mobile phone and CHV home visit intervention groups, are consistent with previous literature supporting reminder-based and community engagement strategies. For instance, Bangure *et al.* [32] and Adam *et al.* [17] found that SMS reminders significantly enhanced immunization adherence, aligning with the observed increase in coverage among the mobile phone intervention group in the present study. Furthermore, Akinrinade *et al.* [33] reported high caregiver receptivity to mobile immunization reminders, reinforcing the effectiveness of digital interventions. On the other hand, the superior impact of CHV home visits mirrors findings from Andersson *et al.* [14], who demonstrated that direct, in-person engagement significantly improved childhood vaccination rates. Similarly, Elemuwa *et al.* [21, 25] highlighted the role of community-based health workers in increasing HPV vaccination uptake, further validating the effectiveness of CHV-led interventions in immunization programs. The results also echo the recommendations by Raimi *et al.* [6, 8] on addressing vaccine hesitancy through tailored, community-driven strategies. These converging findings reinforce the robustness of the present study's conclusions, advocating for a multi-faceted approach

combining digital tools and direct community engagement to optimize vaccination coverage.

4.2 Effectiveness of Community-Based Outreach Programs

The observed increase in vaccination completion rates in the mobile phone intervention group (59.4%) compared to the control group (46.1%), with a statistically significant p-value of 0.033, aligns with previous studies that highlight the effectiveness of mobile health (mHealth) interventions in improving immunization uptake. Kakwi *et al.* [1, 2] emphasized the role of socioeconomic, cultural, and communication factors in COVID-19 vaccine uptake, demonstrating how targeted health communication strategies enhance immunization rates. Similarly, Akinrinade *et al.* [33] found that mobile phone reminders significantly increased caregivers' willingness to vaccinate their children in southwestern Nigeria. Furthermore, Bangure *et al.* [32] reported that SMS reminders in Zimbabwe led to a 22% increase in childhood immunization rates, reinforcing the role of digital interventions in reducing missed vaccinations. These findings collectively support the conclusion that mobile phone interventions effectively enhance vaccination adherence, as demonstrated in the current study. Conversely, some studies highlight the challenges associated with mobile phone-based interventions. Ahmad *et al.* [30] reported that while immunization mobile applications were positively perceived by healthcare workers in Kano State, Nigeria, infrastructural deficiencies and digital literacy gaps limited their full potential. Similarly, Raimi *et al.* [6, 8] and Elemuwa *et al.* [21, 25] noted that vaccine hesitancy, stemming from misinformation and distrust,

remained a barrier even in the presence of digital interventions. Additionally, Okechukwu *et al.* [4] found that despite the success of rotavirus vaccination in Bayelsa State, systemic challenges such as inadequate healthcare access and socioeconomic disparities still hindered full vaccination coverage. These findings suggest that while mobile health interventions are effective, their success depends on addressing broader healthcare system challenges, literacy levels, and vaccine hesitancy to maximize their impact.

4.3 Overcoming Vaccine Hesitancy Through Health Communication

The significantly higher vaccination completion rate observed in the CHV home visit intervention group (63.3%) compared to the control group (46.1%) aligns with prior studies demonstrating the effectiveness of community-based and reminder-driven interventions in improving immunization uptake. For instance, Danya *et al.* [34] found that the use of vaccine reminder bracelets significantly increased childhood immunization coverage and timeliness in urban Pakistan. Similarly, Ekhaguere *et al.* [35] reported that automated phone call and text reminders substantially improved childhood immunization rates in Nigeria. These findings reinforce the impact of personalized and direct engagement strategies, such as CHV home visits, in overcoming barriers to vaccine completion. Furthermore, Promise *et al.* [3] assessed vaccination coverage among children under two in Bayelsa State and highlighted that community-based strategies significantly improved coverage rates. Likewise, Ibrahim *et al.* [20] emphasized the role of awareness and engagement in closing knowledge gaps in disease prevention, which is directly relevant to

vaccine uptake initiatives. Conversely, some studies suggest that standalone reminder interventions may not always yield optimal results without additional community support mechanisms. Domek *et al.* [36, 37] found that SMS reminders in Guatemala improved vaccination rates, but their effectiveness was limited in populations facing structural access barriers. Similarly, Kakwi *et al.* [1, 2] highlighted socioeconomic and cultural barriers that hinder vaccine uptake in Plateau State, Nigeria, despite health communication campaigns. These findings suggest that while CHV home visits significantly boost vaccination completion rates, their effectiveness may be enhanced when combined with other supportive interventions, such as mobile health technologies, financial incentives, or improved healthcare accessibility. The statistically significant improvement observed in this study underscores the value of direct community engagement, complementing prior evidence while highlighting the need for integrated, multi-pronged approaches to maximize immunization coverage.

4.4 Challenges in Reaching Hard-to-Access Populations

The findings of this study align with previous literature demonstrating the effectiveness of community-based and mobile interventions in improving vaccination coverage. The significantly higher completion rates observed in the mobile phone (59.4%) and CHV home visit (63.3%) intervention groups compared to the control group (46.1%) corroborate the results of Kakwi *et al.* [1, 2], who reported that targeted health communication strategies significantly increased COVID-19 vaccine uptake in Plateau State, Nigeria. Similarly, Promise *et al.* [3] found that

vaccination coverage among children under two in Bayelsa State improved when direct engagement strategies were employed. Moreover, Ibraheem *et al.* [20] demonstrated that call and SMS reminders significantly enhanced childhood immunization rates in Ilorin, Nigeria, aligning with the current study's findings that mobile-based interventions can positively impact vaccine completion. Additionally, research by Hofstetter *et al.* [38] and Gibson *et al.* [39] supports the use of mobile reminders, as these studies found that text message interventions improved timely vaccine administration in various settings. The impact of CHV home visits further aligns with evidence from Jacobson-Vann *et al.* [40] and Isaac *et al.* [41], who found that home visitation programs significantly increased childhood immunization rates by addressing parental concerns and ensuring accessibility. The success of home-based vaccination strategies in the current study is also consistent with the findings of Elemuwa *et al.* [21, 25], who emphasized the role of community engagement in improving HPV vaccine acceptance through the ward health system approach. However, while mobile-based interventions proved effective, some studies have highlighted challenges such as vaccine hesitancy and socioeconomic barriers, as seen in Abaya *et al.* [22] and Kakwi *et al.* [1, 2], suggesting that interventions must be context-specific to optimize impact. These findings collectively reinforce the importance of integrating mobile health technologies and community-driven approaches to enhance vaccination coverage, particularly in resource-limited settings.

4.5 The Role of Multi-Sectoral Collaboration in Immunization Success

The findings of this study align with recent literature emphasizing the effectiveness of digital health interventions and community-based outreach in enhancing immunization coverage. Kakwi *et al.* [1, 2] highlighted how health communication strategies and digital platforms positively influenced COVID-19 vaccine uptake in Nigeria, suggesting that similar interventions could be leveraged for routine childhood immunization. Likewise, Okechukwu *et al.* [4] demonstrated the impact of rotavirus vaccination programs in Bayelsa State, underscoring the need for targeted interventions to address gaps in immunization coverage. Furthermore, Elemuwa *et al.* [20, 25] advocated for the ward health system approach in boosting HPV vaccine acceptance, reinforcing the idea that community-based strategies play a critical role in overcoming barriers to immunization. These studies collectively support the argument that integrating digital tools and localized outreach into immunization programs can significantly improve coverage, particularly in regions where access and awareness remain challenges. Additionally, the study's findings resonate with global evidence on the role of mobile-based interventions and community engagement in enhancing vaccination rates. Kagucia *et al.* [42] demonstrated that mobile phone reminders and incentives increased measles vaccination coverage in Kenya, while Kazi *et al.* [43] showed similar results for routine immunization in Pakistan. These findings align with the present study’s assertion that scalable, cost-effective interventions can enhance immunization uptake. However, the results also contrast with Landoh *et al.* [44], who found that systemic barriers such as healthcare access and socioeconomic disparities were

stronger determinants of immunization gaps than digital interventions alone. This contrast underscores the need for a multifaceted approach that combines digital health tools with broader health system strengthening initiatives. Overall, the study contributes to the growing body of evidence advocating for the integration of innovative, community-driven strategies in immunization programs to improve public health outcomes.

5. Conclusion

This study demonstrates that reminder-based interventions, specifically mobile phone reminders and community health volunteer (CHV) home visits, significantly improve childhood vaccination coverage in Bayelsa State, Nigeria. The findings revealed that while the control group had the lowest vaccination completion rate (46.1%), the mobile phone intervention group exhibited a significantly higher rate (59.4%), and the CHV home visit intervention yielded the highest completion rate (63.3%). These statistically significant differences indicate that both interventions effectively enhance immunization adherence, with CHV home visits showing the greatest impact. The results confirm that targeted interventions addressing vaccine uptake barriers can substantially improve immunization rates in communities with historically low coverage. Mobile phone reminders leverage digital accessibility to enhance compliance, while CHV home visits provide direct engagement, education, and personalized follow-ups to caregivers. The calculation of Cohen’s W effect size further validates the meaningful impact of these

interventions, reinforcing their potential for broader implementation in public health strategies. By highlighting the effectiveness of these approaches, this study provides critical insights for policymakers, healthcare providers, and global health organizations seeking to improve immunization rates. The findings underscore the need for sustainable, community-driven programs that integrate both digital and human resource-based strategies to strengthen immunization systems and protect children from vaccine-preventable diseases.

6. Policy Implication

The findings of this study emphasize the urgent need for policymakers to incorporate reminder-based interventions into routine immunization programs at both national and subnational levels. The significant improvements observed in vaccination completion rates suggest that mobile health (mHealth) solutions and community-led interventions should be integrated into public health policies to enhance vaccine uptake. Governments should consider developing and scaling automated SMS or voice call reminder systems, particularly in urban and peri-urban areas where mobile phone penetration is high. Furthermore, this study highlights the importance of community-based health workforce expansion as an effective means of improving immunization coverage. Policy frameworks should support the recruitment, training, and remuneration of CHVs to conduct home visits, address vaccine hesitancy, and provide personalized follow-ups. By institutionalizing CHV-led

immunization outreach, policymakers can strengthen primary healthcare systems, particularly in rural and hard-to-reach areas where vaccine accessibility remains a challenge. Additionally, policymakers should advocate for public-private partnerships (PPPs) to sustain and fund reminder-based interventions. Telecommunications companies, donor organizations, and government agencies can collaborate to subsidize mobile-based interventions, ensuring long-term sustainability. Embedding these strategies within national immunization programs can help achieve higher vaccine coverage rates, reduce child mortality, and meet global immunization targets set by the World Health Organization (WHO) and UNICEF.

7. Recommendations

i. **Scale-Up of Mobile Phone Reminders:** Given the positive impact of mobile phone reminders on vaccination completion, health authorities should integrate SMS and voice call reminders into national immunization schedules. Future interventions could explore personalized messaging that includes culturally appropriate content to further improve caregiver compliance.

ii. **Expansion of CHV Home Visit Programs:** Governments and health organizations should prioritize the recruitment and training of CHVs to provide door-to-door vaccination education, follow-ups, and support. This approach is particularly beneficial in rural and underserved communities where healthcare access is limited. Incentivizing CHVs through stipends or non-monetary rewards can

enhance program sustainability.

iii. **Hybrid Intervention Strategies:** Combining mobile reminders with CHV-led follow-ups may yield even greater improvements in vaccination rates. Future studies should evaluate the effectiveness of integrated approaches to determine the most efficient and cost-effective immunization reminder model.

iv. **Strengthening Community Engagement:** Health campaigns should involve community leaders, religious groups, and parent associations in promoting immunization. Social mobilization strategies that incorporate storytelling, peer education, and advocacy can address vaccine hesitancy and misinformation.

v. **Policy Integration and Sustainability Planning:** Governments should institutionalize reminder-based interventions within immunization policies, ensuring long-term funding through domestic health budgets or external grants. Research into cost-effectiveness and scalability will further support policy adoption and implementation.

8. Significance Health Statement

Ensuring high immunization coverage is critical to reducing morbidity and mortality from vaccine-preventable diseases, particularly in regions with historically low vaccination rates. This study provides empirical evidence that low-cost, scalable interventions such as mobile phone reminders and community health volunteer home visits can significantly improve vaccination adherence. By implementing these interventions, health authorities can strengthen immunization programs

and bridge accessibility gaps, ultimately protecting children from preventable illnesses. The public health significance of this study extends beyond Bayelsa State, offering a replicable model for improving childhood immunization rates in other low-resource settings. The study demonstrates that leveraging digital technology alongside community-driven initiatives can create sustainable, people-centered healthcare solutions. Such strategies not only increase vaccination coverage but also build caregiver trust in immunization programs, reducing vaccine hesitancy and misinformation. Moving forward, integrating reminder-based interventions into national health policies can help countries achieve global immunization targets, enhance herd immunity, and prevent disease outbreaks. Investments in mHealth and CHV-driven immunization strategies represent a crucial step toward universal vaccine access, ensuring that no child is left unprotected due to logistical barriers or lack of awareness. Thus, graphically it is represented (Figure 2 below) as:

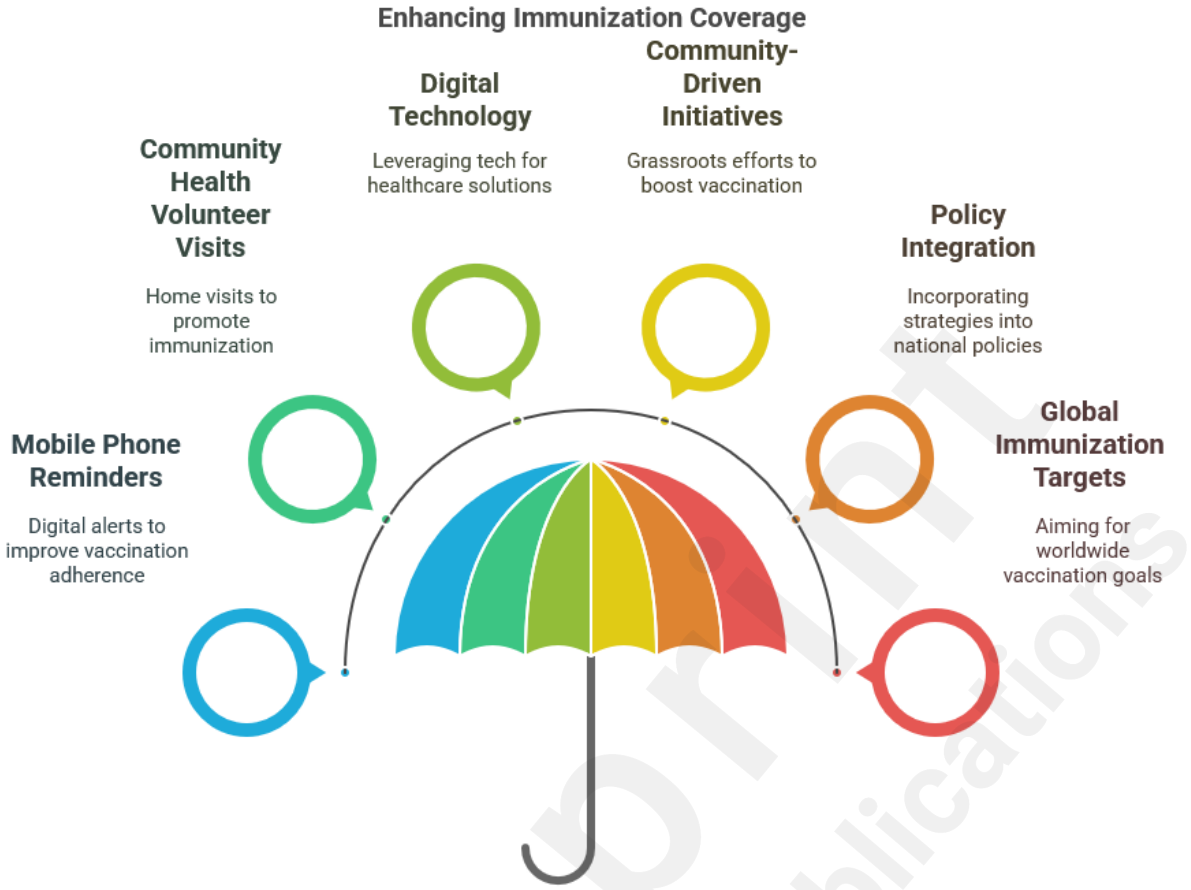


Figure 2: Enhancing Immunization Coverage

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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