Randomized Controlled Trial of Impact of Mobile Health Technologies on Human Papillomavirus Vaccination Uptake in Mothers of Vaccine-Eligible Girls in Lagos, Nigeria (mHealth-HPVac)

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ABSTRACT

PURPOSE Expanding high-risk human papillomavirus (HPV) vaccine coverage in resource-constrained settings is critical to bridging the cervical cancer gap and achieving the global action plan for elimination. Mobile health (mHealth) technology via short message services (SMS) has the potential to improve HPV vaccination uptake. The mHealth-HPVac study evaluated the effectiveness of mHealth interventions in increasing HPV vaccine uptake among mothers of unvaccinated girls aged 9-14 years in Lagos, Nigeria.

METHODS A randomized controlled trial was conducted at the Lagos University Teaching Hospital between June 2024 and March 2025. We randomly assigned n = 180 eligible mothers to either a text message (intervention) or a usual care (control) arm. The primary analysis was conducted using the intention-to-treat principle. Bivariable and multivariable logistic regression models were performed to compare HPV vaccination uptake between the two arms, adjusting for potential confounders using odds ratios (ORs) and 95% CIs.

RESULTS mHealth intervention significantly increased HPV vaccination uptake among mothers of vaccine-eligible girls (adjusted odds ratio [adj OR], 3.05 [95% CI, 1.61 to 5.77]; $P = .001$). Higher education level was also significantly associated with increased vaccine uptake (adj OR, 3.35 [95% CI, 1.77 to 6.33]; $P < .001$). There were no significant interaction effects by baseline characteristics on the association between mHealth intervention and HPV vaccine uptake.

CONCLUSION The study showed that mHealth interventions significantly improve HPV vaccine uptake. Integrating mHealth strategies into routine immunization programs could be a scalable and cost-effective approach to increasing HPV vaccination coverage. However, future multicenter studies should consider using cluster randomization at the facility level to better optimize mobile interventions for diverse populations, identify the key drivers of successful SMS-based mHealth interventions, and gain deeper insights into the complex barriers to HPV vaccination uptake.

ACCOMPANYING CONTENT

Data Sharing Statement

Protocol

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INTRODUCTION

Cervical cancer (CC) is the most common gynecologic cancer,[1] with an estimated 604,000 new cases diagnosed and 342,000 deaths attributed to the disease in 2020. An estimated 70% of these deaths occurred in developing countries, highlighting a significant global health disparity.[2] Persistent high-risk human papillomavirus (HPV) infection is the leading factor in CC development.[3,4] When administered to young and adolescent girls before sexual debut, HPV vaccination is one of the most effective strategies for CC prevention.[3,5]

Expanding HPV vaccine coverage in resource-constrained settings is critical to bridging the CC gap and achieving the global action plan for elimination.[6] HPV vaccination is

CONTEXT

Key Objective

How effective is mobile health (mHealth) intervention in increasing human papillomavirus (HPV) vaccine uptake among mothers of unvaccinated girls age 9-14 years in Lagos, Nigeria?

Knowledge Generated

Findings showed that mHealth intervention, compared with usual care, significantly increased HPV vaccination uptake among mothers of vaccine-eligible girls in Lagos.

Relevance

mHealth interventions via short message service improve HPV vaccine uptake among mothers of vaccine-eligible girls in Lagos. Integrating mHealth strategies into routine immunization programs could be a scalable and cost-effective approach to increasing HPV vaccination coverage.

recommended by the WHO for girls age 9-14 years.[7] This strategy is expected to yield substantial population-level immunity through direct protection and herd effects.[8] In October 2023, Nigeria launched a national HPV vaccine rollout campaign targeting approximately 7.7 million girls age 9-14 years, with a single-dose regimen designed to offer effective protection against HPV types 16 and 18, which are responsible for at least 70% of CCs.[3,9] Despite the availability of safe and effective HPV vaccine, the uptake remains low in many resource-constrained settings, including Nigeria.[6,9,10]

There is compelling evidence of a rapid increase in mobile phone penetration across Nigeria, including in previously underserved rural communities, driven by expanding network infrastructure and the growing affordability of mobile devices.[11] This trend has led to the expansion of mobile health (mHealth) technologies and a rising interest in using digital interventions to improve public health outcomes.[12,13] mHealth has the potential to empower individuals, improve uptake of preventive interventions such as HPV vaccination, and reduce healthcare disparities.[14] Although a few studies in sub-Saharan Africa have investigated the use of mHealth in cancer prevention,[14] no previous research has examined its impact on HPV vaccine uptake among mothers of vaccine-eligible school-age girls. The mHealth-HPVac study was, therefore, designed to evaluate the effectiveness of mHealth interventions, using short message service (SMS), in increasing HPV vaccine uptake among mothers of unvaccinated girls age 9-14 years in Lagos, Nigeria. We selected SMS-based communication as our mHealth tool for improving HPV vaccination uptake in this trial, as mobile phone ownership and use have increased significantly in recent years in Nigeria and in many low- and middle-income countries, making SMS a practical and scalable tool for delivering health interventions directly to the target population.[15] Furthermore, in comparison with more resource-intensive interventions such as in-person education or mass media campaigns, SMS is low-cost, does not require Internet connectivity, and can be deployed at scale with minimal infrastructure,[16] which is ideal for our resource-limited settings.

METHODS

Study Design and Setting

The mHealth-HPVac trial is a randomized controlled trial conducted at the general outpatient clinics of Lagos University Teaching Hospital, Nigeria, from June 2024 to March 2025. The trial protocol has been published elsewhere,[17] with key details outlined below. The authors adhered strictly to the guidelines outlined in the Standard Protocol Items: Recommendations for Interventional Trials checklist for reporting.

Study Population and Eligibility Criteria

We enrolled mothers of unvaccinated girls age 9-14 years who attended routine care at the General Out-Patient (GOP) clinics of Lagos University Teaching Hospital in June and July 2024 and then followed up for 6 months each until January 2025. We included mothers who expressed willingness to vaccinate their children, own and use a personal mobile phone, were free from any mental or physical disabilities that inhibited them from understanding the nature and implications of the study, and those not considering relocating from their current residence within 6 months of enrollment in the trial.

Study Procedures and Randomization

On each day of the study period, the clinic midwives, as part of usual care, gave a 20- to 30-minute health talk on CC prevention, including HPV vaccination, to all women in the GOP clinics, after which the study staff identified eligible mothers who were invited to participate in the trial upon explanation of the objectives and procedures of the study. Participants were enrolled after a health education session

by the study nurse to give clear, concise, and easily understandable information about the study's objectives, procedures, potential benefits and risks, and specific guidance on where and when to get the HPV vaccine. Engaging language and visuals were used to enhance interest and comprehension. Once consent is obtained, baseline information on sociodemographic characteristics of the mothers, their cellphone use, and distance of mothers' residence from the nearest flagship primary health centers with HPV vaccine availability (measured in km using Google Maps) were collected using an electronic interviewer-administered questionnaire created on the REDCap database. Other relevant information collected from the mothers included the age of their oldest vaccine-eligible daughter, the number of female children, awareness of CC, and previous CC screening. Enrolled mothers were then randomly assigned using a computer-generated random sequence generated by an independent statistician to either an mHealth arm or a control arm.

1. mHealth (intervention) arm: mHealth messages were delivered using the MultiTexter Bulk SMS system, an mHealth platform for automated message delivery and participant engagement with backend analytics capable of confirming message delivery status. Each SMS was tagged with a delivery report, which indicated whether the message was successfully sent, delivered, or failed. These logs were periodically reviewed to monitor message flow and troubleshoot failed deliveries.[14] Participants received messages with information about CC and were encouraged to have their daughters, age 9-14 years, vaccinated against HPV. SMS was delivered once a month for 6 months from enrollment. This frequency was based on our findings from a formative focus group discussion (FGD) with mothers of vaccine-eligible girls to gather input from the mothers prior to designing the intervention messages. The FGD explored maternal knowledge, attitudes, cultural beliefs, and perceived barriers related to HPV vaccination, as well as preferences for mobile messaging formats, tone, language, and frequency. Insights from this discussion directly informed the content, framing, and delivery schedule of the SMS that was tailored to local language, literacy level, and cultural values for maximum relevance and impact.
2. Usual care (control) arm: participants received only the usual health education talk on CC prevention at enrollment. They received no additional follow-up SMS.

Trial arm allocations were concealed from the investigators and trial statistician using sequentially numbered, sealed opaque envelopes prepared before the trial. The envelopes were opened only during participants' enrollment, ensuring that the group allocation remains concealed until randomization. Each participating mother was offered free CC screening and a $2.00 in US dollars (2,000.00 Nigerian naira) mobile credit incentive to ensure the retention of their phone details throughout the study period. In addition, the study team maintained an open communication channel via a dedicated phone line for participants in both trial arms, who were encouraged to use the channel to ask questions or opt out at any point during the trial. Data were prospectively collected, with data entry and checking taking place continuously. Queries were actively pursued to ensure prompt clarification. Given that no safety concerns were encountered, there was no unblinding during the study. We tracked the participants via phone calls after the sixth month of enrollment to collect data on their HPV vaccination uptake. We verified HPV vaccination status by requesting mothers to present their daughters' vaccination cards during their follow-up visits and by reviewing the vaccination registers in collaborating flagship primary health facilities where possible. Outcome data collectors were blinded to participants' group assignments throughout the data collection process to minimize the risk of detection bias and preserve the integrity of outcome assessment. The research team instituted an internal review mechanism to monitor recruitment progress, ensure the robustness of the data, and verify adherence to the trial protocol.

Statistical Analyses

The study outcome is the proportion of mothers whose vaccine-eligible unvaccinated daughters received a single-dose HPV vaccination within 6 months of enrollment in the trial. Assuming a randomization ratio of 1:1, a two-sided test with a type I error of .05, and a 20% loss to follow-up or missing outcome data rate, we initially planned to enroll n = 123 eligible mothers to power the trial at 80% in detecting a 30% proportional difference between the mHealth and usual care groups, given a baseline HPV vaccine uptake of 28.5%.[18] However, on the basis of an internal review mechanism to monitor recruitment progress and preliminary effect size assumptions, we conducted an interim analysis after 50% enrollment, without unblinding study arms, to reassess our initial assumptions of a 30% proportional difference in vaccination uptake and we determined that a 21.5% difference would still be programmatically meaningful and clinically relevant for informing policy decisions on HPV vaccination uptake in our setting and similar low-resource settings. This increased the number of participants to n = 180 on the basis of an adjusted loss to follow-up or missing outcome data rate of 10% to ensure adequate statistical power. The revised sample size was approved by the hospital's ethics committee and reflected in our updated trial registration and protocol. Statistical analyses were performed using Stata version 18.0 for Windows (StataCorp LLC, TX). No imputation for missing data was performed as complete trial data were available for analysis. Data were summarized using descriptive statistics with continuous variables presented as mean (standard deviation) for normally distributed data or median (25th-75th centile) for skewed distributions. The primary analysis was conducted using the intention-to-treat principle. HPV vaccination uptake was compared between the two trial arms using the chi-square test. Continuous variables were compared using an independent-sample t-test or the nonparametric Wilcoxon rank sum test. We performed bivariable and multivariable logistic regression models to compare HPV vaccination uptake between the trial arms, adjusting for potential confounders

such as level of education, awareness of CC, and previous CC screening, using odds ratios (ORs) and 95% CIs. Subgroup analyses were also performed to assess the differential or interaction effects of baseline sociodemographic/clinical characteristics, including tertiary education and mHealth, on HPV vaccination uptake. To account for our unplanned interim analysis, we applied a conservative adjustment of $P < .025$ to the final significance threshold in our primary outcome analysis using the O'Brien-Fleming approach.[19]

Ethics Approval

Ethical approvals for the mHealth-HPVac study were obtained from the Health Research Ethics Committees of the Lagos University Teaching Hospital (ADM/DSCST/HREC/APP/6566—May 10, 2024) and the College of Medicine, University of Lagos (CMUL/HREC/5/24/1464—May 15, 2024). The purpose and nature of the study were explained to all potential participants, and participants who were willing signed an informed consent form before study entry. The trial protocol was registered on the Pan African Clinical Trial Registry (PACTR202406727470443) on June 6, 2024.

RESULTS

Out of the 276 screened women, 180 were included in the trial, with 90 in each of the mHealth intervention and usual care arms (Fig 1). Table 1 presents the baseline characteristics of participants randomly assigned to the study arms. The baseline characteristics were well balanced across the study groups. The mean age of participants was 43.6 ± 7.2 years. The median residential location was 12.0 km (IQR, 6.1-24.0), and participants had been using mobile phones for an average of 13.9 ± 5.1 years. The mean age of the oldest vaccine-eligible daughters was 11.7 ± 1.6 years. There were no significant differences in the baseline characteristics of the participants in the two trial arms.

As shown in Figure 2, there is a significant difference in the vaccine uptake rate among mothers of girls who received mHealth intervention compared with those who had usual care alone (62.1% *v* 36.5%; $P < .001$). In the multivariable binary logistic regression model, mHealth intervention significantly increased HPV vaccination uptake among mothers of vaccine-eligible girls (adjusted odds ratio [adj OR], 3.05 [95% CI, 1.61 to 5.77]; $P = .001$). Higher education level was also significantly associated with increased vaccine uptake (adj OR, 3.35 [95% CI, 1.77 to 6.33]; $P < .001$; Table 2). However, in the subgroup analyses by baseline sociodemographic and clinical characteristics, there were no significant interaction effects on the association between mHealth intervention and HPV vaccine uptake (P value for interaction > .05; Table 3).

DISCUSSION

This randomized controlled trial evaluated the impact of a mHealth intervention via SMS on HPV vaccine uptake among

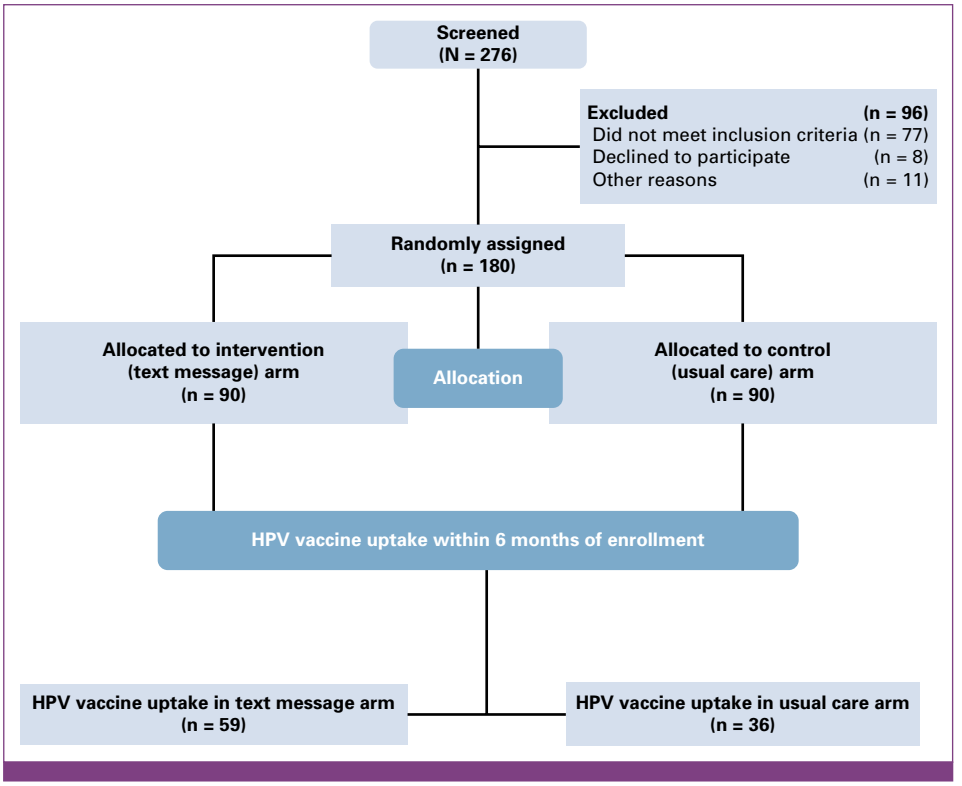

FIG 1. Trial flowchart. HPV, human papillomavirus.

TABLE 1. Baseline Characteristics of Participants in the Study Arms

Characteristic	Total (N = 180)	mHealth (n = 90)	Usual Care (n = 90)	*P*
Age, years	43.6 ± 7.2	44.2 ± 7.4	43.0 ± 7.0	.273
Residential location, km[a]	12.0 (6.1-24.0)	11.0 (6.8-27.0)	12.3 (5.3-22.0)	.792
Duration of mobile phone use, years	13.9 ± 5.1	13.8 ± 4.9	13.9 ± 5.4	.954
Age of oldest vaccine-eligible daughter, years	11.7 ± 1.6	11.8 ± 1.7	11.7 ± 1.6	.928
Previous pregnancies				
One to two	60 (33.3)	32 (35.6)	28 (31.1)	.670
Three to four	90 (50.0)	42 (46.7)	48 (53.3)	
More than four	30 (16.7)	16 (17.8)	14 (15.6)	
No. of daughters				
One	73 (40.6)	33 (35.7)	40 (44.4)	.533
Two	64 (35.6)	35 (38.9)	29 (32.2)	
More than two	43 (23.9)	22 (24.4)	21 (23.3)	
Marital status				
Never married	12 (21.0)	6 (6.7)	6 (6.7)	.911
Married	143 (67.0)	73 (81.1)	70 (77.8)	
Separated/divorced	6 (8.0)	3 (3.3)	3 (3.3)	
Widowed	19 (4.0)	8 (8.9)	11 (12.2)	
Level of education				
No formal education	5 (2.8)	1 (1.1)	4 (4.4)	.677
Primary education	13 (7.2)	7 (7.8)	6 (6.7)	
Secondary education	72 (40.0)	36 (40.0)	36 (40.0)	
Tertiary education	69 (38.3)	34 (37.8)	35 (38.9)	
Postgraduate education	21 (11.7)	12 (13.3)	9 (10.0)	
Tribe				
Hausa	4 (2.2)	1 (1.1)	3 (3.3)	.503
Igbo	78 (43.3)	37 (43.3)	41 (45.6)	
Yoruba	62 (34.4)	35 (38.9)	27 (30.0)	
Others	36 (20.0)	17 (18.9)	19 (21.1)	
Functionality of mobile phone				
Rarely functional	5 (2.8)	2 (2.2)	3 (3.3)	.902
Sometimes functional	18 (10.0)	9 (10.0)	9 (10.0)	
Fully functional	157 (87.2)	79 (87.8)	78 (86.7)	
Awareness of CC				
No	54 (30.0)	26 (28.9)	28 (31.1)	.745
Yes	126 (70.0)	64 (71.1)	62 (68.9)	
Previous of CC screening				
No	87 (48.3)	46 (51.1)	41 (45.6)	.456
Yes	93 (51.7)	44 (48.9)	49 (54.4)	

NOTE. Values are given as mean ± SD, or No. (%) unless indicated otherwise.
Abbreviations: CC, cervical cancer; mHealth, mobile health; SD, standard deviation.
[a]Wilcoxon rank sum test.

mothers of vaccine-eligible school-age girls in Lagos. The mHealth intervention was specifically designed to help mitigate vaccine hesitancy through tailored, evidence-based digital messaging crafted in local languages using clear and nontechnical language that aligned with the sociocultural context of Nigerian parents of vaccine-eligible adolescents to foster trust and relatability. The study demonstrates that mHealth technologies significantly improved HPV vaccination uptake among mothers of vaccine-eligible girls compared with usual care.

The study builds on previous digital health interventions in sub-Saharan Africa by focusing specifically on HPV vaccination uptake among mothers of vaccine-eligible girls, a population and health outcome that has received relatively limited attention in the digital health space within the

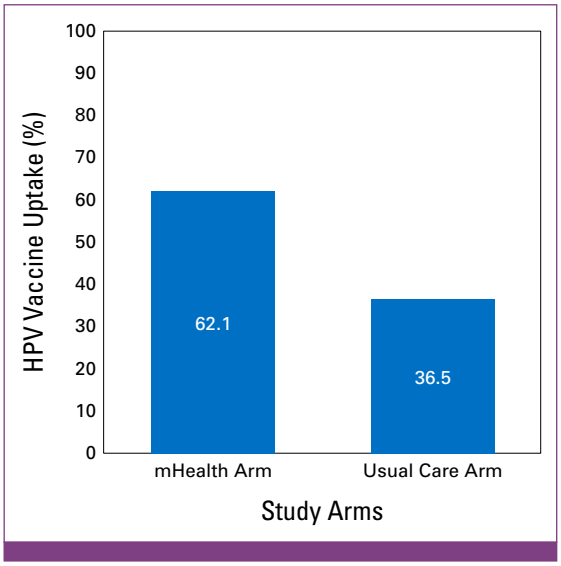

FIG 2. High-risk HPV vaccination uptake according to study arms (P < .001). HPV, human papillomavirus; mHealth, mobile health.

region. Although several mHealth interventions in sub-Saharan Africa have focused on certain maternal, sexual, and reproductive health services, mental health interventions, noncommunicable diseases, and primary health care services,[15,20-22] very few have targeted HPV vaccination uptake like our current study. Our findings reinforced existing literature demonstrating the utility of mHealth interventions in improving health-seeking behaviors.[13,14] Previous studies have shown that text message reminders and mHealth education can enhance compliance with vaccination programs and other preventive health measures.[23,24] The findings of this trial provide further evidence supporting the role of digital health interventions in promoting HPV vaccination,[25-27] particularly in settings with suboptimal vaccine coverage. The effectiveness of mHealth interventions in our study can be attributed to several factors. First, mHealth messaging provides a convenient, accessible, and cost-effective means of delivering health education and reminders.[28] The ability to receive timely, personalized messages may have enhanced mothers' confidence in the HPV vaccine and facilitated informed decision making. Second, mobile interventions may help overcome logistical barriers such as misinformation, forgetfulness, and concerns about vaccine safety, which are commonly cited reasons for vaccine hesitancy.

In addition to the impact of mHealth intervention, our study identified education level as an independent predictor of vaccine uptake. Mothers with a tertiary education were significantly more likely to vaccinate their daughters compared with those with lower educational attainment. This finding underscores the role of health literacy in vaccine decision making[29,30] and suggests that interventions targeting lower-education populations may require additional strategies to maximize HPV vaccine uptake and effectiveness. It also highlights the need for broader health education campaigns to ensure equitable vaccine uptake across diverse sociodemographic groups. Although both mHealth intervention and tertiary education independently increase HPV vaccine uptake, the effect of mHealth intervention on vaccine uptake was not significantly modified by educational level. A possible explanation for this finding is that the mHealth intervention was equally effective across different educational backgrounds, and thus did not provide additional benefits specifically for those with tertiary education. This aligns with previous studies indicating that mHealth interventions can bridge knowledge gaps and improve health behaviors among individuals with varying literacy levels.[31-33] This also highlights the potential for mHealth interventions to be effective across educational groups, rather than being modified or driven primarily by education level alone.

The major strength of our study is the randomized controlled trial design, which allows a rigorous assessment of the causal relationship between mHealth intervention and HPV vaccine uptake. In addition, the mean age of 43.6 years and the average of 13.9 years of mobile phone use experience for the mothers in our study suggest a population most receptive to digital health interventions. Furthermore, the SMS intervention in our study was specifically designed to help mitigate vaccine hesitancy through tailored, evidence-based digital messaging crafted in local languages using clear and nontechnical language that aligned with the sociocultural context of Nigerian parents of adolescent girls and boys to foster trust and relatability. The SMS delivery platform used for the study also complied with data privacy and confidentiality standards and did not store personally identifiable health information alongside the message content. However, despite the promising findings, our study has some limitations. First, the study was conducted in a single-institutional setting, which may limit the generalizability of the results to other populations, particularly those with different health-seeking behavior, awareness, and attitudes toward HPV vaccination. Second, although randomization ensured balanced baseline characteristics, unmeasured factors such as income, transportation, cultural beliefs, or health care accessibility could still influence HPV vaccine uptake. Third, the study relied mostly on self-reported vaccine uptake, which may be prone to poor recall or social desirability. Because of limitations in documentation systems and the fragmented nature of vaccine record-keeping in some of the flagship primary health care facilities that offer the vaccine, complete verification was not feasible for all participants, resulting in information bias. Therefore, future research should incorporate objective verification of vaccination status through veritable clinic immunization records. Fourth, we acknowledge the potential risk of cross-contamination in the study because of participants being enrolled from the same clinic. Although efforts were made to minimize interactions that could lead to information sharing, such as enrolling participants at staggered times and ensuring allocation concealment,

TABLE 2. Sociodemographic and Clinical Predictors of High-Risk HPV Vaccination Uptake in Mothers of Vaccine-Eligible Girls (N = 180)

			Estimates of Effect on Pap Smear Screening Uptake			
			Univariable		Multivariable	
Covariates	Uptake, No. (%), (n = 95)	Nonuptake, No. (%), (n = 85)	OR (95% CI)	*P*	Adj OR (95% CI)	*P*
Intervention						
mHealth	59 (62.1)	31 (36.5)	2.85 (1.56 to 5.23)	<.001	3.05 (1.61 to 5.77)	.001
Usual care	36 (37.9)	54 (63.5)	1.00 (ref)	NA	1.00 (ref)	NA
Age, years						
≥45	41 (43.2)	39 (45.9)	0.89 (0.50 to 1.61)	.713	NA	NA
<45	54 (56.8)	46 (54.1)	1.00 (ref)	NA	NA	NA
Residential location, km						
≥12	49 (51.6)	43 (50.6)	1.04 (0.58 to 1.87)	.894	NA	NA
<12	46 (48.4)	42 (49.4)	1.00 (ref)	NA	NA	NA
Use of mobile phone, years						
≥14	56 (58.9)	44 (51.8)	1.34 (0.74 to 2.41)	.333	NA	NA
<14	39 (41.1)	41 (48.2)	1.00 (ref)	NA	NA	NA
Oldest daughter's age, years						
≥12	57 (60.0)	49 (57.7)	1.10 (0.61 to 1.99)	.749	NA	NA
<12	38 (40.0)	36 (42.3)	1.00 (ref)	NA	NA	NA
No. of daughters						
More than two	24 (25.3)	19 (22.4)	1.23 (0.58 to 2.62)	.593	NA	NA
Two	34 (35.8)	30 (35.3)	1.10 (0.56 to 1.16)	.776	NA	NA
One	37 (38.9)	36 (42.3)	1.00 (ref)	NA	NA	NA
Previous pregnancies						
Multiparous	64 (67.4)	56 (68.9)	1.07 (0.57 to 1.99)	.833	NA	NA
Primiparous	31 (32.6)	29 (34.1)	1.00 (ref)	NA	NA	NA
Marital status						
Ever married	89 (93.7)	79 (92.9)	1.12 (0.35 to 3.63)	.842	NA	NA
Never married	6 (6.3)	6 (7.1)	1.00 (ref)	NA	NA	NA
Education						
At least tertiary education	60 (63.1)	30 (35.3)	3.14 (1.71 to 5.78)	<.001	3.35 (1.77 to 6.33)	<.001
Less than tertiary education	35 (36.8)	55 (64.7)	1.00 (ref)	NA	1.00 (ref)	NA
Functionality of mobile phone						
Fully functional	86 (90.5)	71 (83.5)	1.88 (0.77 to 4.61)	.165	NA	NA
Somewhat functional	9 (9.5)	14 (16.5)	1.00 (ref)	NA	NA	NA
Awareness of CC						
Yes	72 (75.8)	54 (63.5)	1.80 (0.94 to 3.42)	.075	1.02 (0.40 to 2.60)	.975
No	23 (24.2)	31 (36.5)	1.00 (ref)	NA	1.00 (ref)	NA
Previous of CC screening						
Yes	55 (57.9)	38 (44.7)	1.70 (0.94 to 3.07)	.078	1.90 (0.80 to 4.54)	.149
No	40 (42.1)	47 (55.3)	1.00 (ref)	NA	1.00 (ref)	NA

Abbreviations: Adj OR, adjusted odds ratio; CC, cervical cancer; HPV, human papillomavirus; mHealth, mobile health; NA, not applicable; OR, odds ratio; ref, reference.

complete prevention of cross-group influence could not be guaranteed. In addition, we noted that offering a small phone credit could potentially act as an independent motivator for vaccine uptake. However, the airtime incentive was a one-off payment primarily designed to ensure continued engagement with the intervention by supporting the cost of receiving and interacting with the mHealth messages. The value of the airtime provided was minimal and not sufficient to serve as a standalone motivator for vaccination behavior. Finally, although we acknowledge the importance of economic evaluation in informing national scale-up decisions, a formal cost-effectiveness analysis was not conducted in our study. We, therefore, plan to explore cost and cost-effectiveness analyses as part of a potential scale-up or implementation study.

TABLE 3. Subgroup Analyses of High-Risk HPV Vaccination Uptake in Mothers of Vaccine-Eligible Girls

Covariates	mHealth, n/N (%), (n = 90)	Usual Care, n/N (%), (n = 90)	OR (95% CI)	*P* for Interaction
Age, years				
≥45	27/41 (65.8)	12/39 (30.8)	4.34 (1.70 to 11.08)	.238
<45	32/54 (59.3)	19/46 (41.3)	2.07 (0.93 to 4.60)	NA
Residential location, km				
≥12	30/49 (61.2)	15/43 (34.9)	2.95 (1.23 to 6.90)	.921
<12	29/46 (63.0)	16/42 (38.1)	2.77 (1.17 to 6.58)	NA
Use of mobile phone, years				
≥14	34/56 (60.7)	14/43 (31.8)	3.31 (1.44 to 7.60)	.663
<14	25/39 (64.1)	17/41 (41.5)	2.52 (1.02 to 6.21)	NA
Oldest daughter's age, years				
≥12	35/57 (61.4)	19/49 (38.8)	2.51 (1.15 to 5.50)	.622
<12	24/38 (63.2)	12/36 (33.3)	3.43 (1.32 to 8.92)	NA
No. of daughters				
More than two	16/24 (66.7)	6/19 (31.6)	4.33 (1.20 to 15.69)	.466
At most two	43/71 (60.6)	25/66 (37.9)	2.52 (1.26 to 5.01)	NA
Previous pregnancies				
Multiparous	38/64 (59.4)	20/56 (35.7)	2.63 (1.26 to 5.51)	.686
Primiparous	21/31 (67.7)	11/29 (37.9)	3.44 (1.19 to 9.94)	NA
Education				
At least tertiary education	38/60 (63.3)	8/30 (26.7)	4.75 (1.81 to 12.46)	.213
Less than tertiary education	21/35 (60.0)	23/55 (41.8)	2.09 (0.88 to 4.94)	NA
Mobile phone functionality				
Fully functional	38/60 (63.3)	8/30 (26.7)	2.78 (1.45 to 5.32)	.788
Somewhat functional	21/35 (60.0)	23/55 (41.8)	3.60 (0.62 to 21.03)	NA
Awareness of CC				
Yes	47/72 (65.3)	17/54 (31.5)	4.09 (1.93 to 8.68)	.093
No	12/23 (52.2)	14/31 (45.2)	1.32 (0.45 to 3.91)	NA
Previous of CC screening				
Yes	33/55 (60.0)	11/38 (29.0)	3.68 (1.52 to 8.92)	.544
No	26/40 (65.0)	20/47 (42.6)	2.51 (1.05 to 5.98)	NA

NOTE. Values are given as n/N (%), unless otherwise specified. *P* values for interaction are based on a likelihood ratio test in a model with an interaction term for each baseline sociodemographic and clinical characteristics.
Abbreviations: CC, cervical cancer; HPV, human papillomavirus; mHealth, mobile health; NA, not applicable; OR, odds ratio.

In conclusion, this study provides evidence that mHealth interventions significantly improve HPV vaccine uptake among mothers of vaccine-eligible school-age girls in Lagos. Given the growing accessibility of mobile technologies, integrating mHealth strategies into routine immunization programs could be a scalable and cost-effective approach to increasing HPV vaccination coverage. However, future multicenter studies should consider using cluster randomization at the facility level to better optimize mobile interventions for diverse populations and more effectively address the risk of cross-contamination. These studies should also aim to identify the key drivers of successful SMS-based mHealth interventions, such as message frequency, content, and personalization, and incorporate a broader range of socioeconomic and contextual factors to gain deeper insights into the complex barriers of HPV vaccination uptake. Furthermore, while the current study focuses specifically on mothers as primary decision makers for adolescent girls' health in our setting, the broader inclusion of fathers, other caregivers, and school-based delivery platforms could further enhance HPV vaccine uptake. As part of our future studies, we also plan to explore the feasibility of integrating a chatbot or a two-way messaging feature to support real-time communication, address participants' concerns, and personalize HPV vaccination information further.

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DISCLAIMER

The content of this paper is solely the responsibility of the author and does not necessarily reflect the official views of the Conquer Cancer Foundation, the National Cancer Institute, the Fogarty International Center, or the National Institutes of Health. The funders had no role in the study's conceptualization, decision to publish, or manuscript preparation.

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CLINICAL TRIAL INFORMATION

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