Impact of mHealth Intervention on Maternal and Neonatal Health Outcomes in a Southwestern State in Nigeria

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Abstract

Background: Indices of maternal and child health in many low- and middle-income countries are still much higher than the targets under the Sustainable Development Goals. The deployment of mobile health applications has the potential to improve MCH service delivery and outcomes. This study determined the impact of educational and reminder text messages on maternal and neonatal health outcomes among mothers attending primary healthcare centres in Osun State, Nigeria.

Methods: A quasi-experimental research design was utilised. A multistage sampling technique was used to select and randomise the PHCs into the intervention and control groups, and 380 pregnant mothers (190 in each study group) were recruited. The participants were followed up until six weeks after delivery. The rates of specific maternal and neonatal health outcomes were compared between the two groups. Appropriate descriptive and inferential analyses were done.

Results: The mobile health intervention was associated with significantly higher odds of optimal child immunisation uptake (OR = 10.42; CI = 3.69 – 29.42) and good cord status (OR = 3.80; CI = 1.37 – 10.63). The mothers in the intervention group had significantly lower odds of postpartum depression than their control counterparts (OR = 0.32; CI: 0.11 – 0.95). However, no significant difference was observed concerning the incidence of postpartum haemorrhage, postpartum infection, uptake of contraception, and neonatal weight gain. Although the percentage of neonatal deaths (2.2%) was lower in the intervention group compared to the control group (4.2%), the difference was not statistically significant (OR = 0.51; CI = 0.15 – 1.80).

Conclusion: The mHealth intervention was associated with improved cord status and immunisation rates among neonates, as well as reduced maternal postpartum depression. The findings suggest a promising role of mHealth intervention in delivering maternal and child healthcare.

Keywords: mHealth, maternal health, neonatal health, infection, postpartum hemorrhage, immunization, cord status, Nigeria

INTRODUCTION

Maternal and child health (MCH) indices remain poor in many low- and medium-income countries (LMIC), including Nigeria. According to global estimates, Nigeria is second only to India in terms of maternal mortality and has the worst indices in Africa.[1,2] Some factors contributing to these poor MCH indices in the country include poor maternal health literacy, poor utilisation of MCH services, harmful cultural and religious practices, etc.[3-5] The deployment of mobile health (mHealth), such as educational messages and reminders of clinic appointments, has the potential to improve mothers' health literacy, better self-care practices, and increase utilisation of MCH services.[6-10]

According to the World Health Organisation (WHO), the neonatal period (the first twenty-eight days of life) is the most vulnerable period for a child's survival, with 2.4 million neonatal deaths globally in 2020, constituting about half (47%) of all under-5 mortalities.[11] Sub-Saharan Africa accounts for 43% of all neonatal deaths worldwide, and Nigeria has one of the highest neonatal mortality rates (NMR), which stood at 39 per 1000 live birth in 2018.[11, 12] Many concerted efforts, including novel strategic interventions, are required to tackle this challenge and accelerate progress towards the sustainable development goal (SDG) 3.22 target of an NMR of 12 per 1000 live births by 2030.[13,14]

The WHO itemised specific strategies to reduce neonatal mortality as part of every newborn action plan. These include the practice of essential newborn care, exclusive breastfeeding, hygienic cord care, thermal care, appropriate vaccinations, early recognition of newborn illnesses and danger signs, and prompt care-seeking behaviours, among others.[14,15] It has been shown that the inability to recognise danger signs and the delay in seeking care by mothers contribute significantly to neonatal mortality [14,16]

Furthermore, maternal depression is significantly associated with suboptimal newborn care and low uptake of preventive health care services, which increases the risk of neonatal and maternal morbidity and mortality. [14,17] Improving mothers' knowledge on essential newborn care, recognising illness signs, proper cord care, and immunisation can help reduce neonatal health risks. The use of relevant educational short message service (SMS) is a potential tool for increasing mothers' knowledge in these areas, in addition to the reminders for utilisation of MCH services.[14,18] The latent potential for the deployment of mHealth in Nigeria is quite significant because about 90% of the population owns mobile phones, which is much higher in the study area.[19]

Evidence from other low- and middle-income countries suggests that mHealth interventions can improve knowledge, enhance compliance with antenatal and postnatal visits, encourage facility-based deliveries, and ultimately lead to

improved maternal and neonatal outcomes.[8-10, 20-28] However, there is a need for context-specific evidence from Nigeria on the effectiveness of mHealth interventions in improving maternal and neonatal health indicators. Cultural, infrastructural, and health system differences make it essential to generate local evidence to inform policy and scale-up decisions. Moreover, while several systematic reviews, meta-analyses, and the World Health Organisation's guidelines on digital health have emphasised the need for more data on the impact of mHealth interventions on specific health outcomes, particularly in low-resource settings.[20,23,25,26,28-31]

This study, therefore, seeks to assess the effectiveness of a structured SMS-based mHealth intervention on key neonatal and maternal health outcomes in Osun State, Nigeria. It is hoped that the findings will contribute to the evidence base for digital health interventions and provide valuable insights for policymakers, program designers, and healthcare providers working to reduce maternal and neonatal morbidity and mortality in similar settings.

Specific Objectives and Hypothesis

This study assessed the impact of mHealth intervention on the following specific neonatal (uptake of immunisation, cord status, weight gain, and neonatal mortality) and maternal (incidence of postpartum haemorrhage, infection, depression, and uptake of contraceptives) outcomes. We hypothesised that mHealth intervention would lead to an improvement in each of these outcomes. The mHealth intervention can improve maternal and neonatal health outcomes by enhancing mothers' knowledge, promoting timely healthcare-seeking behaviour, reducing harmful practices, and increasing utilisation of MCH services.[14,18,27] For example, increased knowledge of healthy cord care practices can reduce the risk of cord infection, leading to improved cord health status.[14] In the same vein, the educational and reminder SMS can prompt many mothers to seek skilled care at birth and adequately utilise postnatal care services. In that case, there may be a reduction in the risk and occurrence of adverse complications such as postpartum haemorrhage and infections, two of the leading causes of maternal mortality. These will potentially reduce maternal and neonatal morbidity and mortality.[14,27,32]

MATERIALS AND METHODS

Study design and setting

The mHealth intervention project was a quasi-experimental study conducted among women attending antenatal clinics in primary healthcare centres in Osun State, Southwest Nigeria. More than 90% of the adult population in the study area owns a mobile phone, while every town has access to electricity and telecommunication networks.

Sample size and sampling technique

The minimum sample size for each group was 174, using the sample size formula for comparing two groups.[33] However, to allow for a possible 10% attrition rate, 190 respondents were recruited per group, and samples were drawn using the multistage sampling technique. Six of the 30 local government areas (LGAs) in the state were randomly selected for the study. Three of the selected LGAs were randomly allocated to the mHealth intervention group, while the other three served as the control group. Primary health centres (nine in the intervention group and eight in the control group) that met the following criteria were included in the study: availability of facilities for providing essential maternal and child healthcare services and at least one registered nurse. All women who attended ANC in each of the selected PHCs during this study were assessed for their eligibility. Women with pregnancies less than 28 weeks' gestation were excluded, as the intervention targeted the later stages of pregnancy through the postnatal period. Women without functional cell phones or who could not read SMS were also excluded. The details are shown in Figure 1. Respondents couldn't be fully blinded because direct participation is required.

Ethical approval was obtained from the Institutional Review Board of the Institute of Public Health, Obafemi Awolowo University, Ile-Ife (reference number IPHOAU/12/580). Each participant provided informed written consent.

Mobile health intervention

The *postnatal care assistant* (PNCA) software was developed using locally available resources and expertise at a relatively low cost. It was a two-way communication system that was designed using web technology. The system comprised a web app implemented using Hypertext Markup Language (HTML), Cascading Styling Sheet (CSS), JavaScript, Personal Homepage Hypertext pre-processor (PHP), and My Structured Query Language (MySQL). The software was set up to send automated SMS to the registered mobile phone numbers of the participants according to their gestational age. A pilot evaluation of the system yielded an average user satisfaction score of 77%. The feedback was used to make a few necessary adjustments to the system and processes.

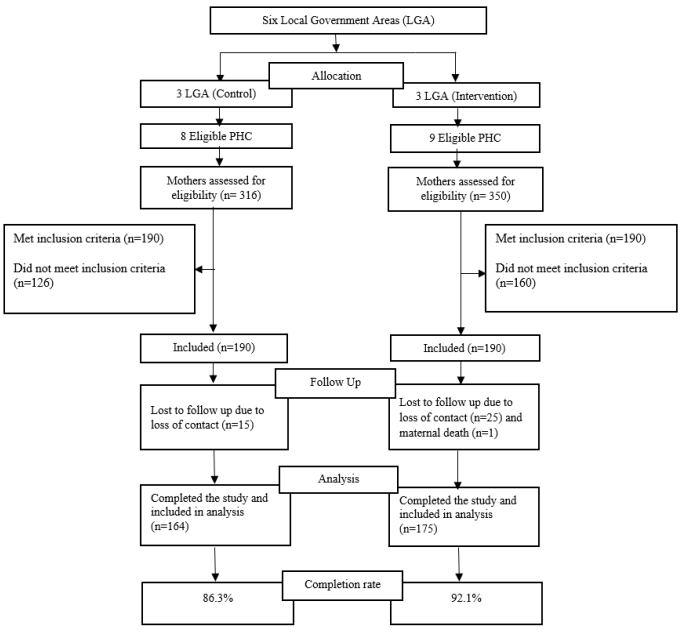

Figure 1: Flowchart of Respondents

The SMS had two components: educational messages on various relevant MCH topics and reminders for healthcare services utilisation, including facility-based delivery and postnatal clinic visits. The intervention began at 35 weeks of gestational age and continued until six weeks after delivery. Educational messages were sent to the participants every week until delivery. On the day of delivery, each participant

sent a pre-arranged code using any mobile network to a designated number attached to the system. Thereafter, the software sent SMS related to the postnatal period until the 42nd day (6th week). The messages were timed to match the needs of different antenatal and postnatal stages. These include, but are not limited to, maternal and neonatal danger signs, the importance of prompt care seeking, essential newborn care practices, umbilical cord care, and immunisation as shown in Table I.

Two messages were sent per week between the 35th week of gestation and delivery. During the postnatal period, two messages were sent on days 1 and 2. Subsequently, SMS reminders were sent every 3 to 4 days until the 6th week, specifically on days 3, 6, 9, 12, 16, 20, 24, 28, 32, 35, 38, and 41. In addition to the above, reminders for postnatal clinic appointments were sent on days 1, 2, 9, and 41. An average of 24 SMS were sent to each participant. The details of health education topics and the respective numbers of SMS are shown in Table I.

The messages were drawn from previously deployed Mobile Alliance for Maternal Action (MAMA) messages[34] and the WHO guidelines on postnatal care services.[35] Messages were available to participants in English or Yoruba, depending on their preference, as all the participants could speak and read either of the two languages.

Table I: Category, Frequency, and Samples of mHealth SMS

Category	Frequency	Example
General information and self-care (e.g., signs of labour)	AN: 5 SMS (Weeks 35, 38, 40, 41, 42)	*Regular, strong contractions are signs of labour. If you feel them, go to the clinic. Please don't wait. (AN; Week 40)*
Psychological and depressive symptoms	PN: 3 SMS (Days 12, 20, 35)	*Are you irritable and weepy? This is quite common among new mothers. Get some rest, make sure you eat well and report to the clinic for proper assessment. (PN; Day 12)*
Health services utilisation (e.g., delivery at the health facility, PNC visits)	AN: 3 (Weeks 35, 36, 38) PN: 1 SMS (Day 1)	*Low back pain is a sign that the baby is low down and ready to be born. Make sure you can get to the clinic in time. Remember to attend the postnatal clinic after delivery (AN; Week 38).*
Maternal danger signs and indications for care-seeking	AN: 1 SMS (Week 38) PN: 3 SMS (Days 2, 5, 9)	*Look out for signs of infection. If your discharge smells, your tummy hurts, or you have a fever, go to the clinic for help (PN; Day 5).*
Family planning	PN: 1 SMS (Day 41)	*Congratulations, your baby is now six weeks old. If you are still deciding on a method of family planning, please do so in your next postnatal care visit (PN Day 41)*
Newborn thermal care	AN: 2 SMS (Weeks 36, 40) PN: 2 SMS (Days 1, 3)	*Your newborn needs warmth. Nurse your baby on your bare chest under a blanket (AN; Week 40)*
Proper cord care	AN: 1 SMS (Week 37) PN: 1 SMS (Day 2)	*A cord infection can make your newborn very ill. Clean with methylated spirit and leave it uncovered to dry. Please do not put anything else on it. The cord will drop off after a week (AN; Week 37).*
Breastfeeding and the need for optimal weight gain	AN: 2 SMS (Weeks 39, 40) PN: 7 SMS (Days 3, 9, 16, 20, 24, 28, 38)	*Your baby needs nothing else apart from breastmilk for the first six months. Your milk will contain all the water and goodness needed by your baby (AN; Week 39)*
Immunisation	AN: 2 SMS (Weeks 37, 39) PN: 2 SMS (Days 1, 41)	*Your baby will need the first dose of vaccines against polio and tuberculosis at birth. Make sure your baby gets them as soon as s/he is born (AN; Week 39)*
Neonatal danger signs	AN: 1 SMS (week 40) PN: 4 SMS (Days 1, 3, 24, 28)	*If your baby's eyes are yellow or having trouble breathing, bring the baby to the clinic (PN; Week 3)*
Reminders for PNC clinic appointments	PN: 4 SMS (Days 1, 2, 9, 41)	*Congratulations, your baby is here! If you deliver at home, please come immediately with the baby to the health facility for the first postnatal contact. (PN; Day 1)*

Key: **AN** – Antenatal period, **PN** – Postnatal period

Implementation and data collection

The healthcare workers at the selected PHCs were mobilised and sensitised concerning the purpose and process of the study. One of the staff members at each of the selected PHCs was trained and served as a research assistant. A trained supervisor was also assigned to each LGA, who visited all the centres weekly for quality control.

The basic demographic data of each enrolled mother was obtained with a structured questionnaire. Information about respondents' obstetric history and other covariates was recorded. Participants had the option to select from two available languages, i.e., English or Yoruba, which are the predominant local languages. All the women received baseline counselling on the importance of ANC, skilled delivery, and the recommended four PNC contacts. After that, they all continued to receive routine care while those in the intervention group received the targeted mHealth intervention. All the respondents were followed up till six weeks after delivery.

At each recommended postnatal contact (immediately after birth, days 3, 10, and 42), data on neonatal and maternal health outcomes were collected using a checklist. At the end of the study, all the mothers and neonates in both study groups had a final assessment. Those who did not come for the PNC visits were contacted by phone. Also, a sample of the mHealth group had a qualitative interview to explore their experience with the mHealth intervention, including feedback on the acceptability, satisfaction, relevance, usefulness, and limitations, the result of which has been reported.[36]

Outcome measures

The impact of the mHealth intervention on PNC clinic attendance had been previously reported.[10] The specific neonatal and maternal health outcomes presented in this article are shown in Table II, including their definitions or indicators and the mode and timing of assessment. As earlier described, mothers and neonates were assessed at follow-up contacts at days 3, 10, and 42. Other contact opportunities included immunisation visits and clinic visits for health complaints, etc. At the end of the 6-week postnatal period, all participants had the final survey and assessments.

Statistical Analysis

The Stata software (version 14.0) was used for the analyses. Appropriate descriptive statistics were used in summarising the data. The baseline characteristics of the two study groups were compared using the Pearson Chi-square test. The principle of complete case analyses was used for the final analyses, thereby excluding those with incomplete follow-up data. Attrition analysis showed no difference between those who dropped out and those who completed the study.

In order to assess the impact of a mobile health intervention on each outcome measure, binary logistic regression models were used to determine the association between group membership (i.e., intervention versus control) and each outcome measure. The socio-demographic variables that were statistically different at baseline were retained in the model, and the results were presented as adjusted odds ratios (AOR).

Given the clustered nature of the data, generalised estimating equations (GEE) were used in all logistic regression analyses.[37] The level of significance for all the analyses was set at $P < 0.05$. The presentation of the report was guided by Consolidated Standards of Reporting Trials (CONSORT) guidelines and the mHealth evidence reporting and assessment (mERA) checklist[38].

RESULT

A total of 380 women were recruited, with 190 in each study group. However, 339 respondents completed the study, with a 92.1% (175) and 86.3% (164) completion rate in the intervention and control groups, respectively. The flowchart summarising the process of recruitment, allocation, and follow-up of participants is shown in Figure 1.

Social Demographic Characteristics

As shown in Table III, the two study groups were similar in most of the social demographic characteristics except for their age ($P = 0.02$) and educational level ($P = 0.01$). Appropriate statistical adjustments were made for these differences in subsequent inferential analyses.

Table II: Neonatal and Maternal Health Outcome

Outcome measures	Indicator / Definition	Time of assessment
Cord status	The presence or absence of signs of cord infection anytime within the first week of life or until the cord drops off. Assessed as poor (infected, foul-smelling, or discharging pus) or good (no infection)	Assessment at any clinic visit* Review of hospital records Data collection in the sixth week†
Immunisation	The uptake of all the essential vaccines (BCG, OPV_0, HBV_0, OPV_1, PCV_1 & $PENTA_1$) expected to be received at six weeks was categorised as optimal, while less than that was considered sub-optimal.	Review of hospital records End of study Review†
Weight gain	An increase of at least 1.0kg above the birth weight at six weeks was assessed as optimal.	Assessment at sixth-week clinic visit* Review of hospital records End of study Review†
Neonatal Mortality	The death of a baby within four weeks after live birth. Hence, the neonatal mortality rate was calculated as the number of deaths per 1000 live births.	Review of hospital records End of study Review†
Postpartum haemorrhage (primary or secondary)	The occurrence of vaginal bleeding after birth above 500mls sequel to a standard delivery or 1000mls for a caesarean section; the diagnosis must have been made by health personnel or a self-report of soaking more than three sanitary pads within 4 hours of delivery. Any significant blood loss at any time within the six weeks (e.g., necessitating blood transfusion) was also regarded as significant haemorrhage.	Assessment during the immediate postpartum period and any clinic visit* Review of hospital records End of study Review†
Postpartum Infection	The presence of any two out of the following: fever (with temperature > 38^0c), pelvic pain, and foul-smelling vaginal discharge was taken as the presence of postpartum infection [39,40]	Assessment at any clinic visit* Review of hospital records End of study Review†
Postpartum Depressive symptoms	The presence of low mood plus any one of the following two symptoms: loss of interest in usually pleasurable activities or low energy[41] at any time during the 6-week postnatal period	Assessment at any clinic visit* Review of hospital records End of study Review†
Contraceptive uptake	The uptake of any form of modern contraceptive method for family planning occurs by the sixth week after delivery.	Assessment at sixth week clinic visit* Review of hospital records End of study Review†

*Clinic visits during which assessments were done include: at birth, routine visits on days 3, 10 & 42; visits for immunisation, care-seeking visits for any complaint, etc. The assessments were done through history taking and physical examination. Each study centre had a research assistant assigned to use a checklist to document findings from the assessment or hospital records.

†All mothers in both study groups had an end-of-study review at the end of the study (sixth week). In a few participants, the necessary information was obtained retrospectively at this stage.

BCG – Bacillus Calmette-Guerin vaccine; **OPV** – Oral Polio Vaccine; **HBV** – Hepatitis B Vaccine; **PCV** – Pneumococcal Conjugate Vaccine; **PENTA** – Pentavalent Vaccine.

Table III: Respondents' Sociodemographic Characteristics

Variables	Intervention n=190	Control n=190	*P* value*
Age (years)			
Mean age	29.54 ± 4.99	27.75 ± 4.73	
18 – 30	119 (62.6)	147 (77.4)	0.02
31 and above	71 (37.4)	43 (22.6)	
Marital Status			
Not Married	5 (2.6)	7 (3.7)	0.39
Married	185 (97.4)	183 (96.3)	
Tribe			
Yoruba	168 (88.4)	177 (93.2)	
Hausa	11 (5.8)	10 (5.3)	0.09
Igbo	11 (5.8)	3 (1.6)	
Educational Attainment			
Primary	21 (11.0)	37 (19.5)	0.01
Secondary	144 (75.8)	107 (56.3)	
Tertiary	25 (13.2)	46 (24.2)	
Occupation			
Civil servant	11 (5.8)	24 (12.6)	
Trader	110 (57.9)	98 (51.6)	0.13
Artisan	55 (28.9)	53 (27.9)	
Unemployed	14 (7.4)	15 (7.9)	
Income per month			
Below 18,000	133 (70.0)	139 (73.2)	0.29
18,000 & above	57 (30.0)	51 (26.8)	

** Based on Pearson Chi-square test*

Neonatal Health Outcomes

Four specific neonatal health outcomes, namely, immunisation status, cord status, weight gain, and neonatal mortality, were compared between the intervention and control groups using binary logistic regression (Table IV).

Immunisation: The odds of having optimal immunisation were ten times higher for those in the intervention group than the control group (OR = 10.42, CI = 3.69 – 29.42).

Cord status: Those in the intervention group also demonstrated significantly higher odds of having a good cord status (OR = 3.80; CI = 1.37 – 10.63).

Weight gain: There was no significant difference between the two groups. ($P = .38$)

Neonatal death: All 339 women who completed the study had live births, eight of which were twin deliveries. Out of the 347 live births, 11 babies (4 in the intervention and 7 in the control group) died within the first 28 days, giving an overall neonatal mortality prevalence of 3.2% (Neonatal Mortality Rate (NMR) of 32/1000 births). There was a lower prevalence of neonatal mortality in the intervention group (2.2%, NMR: 22/1000 live births) compared to the control group (4.2%, NMR: 42/1000 live births), which was not statistically significant (OR = 0.51; CI = 0.15 – 1.80).

Table IV. Neonatal Health Outcomes between Groups

	Intervention n (%)	Control n (%)	AOR* (95% CI) Intervention vs. Control	*P* value
Immunisation (N = 336)				
Optimal	171 (97.2)	120 (75.0)	10.42 (3.69 – 29.42)	0.01
Suboptimal	5 (2.8)	40 (25)		
Cord status (N = 336)				
Good	171 (97.2)	144 (90.0)	3.80 (1.37 – 10.63)	0.007
Poor	5 (2.8)	16 (10.0)		
Weight gain (N = 336)				
Optimal	166 (94.3)	147 (91.9)	2.22 (0.83 – 5.95)	0.38
Sub-optimal	10 (5.7)	13 (8.1)		
Neonatal Mortality (N = 347)				
Dead	4 (2.2)	7 (4.2)	0.51 (0.15 – 1.80)	0.30
Alive	176 (97.8)	160 (95.8)		

*Adjusted for baseline characteristics and clustering

Maternal Health Outcomes

Postpartum depression: As shown in Table V, the mothers in

the intervention group had significantly lower odds of experiencing depression than their control counterparts (2.9% vs 8.5%, OR = 0.32; CI: 0.11 – 0.95).

Postpartum haemorrhage and infections: There was no significant association between the mHealth intervention and the incidence of postpartum haemorrhage (P = .37) and postpartum infection (P = .36), respectively.

Contraceptives: The uptake of contraceptives for family planning was also not significantly impacted by the intervention (P = .21).

Table V. Maternal Health Outcomes (N = 339)

	Intervention n (%)	Control n (%)	AOR* (95% CI) Intervention vs. Control	*P* value
Haemorrhage				
Yes	17 (9.7)	21 (12.8)	0.67 (0.33 – 1.33)	0.37
No	158 (90.3)	143 (87.2)		
Infection				
Has infection	2 (1.1)	4 (2.4)	0.43 (0.09 – 2.18)	0.36
No infection	173 (98.9)	160 (97.6)		
Depression				
Yes	5 (2.9)	14 (8.5)	0.32 (0.11 – 0.95)	0.02
No	170 (97.1)	150 (91.5)		
Contraceptive				
Uptake	117 (66.9)	99 (60.4)	1.33 (0.84 – 2.11)	0.21
No uptake	58 (33.1)	65 (39.6)		

*Adjusted for baseline characteristics and clustering.

DISCUSSION

This study evaluated the impact of a mobile health intervention on neonatal and maternal health status with the hypothesis that educational and reminder messages would improve specific health outcomes. More neonates in the intervention group had optimal immunisation compared to the control group. The odds of having optimal immunisation were ten times higher for those in the intervention group. The mHealth messages emphasised the importance of immunisation and reminded mothers of the due dates for individual vaccines. This probably enhanced the resolve of the mothers to follow through with their children's immunisation. This is consistent with previous reports, in Nigeria and other countries in Africa, Asia and North America, that demonstrated the efficacy of mHealth interventions in improving the uptake of vaccination for children.[28,42]

The status of cord health was another outcome variable significantly different between the two groups. The prevalence of cord infection was lower among those in the mHealth group. Neonates of mothers in the intervention group had about four times the odds of a good cord status than the control group. Unhealthy and sometimes harmful traditional cord care practices are quite common in Nigeria, and many mothers lack adequate knowledge of the recommended approach for this critical aspect of newborn care.[43, 44] This usually leads to cord infection, a common risk factor for neonatal sepsis and death in Nigeria. The SMS messages provided information about appropriate cord care and encouraged mothers to avoid applying unhealthy substances.

Even though the prevalence of optimal weight gain was higher among neonates in the mHealth group, the difference was not statistically significant. This varies slightly from a previous study in the United States of America, where infants in the mHealth intervention group also had a healthier weight gain, which was significantly higher than what was obtained in their control counterparts.[45] The rationale was that the mothers had increased knowledge and reminder messages, leading to enhanced infant feeding practice and frequency, producing a consequent increase in weight gain. Though the increased weight gain in the mHealth group was not significant in our study, the finding nonetheless suggests a role for mHealth in this regard.

The 2.2% rate of neonatal deaths in the intervention group was lower but not statistically different from the control group. It is possible that the mHealth intervention had a substantial impact on the rate of neonatal deaths among the respondents, which requires a larger sample size for the difference to be statistically significant. In a similar study in Tanzania, Lund et al. reported a significantly lower perinatal mortality rate in the mHealth intervention group.[12] However, they also found an insignificant reduction in the death of a child within 42 days of delivery.

There was a significantly lower incidence of postpartum depression among the mothers in the intervention group. This supports earlier findings from systematic reviews and a study in Iran on the potential role and impact of mHealth education support in improving maternal psychosocial health.[25, 46, 47] It has been suggested that mHealth intervention is a veritable way of providing psychological and social support for mothers to complement routine clinical care in preventing or treating postpartum depression.[47] Moreover, one of the potential sources of maternal stress during the antepartum and postpartum period is the uncertainty or lack of confidence regarding the proper care of self or the baby.[14] Therefore, many of the SMS educational interventions were aimed at improving self-efficacy, whereby the mother feels appropriately equipped with the requisite knowledge to make an informed decision about her self-care and that of the child, thus alleviating some of her psychological stress with attendant improvement in overall mental health. The incidence of haemorrhage and infection was lower in the intervention group compared to the control group. However, the differences were not statistically significant. This is similar to the report in the study of Oyeyemi et al[48].

As reported by Lund et. al., [15] the mechanisms through which educational SMS and appointment reminders may impact neonatal and maternal health outcomes include improvement in mothers' knowledge and practice of essential newborn care, an increase in their capacity to promptly recognise signs of newborn illness and reduced delay in seeking care, and increased utilisation of healthcare facilities and uptake of relevant MCH services, among others. Studies have reported a significant association between mothers' knowledge about postnatal care and their utilisation of maternal and child healthcare services, while also highlighting the positive impact of mHealth interventions on enhancing healthcare workers' knowledge[15,49,50].

To the best of the author's knowledge, this study is the first in the country to examine the influence of SMS-based mHealth intervention on the specific maternal and neonatal health outcomes assessed. The

intervention worked with the simplest types of phones, was not internet-dependent, and did not necessitate any specific training. All that was required was the ability to receive and read an SMS. The backend data confirmed the delivery of all the messages. However, the findings must be interpreted within the context of certain limitations.

As earlier described, the study implementation did not involve blinding participants or the researchers, which increases the risk of selection and response biases. The risk of response or information bias is further compounded by the fact that the assessment of some of the outcome measures was based on self-report, such as a history of depressive symptoms. It must also be noted that some respondents experienced delays (an average of 6 – 9 hours) in receiving messages because of flat batteries. However, all mHealth group participants eventually received the SMS.

The study was conducted in a local government area where the PHCs are patronised mainly by people of the lower and middle socio-economic classes. Caution should therefore be exercised in generalising the findings to the population outside the study setting. Finally, the lack of statistically significant difference between the groups, with regard to some morbidity and mortality outcomes, may be due to the sample size. Future studies evaluating maternal and neonatal mortality should utilise a larger sample size.

IMPLICATIONS FOR PRACTICE

The improvement in cord status and immunisation rates suggests that mHealth interventions can be effective in promoting neonatal health. Healthcare workers, especially nurses, should leverage mHealth platforms to educate mothers about proper neonatal care, including umbilical cord care and the importance of immunisations. Providing reminders and educational content through mobile apps can improve adherence to care practices and vaccination schedules. Also, given the significant reduction in maternal postpartum depression in the intervention group, nurses should prioritise providing mental health support to postpartum mothers. This could involve utilising mHealth tools to offer counselling services, mental health resources, and virtual support groups. Regular mental health screenings and follow-ups can help identify and address postpartum depression early.

CONCLUSION

Each outcome assessed in this study was better in the mHealth intervention group. However, statistically significant differences were limited to higher immunisation rates, lower cord infection prevalence, and reduced maternal postpartum depression. Although neonatal mortality was lower in the intervention group, the difference did not reach statistical significance. There is a need for further studies with larger samples. Also, the relationship between the 'dose' (number and frequency) of specific messages and the corresponding behavioural and health outcomes should be investigated. Overall, the study findings underscore the promising role of mHealth interventions in reducing adverse maternal and child health outcomes. The different levels of government in Nigeria need to pay more attention to the resolution of the World Health Assembly, which implored that member countries prioritise the development and greater use of digital technologies.

DECLARATIONS

Ethics approval and consent to participate

The research was carried out per applicable guidelines and regulations. The study was approved by the Institutional Review Board of the Institute of Public Health, Obafemi Awolowo University, Ile-Ife, and all experimental protocols were approved with the assigned number IPHOAU/12/580. Participants were fully informed of the study procedure and proposed duration. All subjects provided informed written consent and were assured that they could withdraw from the study without affecting the healthcare services provided at the various health facilities. Participation was entirely voluntary, and confidentiality was maintained.

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The authors declared no competing interests

Availability of data and materials

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