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Texting from the Bush: Data Collection using SMS Text Messaging in Areas of Low Network Coverage from Low-Literacy Providers

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Abstract

Mobile health technology, specifically Short Message Service (SMS), provides a low-cost medium to transmit data in real-time. SMS has been used for data collection by highly literate and educated healthcare workers in low-resource countries; however, no previous studies have evaluated implementation of an SMS-intervention by low-literacy providers. The Liberian Ministry of Health and Social Welfare identified a lack of accurate data on the number of pregnancies from rural areas. To capture this data from 11 rural communities in Liberia, 66 low-literate traditional midwives (TMs) and 15 high-literate certified midwives (CMs) were trained to report data via SMS. Data were reported via a 9-digit code sent from Java-based mobile phones. Study aims included determining the following components of SMS transmission: success rate, accuracy, predictors of successful transmission, and acceptance. Success rate of SMS transmission was significantly higher for CMs than TMs. The error rate was significantly higher for TMs than CMs.

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Years of education was the only predictor of successful SMS transmission. Both TMs and CMs accepted the intervention, although CMs found it easier to use. Based on our study, CMs performed significantly better than TMs. SMS texting interventions should be targeted toward healthcare workers with higher rates of literacy.

Keywords

Short message service (SMS); mHealth; mobile data collection; Liberia; low-literacy

Mobile phones, particularly simple Java-based mobile phones, are available in almost every corner of the world. The lowest penetration is in sub-Saharan Africa with a rate of 51.7% (MobileMonday, 2012). This penetration decreases further in rural areas, with penetration rates ranging from 0-38 % (MobileMonday, 2012). However, despite these low penetration rates, the use of mobile phones in sub-Saharan Africa is rapidly expanding; in fact, sub-Saharan Africa is the fastest growing region for mobile phone users in the last five years (Maylie, 2013). Africa lacks infrastructure in relation to transportation, power, and landlines, yet mobile phone subscriptions are surging ahead with an 18% increase per year over the last five years (Maylie, 2013). To illustrate this point further, the rate of mobile phone penetration in post-conflict Liberia has steadily increased from approximately 15% in 2008, to 45% in 2011, with current estimates at 69% (International Telecommunication Union, 2009; Lange, 2013; Public-Private Infrastructure Advisory Facility, 2011). This growing communication medium provides a potential avenue for both communication and data collection. Mobile phones and other mHealth devices provide the potential for a real-time and low-cost medium of data exchange that diminishes the barriers of transportation and communication associated with paper-based methods.

Short Message Service (SMS) Data Collection

Short message service (SMS), which provides the ability to transmit data packages of up to 160 characters in length, has been used in a multitude of studies to transmit health-related information (Le Bodic, 2005). In resource-limited countries, SMS has been used as a tool for communication between healthcare workers (Lemay, Sullivan, Jumbe, & Perry, 2012), appointment reminders (Koshy, Car, & Majeed, 2008; Leong et al., 2006), health education (Coomes et al., 2012), cessation of smoking (Rodgers et al., 2005; Ybarra et al., 2013), drug compliance (Cocosila, Archer, Haynes, & Yuan, 2009; Pop-Eleches et al., 2011), and many other purposes. However, only a limited number of studies exist, albeit with a varying degree of success, that evaluate mobile phones as data reporting instruments (Andreatta, Debpuur, Danquah, & Perosky, 2011; Curioso et al., 2005; Evans, Abroms, Poropatich, Nielsen, & Wallace, 2012; Lemay et al., 2012; Tomlinson et al., 2009). Additionally, only a small number of these studies were conducted in rural areas or resource-limited countries.

There is a dearth of studies examining quality of SMS reporting data. This gap in the literature highlights an important aspect of the feasibility for data collection quality, especially in resource-limited countries or rural areas, and among low-literacy populations. Outcomes often report only the total number of messages or content received by the database. Little is known about how much data reporting is actually being attempted

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unsuccessfully from the field and even less about the accuracy of this data. This becomes an issue in resource-limited countries and rural areas, because the mobile network quality is often variable and at times inaccessible (Blaschke et al., 2009; Siedner et al., 2012). Several recent studies have been aimed at assessing this issue. For example, Whitford and colleagues (2012) assessed validity, reliability, acceptability, and practicality of an SMS intervention for data collection, although the study was not done in a resource-limited country or rural area. Evaluation of the accuracy of SMS data reported by healthcare workers in rural India was investigated, finding an error rate of 4.5% for the SMS data sent (Patnaik, Brunskill, & Thies, 2009). Data fabrication was monitored for an SMS data reporting tool in South Africa, although success of data transmission was not assessed (Tomlinson et al., 2009).

Low Literacy and Mobile Health

The majority of mHealth studies have been conducted with high-literacy populations. For example, mHealth systems have been developed to improve continuing education for healthcare workers (Alipour, Jannat, & Hosseini, 2014; Frank, Adams, Edelstein, Speakman, & Shelton, 2005; Walton, Childs, & Blenkinsopp, 2005). Additionally, many mHealth interventions have aimed to improve healthcare knowledge and effect behavior change in university students (Brown, O'Connor, & Savaiano, 2014; Mason, Benotsch, Way, Kim, & Snipes, 2014; Moore et al., 2013).

A limited number of mHealth interventions have incorporated non-or low-literacy participants. Most recently, a few studies have reported that non- or low-literacy individuals do use simple mobile phones for communication. For example, in a study looking at SMS use with mobile phones in Kenya, Zurovac and colleagues (2013) reported 29.9% of mobile phone owners were non-literate and of them, 26.4% used their phone to send SMS messages. Another study in Pakistan, reported the potential of an SMS intervention to provide reminders about taking medication for tuberculosis in a low-literacy population (Mohammed et al., 2012). Other studies have proposed low-literacy levels as a potential limitation for future SMS interventions (Chib, Wilkin, Ling, Hoefman, & Van Biejma, 2012; De Lepper et al., 2013). To date, no study has evaluated the feasibility of implementing an SMS intervention for health outcomes data reporting by low-literacy providers.

I-ROPE Project

This study is one component of the Interventions, Research, Operations, and Planned Evaluation (I-ROPE) project, a study funded by a United States Agency for International Development (USAID) Child Survival Grant to evaluate the impact of maternity waiting homes (MWHs) positioned strategically throughout rural communities of Bong County, Liberia. Liberia has one of the highest maternal mortality ratios in the world (770 deaths/ 100,000 live births), the result of a multitude of factors including a 14-year long civil war that ravaged the country and its infrastructure (World Health Organization, 2012). Inadequate access to delivery services is often a consequence of the long distance and convoluted commute created by a poor infrastructure (Gartland, Taryor, Norman, & Vermund, 2012; Lori & Starke, 2012; Thaddeus & Maine, 1994). MWHs therefore provide women a place to stay prior to delivery to help mitigate the barrier of access to adequate

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delivery services with the goal of increasing skilled delivery and decreasing adverse maternal outcomes (Lori et al., 2013b).

During the planning phase of the I-ROPE project, the Liberian Ministry of Health and Social Welfare identified a lack of accurate data reporting on the number of pregnancies, specifically teen pregnancies (15-19 years old), from rural areas. The impetus to collect accurate data on teenage pregnancy was sparked by the most recent Liberian Demographic and Health Survey results which indicate that about one third of girls aged 15-19 years old have begun childbearing (Liberia Institute of Statistics and Geo-Information Services, 2008). Therefore, an SMS platform and protocol was developed to collect the desired data. Although the Liberian Ministry of Health and Social Welfare encourages facility delivery for all pregnant women, traditional midwives (TMs) remain the primary delivery choice for many women in rural communities (Lori & Boyle, 2011). Therefore, TMs and certified midwives (CMs) were trained to work together in the I-ROPE study to increase referral rates to a healthcare facility, educate women about the benefits of staying at a MWH prior to delivery, and to collect pregnancy monitoring data via Java-based mobile phones (Lori, Munro, Boyd, & Andreatta, 2012; Lori, Munro, Moore, & Fladger, 2013a).

The purpose of this study was to examine the feasibility of implementing an SMS intervention for health outcomes data reporting by both skilled, literate (CMs) and non- and low-literate (TMs) providers from low resource, rural areas. Specifically, we intended to answer the following research questions: (a) What is the success rate of sending SMS data by both TMs and CMs?; (b) What is the accuracy of data sent via SMS text by both TMs and CMs?; and (c) What is the acceptability of using SMS messages to send data? To address these questions we will report on the success rate, accuracy, and acceptability of sending SMS data by TMs and CMs in rural Liberia using simple Java-based mobile phones. The results of this study will help provide baseline data to inform mHealth research on the utility of utilizing SMS data collection in resource-limited countries and rural regions with both high- and low-literacy populations.

Methods

Study Participants and Training

All participants were recruited from 11 communities in Bong County, Liberia and originally included 15 CMs and 99 TMs. TMs in Bong County have very little formal education and consequently have low literacy levels or are often non-literate (Lori & Boyle, 2011). Additionally, many TMs did not have experience using a mobile phone prior to beginning the study. Alternatively, the CMs have at least 12 years of formal education in order to attain their midwifery diploma and many own a personal mobile phone (Munro, Lori, Boyd, & Andreatta, 2014). Inclusion criteria for the CMs included (a) fluency in English, (b) currently working at a participating rural health clinic to provide maternity care to women, (c) willing to work with TMs to identify pregnant women within catchment communities, and (d) willing to participate in a three day training session and then train TMs. Inclusion criteria for the TMs included (a) fluency in either English or Kpelle (the local tribal dialect); (b) currently serving as an active TM within their communities; (c) willing to work with clinic staff, specifically CMs, to identify pregnant women in their communities; and (d)

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willing to participate in a three day training session. Both TMs and CMs were trained on a mobile phone protocol, as previously described, and were then given a baseline assessment of the skills acquired from the training (Lori et al., 2012). Briefly, participants were trained to send a 10-digit code to identify any new pregnant woman within their communities. This included a 9 as an identifier of a pregnant woman, followed by a three digit community ID, a three digit participant ID, the pregnant woman's age, and finally a 0 or 1 to indicate whether or not the woman was referred to go the next level of care (clinic or hospital). An example SMS message would be 9006072231, indicating this is a pregnant woman (9), the community that the midwife works in is the community of Janyea (006), the midwife's ID number is (072), the pregnant woman is (23) years old, and she was referred to the community health post to see the CM for antenatal care (1).

At one-year 66 of the original 99 TMs were available for follow-up. Of these, 63 TMs completed the one-year post-test (Munro et al., 2014) and 3 additional TMs were not able to attend the one-year post-test but were still reporting data, and thus, were able to complete the acceptability questionnaire. Additionally, eight TMs were enrolled over the course of the study that did not complete the original mobile phone training or one-year post-test. All CMs (n=15) were still participating in the study, but only 12 were present to complete the acceptability questionnaire. Table 1 displays the known demographic characteristics of the TMs and CMs included in this study. Three participants from each group were not available to provide demographic information and were therefore not included in all analyses. We were unable to follow-up with 41 TM participants (including 33 TMs from the original cohort and 8 additional TMs enrolled enrolled over the course of the study) due to a number of reasons including late inclusion, death of participants, relocation of participants, personal illness and family circumstances that caused the participant to withdraw from the study. Comparison of the TM participants that completed this study with non-completers did not reveal any significant differences in age (completers: range 24-76 years old, M=50 years; non-completers: range 34-68 years old, M=49 years; $t(60)=.271$, $p=.787$) or number of children birthed (completers: range 1-17, M=7.5; non-completers: range 1-15, M=8.4; $t(81)=.943$, $p=.348$). However, completers had a higher mean number of years of formal schooling (range: 0-12 years, M= 2.44 years) when compared to non-completers (range: 0-9 years, M=0.65 years; $t(58.9)=2.71$, $p=.009$). This study was approved by the University of Michigan, Health Sciences and Behavioral Sciences Institutional Review Board and the Liberian Ministry of Health and Social Welfare.

SMS Platform

An open-source software platform (FrontlineSMS Version 2; Social Impact Lab, Washington, DC, USA) was utilized to collect data via a Global System for Mobile (GSM) communication modem (E153; Huawei Technologies Co., Shenzhen, China) connected to a laptop computer (Inspiron N5010; Dell Inc., Round Rock, TX, USA). An external signal amplifier (Wilson SignalBoost GSM 900/1800 MHz; Wilson Electronics, St. George, UT, USA) was installed and connected to the GSM modem in order to maximize network signal. All participants were provided with a mobile phone (Nokia 1280; Nokia Corporation, Helsinki, Finland) and programmed with the GSM modem number and the mobile phone numbers of the CM or CMs with whom they worked within their community. A schematic

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of data from the TM or CM submitting the data to the personnel managing the database is shown in Figure 1.

Network Availability

The two primary mobile providers in Liberia are Cellcom and Lonestar-MTN. The availability of the network and signal strength in the communities can be a limiting factor in rural areas, where there are large distances between mobile phone towers and varying terrain (Blaschke et al., 2009; Siedner et al., 2012). Therefore, the same mobile phone used to collect data was taken to each community on multiple occasions to quantify the signal strength. This was measured by quantifying the amount of “bars” indicated by the internal antenna on the mobile phone. Although this is only a relative measure due to variability among the internal mobile phone antenna between phones, it is an appropriate comparison between communities, because the same mobile phone and antenna were used.

SMS Center Validity Period

The validity period is the time the SMS Center of the mobile network will store messages if the mobile phone of the recipient is switched off (Le Bodic, 2005). This is an important consideration for the use of SMS in resource-limited countries or rural regions because of unreliable electrical grids, varying terrain, and a low number of mobile phone towers in rural areas. During meetings with both mobile providers, it was difficult to discern the SMS Center validity period. Therefore, a simple test comparing the amount of time the recipient’s phone was turned off and examining if the message was received was conducted to determine the validity period. Validity periods of 2, 4, 8, 24, 48, and 168 hours were tested.

Success Rate of SMS Transmission

All study participants kept a paper log of the pregnancy identification data that they were to transmit with their mobile phone via SMS to the database. This log included the 10-digit code. The date of each SMS transmission attempt was automatically recorded by the software. The paper logs of the pregnancy data that participants attempted to send with their mobile phones were collected by the study team and compared to the actual SMS messages transmitted successfully to the Frontline SMS platform via the GSM modem. The success rate of transmission was defined as the percent of attempts at sending a message that were successfully transmitted to the Frontline SMS database. The number of attempts at data transmission, the number of these that were transmitted successfully, and the percent success rate of transmission to the Frontline SMS platform was calculated for each participant.

Accuracy

Accuracy of the messages successfully transmitted to the database was assessed by quantifying the percent of messages with errors in the length of the message or the order of the digits in the message. An example of a length error is an SMS message missing digits such as when the referral code of “0” or “1” was left off. An example of a common order error is the inversion of the location and personal ID codes. The success rate of transmission of the data to the server and the accuracy of the messages transmitted successfully were compared between the group of CMs and TMs.

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Community Comparison and Predictors of Success

The performance by the TMs of each community in regard to the success rate of messages sent was assessed to determine which communities were the highest and lowest performing. A variety of potential factors were responsible for differences in the performance by the TMs. Subject-specific demographic data including age, years of education, and number of children was collected prior to SMS data collection. The assessment score following training along with the assessment score at the one-year follow-up time point was analyzed for predictability of success using the SMS intervention. The network signal strength was also analyzed for ability to predict the success of sending SMS messages successfully. At the one year follow-up, participants were also asked if they received help sending messages. The success rate of SMS transmission was compared for TMs who received help and those who did not.

Acceptability

At the completion of the SMS data collection period, study participants were given a questionnaire about the overall acceptability of the SMS intervention for submitting data and monitoring pregnant women in their communities. A dichotomous ‘yes’ or ‘no’ response was given for each question. These data were collected in order to summarize the perception of the study participants, regardless of their actual performance using the SMS intervention. Logistic regression analyses were performed using the variables of years of education, age, number of children, and the signal strength of their location.

Data Analysis

Descriptive statistics represented by the mean and standard deviation are used to describe the success rate of transmission, accuracy, and acceptability of data throughout the study. Independent t-tests are used to compare success rate of transmission and accuracy data between TMs and CMs. A one-way analysis of variance (ANOVA) was used to compare success rates of transmission among the 11 different communities. A multiple linear regression was conducted to determine the predictors for success rates of transmission. Simple linear regressions were conducted to determine the impact of each predictor variable on the outcome of percent rate of SMS data transmission. Predictors utilized in regression modeling were: age, education, number of children, network signal strength, and pretest and posttest assessments. Fisher’s exact test was performed to compare acceptability data between CMs and TMs. All data was analyzed using IBM SPSS Statistics V.21 (SPSS, Inc., Chicago, IL, USA). Statistical significance is represented as $p<0.05$ unless stated otherwise.

Results

TM Performance and Signal Quality by Community

One community, Bong Mines, had a statistically significantly higher success rate of SMS data transmission compared to the communities of Fenutoli, Tokpaipolu, and Naama (Figure 2A). There were large differences in the strength of the signal from the mobile phone networks (Figure 2B). While Bong Mines had a strong network connectivity, other communities with a strong network did not perform as high on success rate of SMS data

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transmission. Conversely, Zebay and Yila had low network connectivity, but still managed to have a success rate equal to that of other communities with high network connectivity. The signal strength is represented by the amount of bars (0-5) presented on the midwives' mobile phones (from the internal antenna) in Figure 2.

SMS Center Validity Period

Messages tested at 2, 4, 8, 24, 48, and 168 hours of the GSM modem being turned off were all received successfully once the modem was turned back on. Therefore, the SMS Center validity period of messages sent over both networks was determined to be at least 168 hours long.

Success Rate of SMS Transmission

Over the one year time period, CMs and TMs collectively attempted to transmit 7965 SMS messages. Of these, 4132 messages were successfully received at the server, yielding a 51.9% success rate of SMS transmission. CMs accounted for 3442 attempted data transmissions and 3006 successful data transmissions, resulting in an 87.3% success rate of SMS transmission, while TMs accounted for 4523 attempted data transmissions and 1126 successfully received transmissions, yielding a 24.9% success rate of SMS transmission. The success rate of transmission of the messages sent as measured by the mean number of attempted SMS transmissions, the mean number of messages transmitted successfully, and the success rate of data transmission was significantly better for CMs as compared with TMs (See Table 2).

Accuracy

On average, CMs produced fewer errors than TMs. TMs had a 5.47% higher length error rate and a 4.61% higher order error rate when compared to CMs. A majority of the errors in the length of the message came from not including the referral code of “0” or “1” at the end of the message and a majority of the errors in the order of message content came from the inversion of the ID and Location Code (See Table 2).

Predictors of Success

In an attempt to understand what factors influence the success rate of sent messages, a number of predictors were utilized including age, number of children, years of education, network signal strength, and pretest and posttest assessments. Regression analyses revealed that only years of education was predictive of the percent success rate of submitting messages correctly ($F(1,73) = 13.015$, $r^2=0.151$, $p<0.005$). None of the other metrics analyzed, including age, number of children, network signal strength, and pretest and posttest assessments were predictive of the success rate of SMS data transmission.

However, when regression analyses were performed solely within the group of TMs, none of the factors analyzed were predictive of success. Specifically, the pretest and posttest assessments, indicating how proficient a TM was in performing the functions to send an SMS text message, were not indicative of success at sending messages. Further investigation into who was sending the messages received from the phones of the TMs yielded interesting results. Seventy-three percent of TMs sought help from someone in the community, either a

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CM, nurse, community health volunteer, or a family member to send their messages. TMs who sought out help had a significantly higher ($p = 0.005$) success rate of transmission than those who did not seek help. The success rate of SMS transmission was 39.95 % ± 41.22 for those who received help, whereas it was 13.95 % ± 18.58 for TMs who sent messages independently.

Acceptability

On average, both CMs and TMs agreed that sending messages was convenient, not a nuisance, and not time consuming. They also agreed sending SMS messages made them feel empowered, allowed them to communicate with other midwives, and they wanted to continue to send SMS data. When analyzing the data for differences between the two groups (CMs and TMs), CMs found it easier to send messages than TMs and also had a better understanding of the purpose of the SMS data collection (Table 3).

The logistic regression model, which included age, years of education, number of children, and cell phone signal strength, was statistically significant for the following statements (a) “It is easy for me to send messages,” (b) “I used my phone to call or text other midwives,” (c) “I know what the SMS data will be used for,” and (d) “Someone else in my nuclear family owns a phone.” Of the four predictor variables, only years of education was statistically significant for “It is easy for me to send messages,” and “I know what the SMS data will be used for.” Additionally, of the four predictor variables, only cell phone signal strength was statistically significant for “I used my phone to call or text other midwives,” and “Someone in my nuclear family owns a phone.”

Discussion

In summary, this is one of the first reports of SMS data collection in a rural region of a resource-limited country with a non- and low-literate population examining success rates, accuracy, and acceptability. Over a one-year time period, study participants, including TMs and CMs, attempted to transmit 7965 SMS messages with a 51.9% success rate. Based on study results, the CMs performed significantly better than the TMs in the success rate of SMS text messages sent and in the accuracy of the SMS text messages sent. This appeared to be primarily due to two factors: (a) the CMs had a higher level of education and therefore literacy and (b) the CMs had previous experience utilizing mobile phones and the SMS text message function. Among TMs, those who received assistance in sending their SMS text messages had higher success rates for messages sent and had higher accuracy scores. These results indicate that using an SMS text message data collection protocol with non- and low-literate participants may not be feasible unless the participants have assistance. However, data collection in a rural region of a resource-limited country did prove to be a manageable task among the higher-literacy sample.

Despite the difficulties faced by the TMs sending the SMS text messages they still considered this form of data collection to be an acceptable approach, citing it was convenient and they desired to continue sending messages. In fact, past research has suggested that having the TMs work with the CMs in study development and data collection may have improved trust and teamwork among the two cadres of healthcare workers (Lori et

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al., 2013a). Thus, even though the SMS data collection protocol was not successful, it may be worthwhile to consider alternative avenues to incorporate traditional healthcare providers into data collection protocols. Alternative options may include multimedia messaging service (MMS) utilizing pictures and interactive voice response (IVR). Additionally, a team approach to SMS data collection in which the TM, or traditional healthcare provider, is assigned to work in a team with a CM, or skilled provider, may further improve success rates, accuracy, acceptability, and teamwork.

Limitations

This study was limited to one geographic location and thus results should be extrapolated to other regions with caution. Mobile phone networks and receptivity vary greatly by region and thus should be individually assessed for each study region (Blaschke et al., 2009; Siedner et al., 2012). Additionally, this study only utilized the traditional healthcare worker cadre of TMs. While there are numerous cadres of traditional healthcare workers within sub-Saharan Africa with varying characteristics, the majority of these individuals are often non- or low-literate and would most likely suffer from some of the same dilemmas as our sample. Literacy was determined based on educational level and was not measured independently. In developing countries, it is generally assumed that those with more education will have higher literacy levels. However, we realize that future studies should directly measure literacy as a potential factor impacting the ability of participants to utilize SMS messages for data collection. Finally, this study only utilized one version of a Nokia mobile phone. There are a large variety of mobile phones currently available in sub-Saharan Africa with characteristics that may make them easier or more difficult for non- or low-literate populations to use. For example, the ability to enter the “alpha” function of the phone where the participant could search contacts using letters instead of numbers proved to be a barrier to many of the TMs in our sample. When speaking with the TMs, it was this inability to navigate the mobile phone functions and enter the data into the phone that led many of them to seek help from someone with higher literacy.

Conclusion

In conclusion, utilizing SMS messages for data collection appears to be a feasible approach in rural regions and resource-limited countries, especially in sub-Saharan Africa where mobile networks are rapidly expanding ahead of paved roads, the internet, and landlines (Maylie, 2013). However, based on our study results the more highly educated and highly literate CMs performed significantly better than the non- or low-literate TMs. Our findings support that SMS texting interventions should be targeted toward healthcare workers with higher rates of literacy or a team approach combining low and non- and low-literate traditional healthcare workers with highly literate skilled providers. Regardless of the approach, SMS data collection provides a promising avenue for data collection that extends to all corners of the world.

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Figure 1.
SMS Data Transfer (Social Impact Lab, Washington, DC, USA)

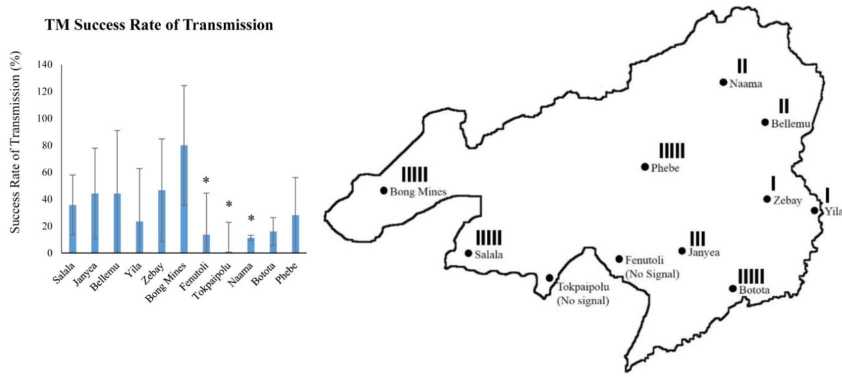

Figure 2. TMs SMS Transmission Success Rates and Mobile Network Strength

(A) The success rate of SMS transmission by the TMs in each community. The TMs in Bong Mines had a higher percent success rate of transmission than Fenutoli, Tokpaipolu, and Naama (* = $p < 0.05$). **(B)** Map of Bong County, Liberia showing the strength of the mobile phone network at each community.

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Table 1

Select Characteristics of Sample

	CMs (n=12)[a] n (%)	TMs (n=63)[a] n (%)
Age Range (years)	28-74	24-76[b]
Mean (years)	45	50[b]
Number of Children Birthed Range	0-6	1-17
Mean Number of Children Birthed	3	7.5
Years of Formal Schooling		
None	0 (0)	40 (60.6)
2nd – 6th grade	0 (0)	14 (21.2)
7th – 12th grade	0 (0)	9 (13.6)
Beyond 12th grade	12 (100)	0 (0)
Missing	0 (0)	3 (4.6)

[a]Characteristics are missing for n=3 TMs and n=3 CMs

[b]Statistics were computed only on those who knew their age (n = 48)

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Table 2

Success Rate and Accuracy of SMS messages sent by CMs and TMs

	CMs n = 15	**TMs n = 66**
Success Rate of Transmission		
Number of Attempted Transmissions[a]	229.47 ± 100.8	65.6 ± 81.5
Number Successfully Transmitted[a]	188.7 ± 106.4	16.3 ± 22.5
Success Rate of Transmission (%)[a]	82.1 ± 22.8	33.0 ± 37.1
Accuracy		
Length Error Rate (%)[a]	2.51 ± 3.18	7.98 ± 13.47
Order Error Rate (%)	1.99 ± 6.91	5.60 ± 18.95
Total Error Rate (%)[a]	4.5 ± 8.0	13.2 ± 25.3

[a]Indicates p-value < 0.05

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Table 3

Acceptability of SMS intervention by CMs and TMs

Question	Percent "Yes"		P-value
	CMs n = 12	TMs n = 66	
It is easy for me to send messages.[a, b]	100	71.2	0.032
Sending messages is time consuming.	33.3	31.8	1.00
It troubles me (is a nuisance) to send messages.	0.00	25.8	0.059
I find sending messages to be convenient.	100	97.0	1.00
I want to continue to send in data.	100	100	-
I am able to assess if I am connected to the network.	100	97.0	1.00
I used my phone to call or text other midwives.[c]	75.0	66.7	0.742
Using the phone makes me feel empowered.	100	100	-
I know why I am sending the SMS data.	91.7	89.4	1.00
I know what the SMS data will be used for.[a, b]	75.0	36.0	0.023
Someone else in my nuclear family owns a phone.[c]	100	87.9	0.346

[a]Indicates p-value < 0.05 for t-test comparison between CMs and TMs

[b]Indicates p-value < 0.05 for logistic regression; years of education is the predictor variable with p < 0.05.

[c]Indicates p-value < 0.05 for logistic regression; cell phone signal strength is the predictor variable with p < 0.05.