J Telemed Telecare OnlineFirst, published on June 30, 2016 as doi:10.1177/1357633X16653540

Journal of Telemedicine and Telecare
0(0) 1–8

DOI: 10.1177/1357633X16653540
jtt.sagepub.com
SAGE

Usability and feasibility of a mobile health system to provide comprehensive antenatal care in low-income countries: PANDA mHealth pilot study in Madagascar

Anne Caroline Benski[1,2], Giovanna Stancanelli[3], Stefano Scaringella[2], Josea Léa Herinainasolo[2], Jéromine Jinoro[2], Pierre Vassilakos[1], Patrick Petignat[1] and Nicole C Schmidt[1,4]

Abstract

Background: Madagascar's maternal health mortality ratio in 2013 was 478 deaths per 100,000 live births. Most deaths are related to direct complications during pregnancy and childbirth and could be reduced by providing comprehensive antenatal care (ANC).

Objective: The objective of the study was to assess the usability and feasibility of a mobile health system (mHealth) to provide high-quality ANC, according to World Health Organization (WHO) recommendations.

Methods: PANDA (Pregnancy And Newborn Diagnostic Assessment) is an easy-to-use mHealth system that uses affordable communications technology to support diagnosis and health care worker decision-making regarding ANC. From January to March 2015, a cross-sectional pilot study was conducted in Ambanja District, Madagascar, in which ANC using PANDA was provided to 100 pregnant women. The collected data were transmitted to a database in the referral hospital to create individual electronic patient records. Accuracy and completeness of the data were closely controlled. The PANDA software was assessed and the number of abnormal results, treatments performed, and participants requiring referral to health care facilities were monitored.

Results: The PANDA system facilitated creation of individual electronic patient records that included socio-demographic and medical data for 100 participants. Duration of ANC visits averaged 29.6 min. Health care providers were able to collect all variables (100%) describing personal and medical data. No major technical problems were encountered and no data were lost. During 17 ANC visits (17%), an alert function was generated to highlight abnormal clinical results requiring therapy or referral to an affiliated hospital. Participants' acceptability of the system was very high.

Conclusion: This pilot study proved the usability and feasibility of the PANDA mHealth system to conduct complete and standardised ANC visits according to WHO guidelines, thus providing a promising solution to increase access to high-quality and standardised ANC for pregnant women in remote areas.

Keywords

Antenatal care, mHealth, mobile application, smartphone, Madagascar

Date received: 2 February 2016; Date accepted: 1 May 2016

Introduction

Maternal mortality continues to be a burden in low- and middle-income countries. According to the World Health Organization (WHO), 289,000 women died worldwide in 2013 from complications during pregnancy or childbirth, and 62% of those maternal deaths occurred in sub-Saharan Africa.[1] In Madagascar, maternal mortality continues to be high, with an adjusted maternal mortality rate of 478 per 100,000 live births in 2013.[2]

The majority of maternal deaths are directly related to complications during pregnancy such as severe haemorrhage, eclampsia, or puerperal sepsis. These deaths could be avoided by providing skilled delivery care and access to emergency obstetric care.[3,4] According to national data for 2010, only 35% of women in Madagascar gave birth

[1]Department of Obstetrics and Gynecology, University Hospitals of Geneva, Switzerland
[2]Faculty of Medicine, University of Geneva, Geneva, Switzerland
[3]AISPO, Associazione Italiana Solidarietà tra I Popoli, Milan, Italy
[4]Centre Médico-chirurgical Saint Damien, Ambanja, Madagascar

Corresponding author:
Anne Caroline Benski, Maternité de Genève, Boulevard de la Cluse 30, 1205 Genève, Suisse, Switzerland.
Email: anne-caroline.benski@hcuge.ch

in health facilities, and only 44% of deliveries were assisted by skilled health workers.[5] Furthermore, even in cases where women had at least one antenatal care (ANC) visit during their last pregnancy (86.2%), few received the four ANC visits recommended by the WHO.[6] Evidence suggests that ANC can improve maternal and child health (MCH) by providing health education and creating a link between women, their families, and the health care system. ANC is also important to prevent, detect, and treat communicable diseases or maternal morbidities.[7,8]

According to WHO guidelines, comprehensive ANC requires quality medical services, including availability of screening tests and treatments, as well as provision of comprehensive education.[7] These conditions are often difficult to achieve in low-income countries where trained and qualified health staff are in short supply. In recent years, a growing body of literature has reported that mobile health technologies (mHealth) can facilitate quality data collection. Studies suggest that mobile technologies can improve MCH by providing information and education to pregnant women, increasing the use of health facilities, and facilitating access to emergency obstetric care.[9-13]

The PANDA (Pregnancy And Newborn Diagnosis Assessment) system is an easy-to-use mHealth system created to support community health care workers in education, screening, diagnosis, and management decisions with respect to ANC. The purpose of this pilot study was to assess the usability and feasibility of the PANDA mHealth system in the provision of comprehensive and standardised ANC in Ambanja District. A pilot study was launched in Ambanja, Madagascar in January 2015 to provide standardised high-quality ANC and to map pregnancies, including maternal risk factors. This article describes the first experience of ANC provided by the PANDA system.

Methods

The cross-sectional PANDA study received ethics approval from local health authorities in Ambanja, Madagascar, as well as from the Ethical Cantonal Board of Geneva, Switzerland (CER 14-217). The Ambanja District in northwest Madagascar is a mainly rural area with a population of 125,056 inhabitants.[14] The project was based at the Saint Damian Health Centre, a private non-profit clinic founded in 1988, which collaborates with the Ministry of Health to provide ANC at 13 health dispensaries in rural areas. Dispensaries are small, peripheral health posts in rural areas that are staffed with a nurse or midwife who can manage basic health problems and refer more serious problems to the next level, in this case the hospital. A public hospital provides ANC for women living in the city of Ambanja.

From January to March 2015, 100 pregnant women were invited to participate in a pilot study to collect data on the usability, feasibility, and acceptability of the PANDA mHealth system. Pregnant women were recruited by the principal investigator (CB), the co-investigator (GS), and local health staff. Both investigators are trained medical doctors, and the local staff comprised medical doctors, midwives, and nurses. The ANC visits took place at either the Saint Damian Health Centre or one of the affiliated dispensaries. Health dispensaries were selected based on their proximity to paved roads in the area, to ensure access during the rainy season both by health providers and patients. Local staff received a half-day training session followed by on-the-job training and continuous supervision. After having provided informed consent, both on paper and electronically, the 100 women were each invited to participate in a one-on-one interview using the PANDA mobile phone device. The inclusion criteria were pregnancy, regardless of age, stage of pregnancy, ethnicity, or religion. The recruitment plan was to include 100 consecutive patients. The only exclusion criterion was inability to understand and act; no further criteria were applied. No woman refused study participation. After completion of the ANC visit using the PANDA mHealth system, the women received the PANDA Pregnancy Logbook containing a summary of the visit, illustrated instruction regarding preparation for childbirth and newborn care, and a personalised patient card (NFC card). This NFC card was tagged by the PANDA application at the first visit and given to the woman to allow the retrieval of encrypted patient data during the subsequent visits.

Technical details

PANDA is a telemedicine system based on mobile technology that incorporates the WHO recommendations for ANC.[9] The telemedicine system consists of three linked components (Figure 1).

PANDA Phone

The system includes a smartphone with an Android icon-based application that enables health personnel to collect patient information including medical and obstetric history, to support clinical screening and provide a guide for dispensing health education. The interviews were conducted on a one-on-one basis, mainly in the local language Sakalava, more rarely in French. Each interview contains four parts:

1. Personal data collection
2. Medical, surgical and obstetric history
3. Screening to detect obesity/malnutrition, hypertension/eclampsia, anaemia, HIV, syphilis, malaria, diabetes, infections other conditions
4. Health education with a focus on birth preparedness

The interview was conducted using the PANDA mHealth application, which is icon based to ensure comprehensiveness by literate and illiterate patients. Illiterate patients represented 13% of the study sample and were

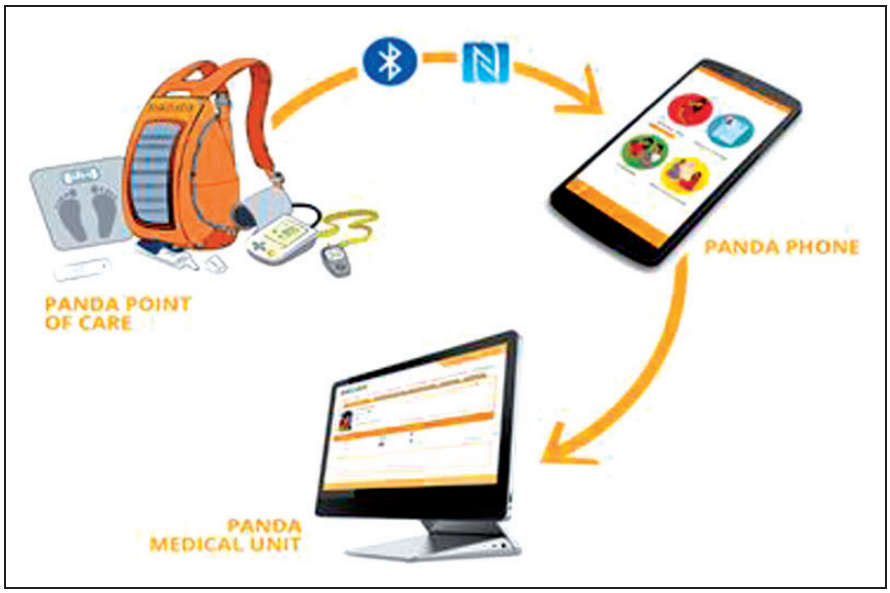

Figure 1. PANDA System.

able to follow the PANDA mHealth interview without any problems. Figure 2 shows information collected by the PANDA Phone, which is also available from the PANDA medical unit. In addition, the system provides information on duration of the ANC visit, verification of dates, and further information on activities carried out by the health workers.

PANDA point of care

This component is a solar backpack with photovoltaic power that contains diagnostic devices to test for blood pressure, fever, or to take measurements such as maternal height and weight as well as uterine fundal height. Furthermore, the ForaDuo combined test is used to screen for diabetes; SD Bioline diagnostic tests screen for HIV, syphilis, and malaria; and the Bi-Trumed device is used to detect anaemia.

PANDA medical unit

A Java-based software system is hosted in the referral hospital, allowing doctors to check the data, create a clinical chart with individual patient characteristics, and assign a pregnancy risk level to each patient.

The PANDA mHealth system guides the health worker through a comprehensive ANC visit according to WHO guidelines. Alert functions are integrated into the PANDA Phone application to notify the user of abnormal clinical results, technical problems, or missing patient information, thereby assuring a full assessment.

Technical performance of the Android application and Java database was assessed using the Redmine online project management application (www.redmine.org), an open source web application with a ticket tracking system. Tickets are messages that are automatically created in the event of bugs, defects, or system failure. In addition, some tickets (mock objects) were created by the developer to reproduce system bugs or errors. Discussion and analysis of these tickets were carried out by the PANDA team during weekly meetings. Furthermore, all patient data were collected on an analogue paper version, to verify correctness of the PANDA Phone data and precise transmission to the medical unit. Evaluation of patient acceptability was carried out using binary visual responses (good or bad) on a six-item icon-based questionnaire that included satisfaction with the visit duration, evaluation of the patient learning experience, willingness to recommend the visit, and overall satisfaction with the visit.

Cell phone connection and electricity in Ambanja/ Madagascar

In 2015 the three main operators existed in Madagascar: Airtel, Orange, and Telma. Penetration rate of mobile phones is 40%, below the African average. However, penetration is growing fast since 2009 with the arrival of the first submarine fibre optic cables, which brought down costs and furthermore made internet and cell phones access available to a wider part of the population.

Electricity, internet and cell phones services are available at the CMC hospital. However, power failures occurred on a daily or weekly basis during the study period. In the dispensaries electricity is not available, but there was sufficient cell phone network to ensure the transmission of data by the PANDA mHealth application.

Statistical analysis

Stata Statistical Software Release 13 (StataCorp., College Station, TX, USA) was used to describe the study population. Because the primary objective of this pilot study was to describe the technical feasibility of the PANDA mHealth system, no further statistical analysis was performed.

PERSONAL INFORMATION	OBSTETRIC HISTORY	ACTUAL PREGNANCY	MEDICAL HISTORY	SCREENING
Name	No. of previous pregnancies	Month of pregnancy	Smoking	Height
Consent	For each pregnancy	Last menstrual period	Alcohol use	Previous weight
ID card photo	Photo previous obstet. clinical chart	Expected Delivery Date	Use of drugs	Actual weight
Participant photo	If miscarriage ==> date	Foetal movements	HIV status	Uterine fundus
Age	If no miscarriage	Recent fever	ARV treatment	Foetal movements
Language	Date and place of the birth	Urinary burning sensation	TB history	Haemoglobin
Address	Who attended the birth	Vaginal discharge	Breathing problems > 3 weeks	Blood pressure
Village	Duration of labour	Vulvar itching	Chest pain	Pulse
Visit location	Vaginal/vacuum/ forceps/caesarean	Partner urinary problems	Blood in sputum	Temperature
Marital status	If caesarean => check the scar	Iron supplement	Anti TB treatment	HIV test result
Telephone	3° tear, OF, convulsion, bleeding	Mebendazol prophylaxis	Anti TB injection treatment	Syphilis test result
Education	Single or multiple pregnancy	Antimalarial prophylaxis	History of surgery	Malaria test result
Running water at home	Alive or stillbirth	Tetanus immunization	History of disease	Photo rapid tests
Work	Healthy/unhealthy newborn	Insecticide-treated bed net	Tetanus immunization	Glucose level
Plans to give birth	< 28 days / < 5 years mortality	Plans to deliver at home or health facility	Female genital mutilation	
Domestic violence	Preterm or full term		Previous use of family planning	
	Newborn weight			
	Breastfeeding			

Figure 2. ▮▮.

Results

Demographic information of participants

Ambanja district is a mainly rural area, which is sub-divided into 21 municipalities, with an estimated 200,000 inhabitants, 30,000 of whom live in the capital Ambanja. Taking into account the rural/urban ratio, we recruited 69 women of the pilot sample size of 100 participants during their ANC at rural dispensaries. The remaining women were recruited at the CMC hospital, to ensure the representativeness of our sample.

The median age of the 100 pregnant women was 22 years (interquartile range (IQR) 19–27.5 years). Three-quarters of the participants were married or living with a partner. The majority spoke Sakalava (83%) and had a primary school level education or less (61%). The main occupation was farm worker (44.4%), followed by housewife (39%). Only a third of participants provided a telephone number (32%), and availability of running water in the home was low (8%). Table 1 summarises the demographic and obstetric characteristics of the 100 participants.

The PANDA system collected information on at least 64 variables concerning participants' medical history, past and current obstetric history, and clinical screening data. Table 2 summarises some of the clinical characteristics regarding current obstetric history of participants. At the time of inclusion, the majority of the women were in their second (52%) or third trimester (46%) of pregnancy; 41% were expecting their first child. Multiparous women (59%) had given birth to between 1 and 10 children, with a median of two children (IQR 1–3 children); more than half of them (54.2%) had given birth in a health facility for their last pregnancy.

Over half of the women (62.7%) reported that their delivery was attended by a skilled birth attendant (doctor or midwife), and 94.9% had been assisted by either a skilled birth attendant or a traditional midwife during delivery. More than three-quarters of participants

Table 1. Sociodemographic and obstetric characteristics of participants.

	N (%)
Age	
Mean	23.74
Range	13–40
Marital status	
Single	24 (24%)
Married or cohabitation	75 (75%)
Widow	1 (1%)
Education	
No school	13(13%)
Primary school	48 (48%)
Secondary school	36 (36%)
University	3 (3%)
Work	
Housewife	39 (39%)
Farm worker	44 (44%)
Salesperson	9 (9%)
Other	8 (8%)
Language	
Sakalava	83 (83%)
French	14 (14%)
Phone availability	32 (32%)
Running water	8 (8%)

Table 2. Participant characteristics regarding past and current pregnancy.

Obstetric history	*N* (%)
Gestity	
1	32 (32%)
2–4	53 (53%)
>4	15 (15%)
Median (IQR)	2 (1–2)
Parity	
0	41 (41%)
1	25 (25%)
2–4	25 (25%)
>4	9 (9%)
Median (IQR)	1 (0–2)
Last childbirth	*N*=59
Less than 2 years	14 (23.7%)
More than 2 years	43 (72.9%)
Unknown	2 (3.4%)
Place	
Health facility	32 (54.2%)
Home	27 (45.8%)
Assisted by	
Doctor/midwife	37 (62.7%)
Traditional birth attendant	19 (32.2%)
Unknown	3 (5.1%)
Pregnancy* (Trimester)	
1	2 (2%)
2	52 (52%)
3	46 (46%)
Preference for future birth	
Health facility	85 (85%)
Home	12 (12%)
Unknown	3 (3%)
Prophylaxis received by pregnant women prior to PANDA ANC visit	
Iron	68 (68%)
Mebendazole	49 (49%)
Sulfadoxine-pyrimethamine	66 (66%)
Treated bed net	92 (92%)
Screening received by pregnant women prior to PANDA ANC visit	
HIV	0
Syphilis	6 (6%)
Malaria	4 (4%)
Anaemia (g/ml)	
Normal (>109 g/ml)	46 (46%)
Mild (100–109 g/ml)	31 (31%)
Moderate anaemia (70–99 g/ml)	23 (23%)
Glucose (mg/dl)	
Mean	82.9
Range (Normal 40–190 mg/dl)	41–155

Note: *Corresponds to the time of enrolment.

(85%) expressed a desire to give birth in a health facility for their current pregnancy. Clinical screening revealed six women who were positive for syphilis, and three were positive for malaria. No one included in the pilot study had a positive HIV test result. This result is in accordance to the low prevalence of HIV in Madagascar, which at 0.3% is the lowest rate in sub-Saharan Africa.[15] Over half of the participants had mild to moderate anaemia (54%).

During the pilot study, 17 alert messages were automatically created by the PANDA mHealth system, highlighting abnormal clinical results. As a result of these alerts, six women were referred to the hospital for syphilis treatment. The remaining 11 alerts were for treatment of moderate anaemia (six cases), malnutrition (two cases), and treatment of malaria (three cases). Participants' acceptance of the PANDA mHealth system was very high. All women expressed a 100% level of satisfaction regarding their ANC visit using the PANDA mHealth system. They appreciated the illustrations provided (100%), and 98% of participants indicated that they had acquired new knowledge. Thirteen percent of women indicated that the duration of the visit was too long. Utilisation of the PANDA system permitted creation of individual electronic patient records that included a large amount of socio-demographic and medical data, with an average of 153 items per participant. The duration of ANC visits varied between 20 and 46 min, with a mean of 29.6 min.

Technical results

The Redmine application registered 580 tickets, of which 576 (99.3%) were mock objects or non-fatal errors and were automatically solved by the PANDA software. The majority of non-fatal errors (56.2%) were explained by connection errors, 42.6% were due to mock objects created by the application developer team to reproduce previous errors and verify system operation, and three non-fatal errors (0.5%) were caused by a software installation problem or an error during voice recording. Four fatal errors (0.7%) required intervention of the software developer. On one occasion, the system crashed when the health provider clicked on the back command to modify data during the visit; the remaining three occasions were attributed to database access errors. Furthermore, the paper recording system identified two major problems in relation to test result transmission. First, haemoglobin results were sent to the PANDA Phone in only 30% of cases. This was owing to a multi-part transmission process (using the Raspberry device via Bluetooth from the PANDA Phone), which was only successfully completed once health care providers had acquired more experience toward the end of the pilot study. In case of a failure in transmission, the system creates an alarm that is directly visible to the health care provider, thereby allowing them to manually enter the remaining haemoglobin results. The second identified problem, which occurred in one case, was that the blood pressure monitor failed to send the result to the PANDA Phone. In both cases, no data were lost because the alert function permitted manual data entry.

This pilot study revealed a patient identification problem when using the NFC card, which was ascribed to a PANDA application error and has been solved. The technical team has worked to ensure smooth identification of each patient via the NFC card in the future and is currently resolving the remaining technical issued described.

Other technical difficulties concerned registration and transcription of the patient code on the NFC card, which worked successfully in only 40% of visits. Furthermore, the rapid test timer did not function properly on three occasions, and body temperature measurement had to be repeated on two occasions, as did glucose measurement.

Discussion

This pilot study supports the usability and feasibility of the PANDA mHealth system to conduct a complete and standardised ANC visit according to WHO guidelines. The system proved an effective way to collect large amounts of digital patient information and to create clinical files for each patient. However, it is important to recognise several factors that have been described, such as the suboptimal quality of transmission owing to locations far from a cellular tower, interference, large network volume, as well as variations in network technology and cellular devices. These factors must be considered, especially when mHealth systems are to be used in remote rural settings.[16] Despite these limitations, the PANDA mHealth system permits immediate identification of transmission problems thanks to its generated alerts, thereby allowing manual data entry to ensure that all data are correctly transmitted.

Besides the technical challenges, a limitation of the PANDA mHealth system concerns the length of the first ANC visit, which was perceived by 13% of the study participants as being too long. Because the first PANDA visit involves collecting a comprehensive patient history (including personal information and medical and obstetric histories) as well as providing screening and education, this visit lasted on average more than twice the currently provided ANC visit. However, it should be noted that the average duration of PANDA ANC visits (29.6 min) remains at the lower end of the WHO recommended duration for a first ANC visit.[17] To shorten the visit duration, we have organised group educational sessions covering topics of personal hygiene, nutritional recommendations during pregnancy, warning signs of the onset of labour, and danger signs during delivery and regarding newborn health. In addition, we expect that by conducting ongoing PANDA ANC visits, the capacity of health workers will increase and the duration of these visits will decrease. Furthermore, we consider a longer visit duration to be acceptable if the system enables health staff to provide high-quality, standardised ANC care to pregnant women.

An important strength of the PANDA mHealth system is that during the pilot study, individual electronic patients

charts were created for every participant. The primary descriptive data analysis showed similarity with the country data reported in the last Demographic Health Survey (2010), thus suggesting the representativeness of our study population. Furthermore, health care workers and pregnant women participating in the PANDA mHealth ANC visits expressed their satisfaction with the system, which is important for future implementation. This is in accordance with previous studies that have reported good acceptability of mHealth interventions by patients in different African countries.[13,14] Furthermore, Watterson and colleagues[12] noted that mHealth interventions have a positive impact on patient and health worker behaviour. Among other findings, they reported a 10% increase in the number of participants attending at least four ANC visits in the intervention arms of a randomised controlled study. However, because the studies included in their review were very diverse and only 2 of 10 were randomised controlled trials, further research is needed to evaluate if mHealth indeed improves the quality of ANC.[13]

Other strengths of the PANDA system include the comprehensive and interactive approach in which patients, health providers, and the technical team exchange data collected during a standardised visit. The icon-based and intuitive application facilitates comprehension by patients and handling by less trained health workers, without diminishing the quality of data collection. Another important strength is that the system generates risk-flagging alerts for immediate intervention and further follow-up. Furthermore, the clinical charts created through the digital network enable distance monitoring and supervision as well as mapping of high-risk pregnancies and communicable diseases, such as syphilis or HIV, for better care management; this also facilitates follow-up during consecutive pregnancies. The latter is especially important because the shortage of skilled health workers in low-resource settings might increase in the future. This will require that tasks will be shifted to less skilled health personnel. Distance supervision will ensure the high quality of ANC in these settings.

Of the studies cited in the introduction, none had the same impact and approach, although some used similar mHealth technologies. The application of WHO guidelines to an application's icon, to improve the quality and the completeness of the ANC, and to facilitate the healthcare providers' role, is unique to our study.[18] A systematic review of the literature showed evidence that mHealth interventions can make changes in the behaviour of health providers and improve access to MCH services.

In 2012 a mobile case management and decision support mobile application was implemented in 20 primary health centres in northern Nigeria. The study suggests that the application can improve the quality of services provided by community health workers. Future research should be done to measure effects in the long term and the outcomes.[19]

A recent article published by the WHO, UNICEF, Johns Hopkins, and Frog, built consensus around a framework that makes mHealth projects a real innovation in the reproductive, maternal, newborn, and child health field.[20] The PANDA system meets many of the points illustrated by the authors in targeting specific health system constraints.

In conclusion, this pilot study indicates that the PANDA system is feasible and provides an effective way to collect large amounts of patient information in digital form. However, despite the encouraging initial results, there is a need for further studies to evaluate the benefits of the PANDA system for maternal health at a larger scale. Furthermore, to verify improvement in the quality of ANC, the PANDA mHealth system should be compared with the standard ANC, including acceptability by health care providers and patients. Lastly, the effectiveness of the mHealth system must be proved when used by less skilled health workers, and it should be carefully evaluated via a cost-benefit analysis before it can be more widely implemented.

Acknowledgements

The authors would like to acknowledge all personnel of the Centre Saint Damien for their enthusiasm, support, and collaboration throughout the duration of the project. The authors would also like to acknowledge Maria Catena Petrella and Giuseppe Iuculano for their technical support and patience. All authors contributed equally to this paper.

Declaration of conflicting interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: GS is project manager of the group that developed the PANDA mHealth system with EU funds and is co-owner of PANDA, registered in Italy in 2012 under copyright (CI 47.10.01/441). All other authors declare that they have no conflicts of interest.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: funding for this study was provided by the Commission des Affaires Humanitaires (University Hospitals Geneva, Switzerland), the Latin branch of the Swiss Society of Gynecology and Obstetrics (www.grssgo.ch) and the Tavola Valdese Italia, Union of Methodist and Waldensian Churches (www.chiesavaldese.org).

References

1. World Health Organization. *Trends in maternal mortality: 1990 to 2013. Estimates by WHO, UNICEF, UNFPA, The World Bank and the United Nations Population Division*. WHO/Geneva, http://www.who.int/reproductivehealth/publications/monitoring/maternal-mortality-2013/en/ (May 2014).
2. World Health Organization. *Global Health Observatory (GHO) data. Trends in maternal mortality 1990-2013*. WHO, UNICEF, UNFPA, The World Bank, and United Nations Population Division Maternal Mortality Estimation Inter-Agency Group Madagascar, http://www.who.int/gho/maternal_health/countries/mdg.pdf (May 2014).

3. Wagstaff A and Claeson M. *The Millennium Development Goals for Health: Rising to the Challenges*. World Bank Publications, https://openknowledge.worldbank.org/bitstream/handle/10986/14954/296730PAPER0Mi1ent0goals0for0health.pdf?sequence=1 (1 January 2004).
4. UNICEF, WHO, World Bank, UN-DESA Population Division. *Level and trends in child mortality*. New York, http://www.unicef.org/media/files/Levels_and_Trends_in_Child_Mortality_2014.pdf (2014).
5. Institut National de la Statistique (INSTAT) et ICF Macro. *Enquête Démographique et de Santé de Madagascar 2008–2009*. Antananarivo, Madagascar: INSTAT et ICF Macro, http://pdf.usaid.gov/pdf_docs/PNADT385.pdf (2010).
6. World Health Organization. *Antenatal care in developing countries: promises, achievements and missed opportunities: An analysis of trends, levels and differentials, 1990–2001*. WHO/Geneva, http://whqlibdoc.who.int/publications/2003/9241590947.pdf (2003).
7. Hall MH, Chng PK and MacGillivray I. Is routine antenatal care worthwhile? *Lancet* 1980; 2: 78–80.
8. World Health Organization. *Pregnancy, Childbirth, Postpartum and Newborn Care: A guide for essential practice*. WHO, UNFPA, UNICEF, The World Bank Group, http://www.who.int/reproductivehealth/publications/maternal_perinatal_health/924159084X/en.
9. Tomlinson M, Solomon W, Singh Y, et al. The use of mobile phones as a data collection tool: A report from a household survey in South Africa. *BMC Med Inform Decis Mak* 2009; 9: 51.
10. Patnaik S, Brunskill E and Thies W. Evaluating the *Accuracy of Data Collection on Mobile Phones: A Study of Forms, SMS, and Voice*, http://www.cs.cmu.edu/~ebrun/patnaik-ictd09.pdf (2009).
11. Obasola OI, Mabawonku I and Lagunju I. A review of e-health interventions for maternal and child health in sub-Sahara Africa. *Matern Child Health J* 2015; 19: 1813–24.
12. Watterson JL, Walsh J and Madeka I. Using mHealth to improve usage of antenatal care, postnatal care, and immunization: A systematic review of the literature. *Biomed Res Int* (Accepted 22 January 2015), in press. http://www.hindawi.com/journals/bmri/aa/153402/.
13. Lund S, Nielsen BB, Hemed M, et al. Mobile phones improve antenatal care in Zanzibar: A cluster randomized trial. *BMC Pregnancy Childbirth* 2014; 14: 29.
14. CITY POPULATION - Population Statistics for Countries, Administrative Areas, Cities and Agglomerations – Interactive Maps and Charts. Ambanja (District), http://www.citypopulation.de/php/madagascar-admin.php?adm2id=71719.
15. Ministère de la Santé de Madagascar, Comité National de lute contre le SIDA. *Rapport sur la réponse face au VIH et au SIDA à Madagascar en 2014*. Ministère de la Santé de Madagascar, Comité National de lute contre le SIDA.
16. Luxton DD, Mishkind MC, Crumpton RM, et al. Usability and feasibility of smartphone video capabilities for telehealth care in the U.S. Military. *Telemed J E Health* 2012; 18: 409–412.
17. World Health Organization. *WHO antenatal care randomized trial. Manual for the implementation of the new model*. WHO/RHR, http://www.who.int/reproductive-health/publications/maternal_perinatal_health/RHR_01_30/en/ (30 January 2002).
18. Watterson JL, Walsh J and Madeka I. Using mHealth to improve usage of antenatal care, postnatal care, and immunization: A systematic review of the literature. *BioMed Res Int* 2015; (2015): 153402.
19. McNabb M, Chukwu E, Ojo O, et al. Assessment of the quality of antenatal care services provided by health workers using a mobile phone decision support application in northern Nigeria: A pre/post-intervention study. *PLOS One* 2015; 10: e0123940.
20. Labrique IB, Vasudevan L, Kochi E, et al. mHealth innovations as health system strengthening tools: 12 common applications and a visual framework global health. *Sci Pract* 2013; 1, http://www.ghspjournal.org/content/1/2/160.