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CASE REPORT

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Purpose: To describe a self-made smartphone adaptor which can be attached to a surgical microscope and a smartphone telescope which can be wirelessly linked to an LED TV or monitor.

Methods: A smartphone slit lamp adaptor is built for microscope-assisted ocular surgery in which video can be recorded. For surgeries not utilising the microscope (such as those using surgical loupes), we employed a smartphone attached to a telescope for videography. Videos from both methods are then wirelessly streamed to a TV/monitor using EZCast, Google Chromecast or Apple TV.

Results: The video captured by a smartphone is comparable to conventional digital video recording. It is affordable, easy to use and highly portable.

Conclusion: Smartphone videography will be a valuable instrument in ophthalmology for both teaching and research purpose.

Introduction
Capturing video in ocular surgery is important for both training, research, ethical and legal issues. Eye surgeons have been recording their own surgical videos using the conventional video recorders which were incorporated into the surgical microscope. These recorders have evolved from video cassette recorder (VCR) then to digital video recording at present.

Smartphone ownership has increased exponentially ever since its introduction. In the US, 64% of American adults own a smartphone. As of August 2014, 1.64 billion people worldwide own at least one smartphone. Smartphones in ophthalmology have been widely used to incorporate apps for diagnostic purposes, referencing, and photography of the anterior and posterior segments of the eye. The newer smartphones are capable of capturing superior quality videos of up to 720p and 1080p in high definition (HD). The use of smartphone in capturing surgical videos for archiving and viewing purposes is easy and of superior quality.

With the advancement in technology and availability of high-speed wireless fidelity (wi-fi) connection, video streaming can also be done effortlessly. Video streaming devices like Apple TV, Chromecast and Ezcast are newer methods of wireless video viewing with real-time HD video.
Materials and Methods

For Surgery Requiring Surgical Microscope

We constructed a smartphone adaptor that was able to fit into the assistant viewer eyepiece of our surgical microscope – Leica F40 (Leica, Wetzlar, Germany). It was built from a smartphone casing, sponge (made of Ethylene-vinyl acetate pads) and glue (cyanoacrylate glue). After mounting the adaptor, the smartphone was set into the video-taking mode with no further modification needed. It was then wirelessly linked to a device called EZcast which would be plugged into the TV for wireless streaming display.

For Surgery Not Requiring Surgical Microscope

We attached an 8x-12x portable telescope (Universal Zoom Telephoto Optical Camera Lens, China) for smartphone and then mount the smartphone to an adjustable smartphone clamp (CTA Digital, Brooklyn, USA). The smartphone clamp was then attached to a standard drip stand for stability.

For Display System

We attached a wi-fi streaming device called EZcast to an LED TV and wirelessly connect the smartphone.
to the EZCast. Other devices which had similar functionality include the Google Chromecast and Apple TV. These devices assist in streaming video wirelessly to an LED TV. The clarity is of High Definition of up to 720p/1080p.

For Control of the Recording
In Android OS-based smartphones, a wireless mouse can be easily connected to the smartphone, making control for recording in a remote area easy. The start and stop of a video recording can be controlled just by using a click of the mouse instead of direct contact with the smartphone screen (which may cause image blur due to movements to the smartphone during the video recording).

In the iOS system, additional apps need to be downloaded and tweaked in order to connect the smartphone to a mouse. Subsequently, controlling of the recording is similar to the Android OS system.

Results
Video quality
We recorded a phacoemulsification surgery. With newer smartphones employing features such as rapid auto-focus and optical image stabilization, videos turned out clear and crisp. The video quality of 720p HD and 1080p HD recording with fast frame rates up to 60 frames per second improves video quality which is compatible to the conventional digital video recording.

Video Editing
Video editing can be done using additional smartphone apps or the videos can be transferred out from the smartphone for easy editing on a personal computer.

Video Transfer and Sharing
Video transfer has been made much easier with the availability of new social media apps such as WhatsApp and Facebook. With just a click away, the edited video can be shared and transferred.

Discussion
In the era today, most people are very dependent on their smartphones for their daily activities and work. There are several apps which may help in our management and archiving the data of our patient.7,8 With the addition of a few accessories, we converted the smartphone into a clever videography system which will be able to capture high quality videos of ocular surgeries utilising both microscope and non-microscope assistance. This method will be very useful especially in rural areas and developing countries where there is limited access to higher grade video cameras and microscopes.

There is a high potential in this video system as it is portable, affordable and of good quality. Link below shows video comparison of a phacoemulsification surgery taken with a standard Leica video recorder and iPhone 5s simultaneously.

Phacoemulsification: https://www.youtube.com/watch?v=5DTsJL5NF7M
Extracapsular Cataract Extraction: https://www.youtube.com/watch?v=capb2ekWvqg

Link to sample videos of non-microscope related surgeries taken with Samsung Note 3
Epiblepharon repair: https://youtu.be/Jzmfl9pBqn4
Squint Surgery: https://youtu.be/lbVoIawn6is

Figure 4: Diagram of wireless videography concept
than 2 hours may not be ideal for video capturing using standard smartphone as the file will be very large. To improve on the length of video, the capacity of the smartphone memory should be increased or to add in an additional memory card for extra storage.

An informed consent has been taken in all videos taken in this study. The identity of patients and surgeons remained confidential.

Conclusion
Smartphone videography will be a valuable instrument in ophthalmology for teaching and research.

Acknowledgements
We would like to thank the staff from Hospital Universiti Sains Malaysia and Hospital Tuanku Ja’afar Seremban for assisting in the recording of the surgical procedures shown in the videos.

References
META-ANALYSIS OF MOBILE PHONE REMINDERS ON HIV PATIENTS’ RETENTION TO CARE

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Aims: This research aims to systematically review the current clinical evidence of the efficacy of mobile phone reminders on retention to care among HIV patients. This study also seeks to determine an effect size of the intervention and presents implications for future studies.

Background: Use of mobile technologies is an innovative and affordable approach to HIV prevention and care, particularly in resource limited settings. Approximately two-thirds of people who are initially diagnosed with HIV are lost to follow-up before starting HIV treatment in low and middle-income countries, posing serious global health concerns. While mobile text message reminders for HIV medication adherence have shown positive health outcomes, it is not well understood whether the reminders can also improve patients’ retention to care.

Methods: The authors conducted a meta-analysis of literature in the following databases: PubMed, CINAHL, ProQuest, and Web of Science. Of the 667 peer-reviewed research articles reviewed, nine studies were included in the final analysis. Stata version 13 was used for the analysis.

Results: Nine studies (5 randomized controlled and 4 before and after studies) from 7 countries included 3,004 HIV patients. Random-effect meta-analysis (I-squared = 94.1%) found that HIV patients who received mobile phone reminders for their follow-up appointments were two times more likely to return to care than those who didn’t receive reminders (pooled odd ratio (OR) = 2.04, 95% CI: 0.97–4.27). Our sub-group analysis of 5 randomized controlled studies showed a significant effect of mobile phone reminders (OR = 2.04, 95% CI: 1.11–3.74). Six studies in Africa showed that HIV patients (mostly women) receiving mobile phone reminders were three times more likely to return to care than those who received no reminders (OR = 2.92, 95% CI: 1.13–7.53).

Conclusion: Mobile phone reminders are an effective intervention to improve retention to HIV care. Women with HIV living in resource limited settings benefit significantly from the intervention. Also, mobile phone reminders using text messages are as effective as phone calls to improve retention to HIV care.
Introduction
HIV remains a devastating disease and is ranked as the second leading cause of death in low-income countries. Worldwide, the adult prevalence of HIV is 0.8%; in Sub-Saharan Africa, the adult prevalence is as high as 16%. Sub-Saharan Africa is the epicenter of the HIV epidemic and is the region most affected by the disease. According to the Joint United Nations Programme on HIV/AIDS (UNAIDS), there were approximately 23.5 million people living with HIV in Sub-Saharan Africa. This accounts for 69% of the global HIV burden in 2011. HIV affects women disproportionately compared to men; 58% of those infected by HIV in this region are women.

Universal access to HIV treatment, specifically antiretroviral therapy (ART), has improved survival among people living with HIV/AIDS (PLWH). HIV is a condition requiring a lifetime of ART with close management by health care providers. In regions with good ART coverage, HIV has become a manageable chronic disease. One of the challenges in HIV prevention and management has been providing continuity of care, particularly in developing countries where the health care infrastructure is poor. The President’s Emergency Plan for AIDS Relief (PEPFAR) recently reported that up to two-thirds of patients in developing countries may be lost to follow-up after HIV diagnosis and before starting ART.

Mobile phone technology, with its ubiquitous capability to reach people at a low cost, can benefit health care systems and has become an important method for improving continuity of care for PLWH. Acknowledging that providing continuity of care for PLWH is critical for HIV-related health outcomes, the purpose of this paper is to systematically review the effectiveness of mobile phone reminders for improving patients’ retention in HIV care.

Patient Retention in HIV Care: Challenges and Consequences
Non-attendance at health care appointments is a significant independent predictor of progression of HIV. Non-adherence to medications leads to progression of HIV disease, posing a higher risk of transmitting HIV to others in the community. Authors of a retrospective cohort study identified that HIV patients with poorer retention to care were more likely to have poorer survival over time, less improvement of CD4 cell counts and less reduction in plasma HIV level than those adhering to HIV care. Obviously, people who do not return for periodic appointments are eventually lost to follow-up (LTFU). A meta-analysis reported a retention rate for PLWH in care was 62% in 3 years in the United States. Gardner et al. estimated that less than 50 percent of PLWH in the United States are actively engaged in HIV care, and only 19% of PLWH have an undetectable HIV viral load. The rate of LTFU in treatment programs varies widely based on setting, ranging from five to 40 percent within six months of ART initiation in resource-limited settings.

Several terms are often used interchangeably to describe patients’ retention to care and provision of continuity of care: missed appointments, non-attendance, and LTFU (lost to follow-up). Chi and the colleagues defined LTFU as ‘patient does not present to medical appointment within 180 days from the last clinic visit’, based on HIV patients attending 111 health facilities in 19 countries. In other studies, measuring attendance is defined as returning to care within a certain interval ranging from 3 days to 9 months. The present literature review acknowledges a wide variation in definition of attendance, and uses the definitions as specified by each author as LTFU.

Reasons for LTFU are multi-factorial, and differ based on ability to access resources. In resource-limited settings, including many African rural areas, lack of transportation and cost of travel have been identified as major barriers to retention to HIV care. In one study from Kenya, participants who had to pay more than US$1.25 for transportation to a clinic were significantly more likely to fail to return for care compared to those paid less than that amount (RR: 1.35, 95% CI 1.15–1.58), which is consistent with other study findings about distance from clinic. A qualitative study identified substance use and HIV-associated stigma, as two principle reasons for LTFU in Ethiopia. The authors of a retrospective cohort study in South Africa identified that death, relocation and transfer to other clinics were reasons for LTFU rather than gender, ethnicity, and age.

A randomized controlled study in Switzerland conducted in large urban HIV clinics found that younger age, male sex, follow-up appointment greater than 1 year, and substance abuse were significant predictors for LTFU. Other patient-related factors are health beliefs, health status, transportation, scheduling, and financial status. Lack of communication between providers and patients, waiting time at clinic, and quality of consultations are additional health care related factors that impact LTFU.
A review of U.S. studies suggested multiple strategies to improve retention to care of HIV patients, such as facilitating access to care (e.g. transportation services), case management, peer support, and promoting diversity in clinical care (e.g. bilingual/bicultural services). A randomized controlled study from Malawi used incentives to encourage people to return to the clinic to receive their HIV test results and even a small incentive doubled the return rates.

Mobile technologies, an affordable, innovative approach to improving retention to HIV care

Mobile phone subscriptions have almost saturated the globe. With a world population of over 7.2 billion people, there were 6.8 billion mobile subscriptions in 2013. This phenomenon has been reported in several research studies. Three studies from rural Uganda, Kenya and rural Swaziland reported that the proportion of cell-phone ownership among screened participants reached 65 to 75%.

Compared to phone calls, which can be relatively costly for low-income subscribers, text messages or short message service (SMS) are more affordable with less interruption of recipients’ daily life. SMS can be stored and accessed later. With the fast penetration of mobile phone subscription in developing countries, studies have used mobile technologies to assess a range of health outcomes, such as medication adherence, monitoring chronic health outcomes, and providing psychological support. A recent meta-analysis that included 9 intervention studies showed that SMS reminders improved adherence to ART. PLWH who received SMS reminders had significantly higher ART adherence (pooled odd ratio (OR)=1.39; 95% confidence interval (CI)=1.18, 1.64) and lower HIV RNA load (pooled OR=1.56; 95% CI=1.11, 2.20) compared to the control group.

In addition to improved patient health outcomes, mobile technologies assist health care delivery by providing a platform for staff training, disease surveillance, data collection and reporting, and monitoring of drug supply chains. This innovative approach has the potential to fill gaps in health care delivery in many developing countries.

Significance of This Paper

Despite the rapidly increasing research on the use of mobile technologies for improved health outcomes, it is not clear whether mobile phone reminders can prevent LTFU and improve retention to care among PLWH. While its effectiveness on adherence to ART is promising, individuals outside of care or LTFU do not benefit from the intervention. Considering that one of the biggest challenges in the provision of HIV care is linkage to care from diagnosis to life-long commitment to ART adherence, understanding mobile phone effectiveness on retention to care is critical. Using a systematic review, meta-analysis approach, we answer the following three research questions: (1) what is the available clinical research evidence on mobile phone reminders for retention to HIV care? (2) what is the effect size of an mobile phone reminders intervention?, and (3) what are the implications of these findings to future studies?

Methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines. Two researchers conducted independent literature searches and selected nine studies based on the inclusion criteria. Using these nine studies, we performed sensitivity analyses and an assessment of publication bias.

Search Strategies

The authors conducted an initial literature search using Boolean strategy using the following databases: PubMed, CINAHL, ProQuest, and Web of science. Search terms were ‘HIV AND mobile phone, cellular phone, text message* OR SMS (short message service)’. Databases were searched between March 28 and April 26, 2014 with a second search in November 2015 for possible inclusion of additional studies. There was no restriction based on language or year published although most of the literature was from the last 15 years due to the nature of mobile technology used in health care research. The searches resulted in 1,438 peer-reviewed articles (see Figure 1). The authors independently reviewed the abstracts and screened duplications of the articles using a citation management program (RefWorks/EndNote). Inclusion criteria for the final reviewed papers were: 1) clinical research employing mobile phone reminders to improve retention to care; and 2) inclusion of HIV patients and family member paired
with babies exposed to HIV. Study protocols or review articles were excluded.

**Data collection**
The authors manually extracted data from full scripts of selected articles using a standardized extraction form.

The form includes general information about the study (author, year of published, study location and study period), study design (types of study design and control for threat to validity), sample characteristics (age, gender, race/ethnicity), types of intervention, outcome variables (measurement and parameter of outcome variable, effect size, p-value, 95% CI),
statistical methods used in the studies, and appraisal of strengths and weakness of the studies. For studies having HIV patients as a subgroup of a larger study sample, the subgroup data were primarily used. Authors extracted and calculated the odd ratio (OR) and 95% CI to obtain the effect size of the intervention. To improve the consistency between the studies, for studies that employed more than one intervention arm, the OR based on mobile text message reminder intervention was compared to standard care. For longitudinal studies, data from the last measurement period was used to evaluate the sustainability of the intervention.

Data analysis
In order to assess heterogeneity between study results, the I-squared statistic was used to inform the method of meta-analysis. In the preliminary analysis, the I-squared values were 94.1% (heterogeneity chi-squared = 136.41 (d.f. = 8), p < 0.001), suggesting study heterogeneity, and the need to use a random effects model of analysis to obtain overall effect sizes (ES). The random effects model assumes that the variability of ES across the studies is attributable not only to sample errors at the subject-level but to other unmeasured sources of error. This leads to a wider 95% CI for the ES using a random effect model. Funnel plots were evaluated for publication bias together with statistical tests (Egger's and Begg's tests). Stata 13 was used for analysis.

Study Outcomes: LTFU and Non-Attendance Rate
Given that studies were conducted with participants in HIV health care settings, the proportion of attendance at follow-up appointments was the primary outcome for the studies reviewed. In other words, non-attendance is used as a proxy measure for LTFU. The proportion of non-attendance is inherently a dichotomous variable. Therefore, the OR is used to calculate the effect size. Attendance was extracted from and confirmed by patients’ medical charts or clinic records. Attendance was counted as returning to care within a time frame as determined by study authors.

Results
Study Design and Types of SMS Reminders
All nine studies were conducted within the past 5 years, ranging from April 2010 to April 2015 (Table 1). Five RCTs and four before and after controlled studies were included in the final analysis. Before and after controlled studies were conducted at the clinic level to test the effectiveness of the mobile phone reminder intervention. Post-intervention groups were compared to pre-intervention groups, although the members in the two groups were different. Study settings were HIV clinics or hospitals from United States (US), Switzerland, United Kingdom (UK), Kenya, Cameroon, South Africa and Swaziland.

The pooled sample size was a total of 3,004 participants. Study participants were adult patients with HIV or HIV-exposed babies paired with their mothers with HIV. For example, a study from Kenya implemented mobile phone reminders for HIV positive mothers to alert test results availability and clinic appointments for their babies exposed to HIV during birth. The unit of analysis for this study was the mother/caregiver and baby dyad. Sample characteristics are limited because one study did not provide any demographic information for the HIV sub-group, which was used in this review. Approximately 79.7% of the pooled sample were women and the median age of the sample was 34.6 years old.

Types of mobile phone reminders are divided into two categories: (1) appointment reminders, one or two days prior to the appointments using SMS; and (2) sequential reminders including mobile phone calls, and postal reminders after SMS reminders. The content of the reminders was not individualized. Examples of SMS from these studies were “come back to clinic” or “Remember: you have a doctor's appointment tomorrow”. SMS were usually delivered once without confirmation of whether participants actually received the message or not.

Review of the studies
While all study interventions were automated text message reminders, Kliner et al. (2013) implemented ‘buzzing’ text message reminders at no cost to the patient and the clinic. The message received by the patient registered the hospital's number as ‘go to hospital’ on participants’ mobile phones. However, the intervention did not increase return rates to the hospital to collect CD4 count results. The reminder maintained patient privacy, yet lacked specific reminder messages.

Norton and the colleagues used mobile phone text message reminders to PLWH to improve retention to care in the United States. The intervention group (n = 25) received a text message and the control
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<td>Urban HIV ambulatory clinic, Geneva, Switzerland</td>
<td>Vulnerable population/undocumented migrants, asylum seekers, immigrants with HIV (n = 303), HIV subgroup demographic info: NA</td>
<td>Randomized Controlled Trial (RCT)</td>
<td>Sequential reminders: phone call -&gt; SMS -&gt; postal reminders VS no reminders 2 days prior to the appointment</td>
<td>Rate of missed appointment in the clinics</td>
<td>Intervention: 12.7%, Control: 15% (p = 0.62)</td>
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<td>Kliner (2013)</td>
<td>Regional hospital, rural Lubombo, Swaziland</td>
<td>People with recent HIV diagnosis (n = 459, male = 210, female = 249, mean age = 33)</td>
<td>Before and after study</td>
<td>Buzz message reminder sent 1 day prior to appointment: CD4 cell counts result collection VS no reminder</td>
<td>Rate of attendance at the HIV testing and counseling department</td>
<td>Intervention: 83.3%, Control: 80.1% (p = 0.40) No effect</td>
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<tr>
<td>Bigna (2014)</td>
<td>Multisite: urban, semi-urban, and rural HIV clinics in Cameroon</td>
<td>Care givers of children with or exposed to HIV (n = 242 adult-child pairs, male = 37, female = 205, age = 43)</td>
<td>RCT</td>
<td>SMS &amp; phone call, SMS, phone call, or no reminders (control) 2–3 days prior to the appointment</td>
<td>Proportion of patients attending a schedule appointment</td>
<td>SMS &amp; phone call (89%), SMS (75%), phone call (85%), or control (51%) OR = 2.9 (SMS vs control) OR = 4.7 (intervention vs control)</td>
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<td>Farmer (2014)</td>
<td>Sexual health clinic, London, UK</td>
<td>Young adults with HIV* (n = 467, median age = 45, male = 263, female = 204). Demographic info obtained through corresponding</td>
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<td>SMS reminder 2 days prior to follow-up appointment</td>
<td>Rate of attendance for 12 months before/after the intervention</td>
<td>Intervention: 75%, Control: 72% (p &gt; 0.05)</td>
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<td>Finocchiaro-Kessler (2014)</td>
<td>Urban and peri-urban hospital, Kenya</td>
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<td>EID (early infant diagnosis): text message reminders to mothers’ cell phone to alert test results and clinic appointments</td>
<td>Retention to EID: the proportion of infants engaged in EID care by 9 months postnatal</td>
<td>Intervention: 93.6%, before intervention: 44.2%</td>
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<td>Norton (2014)</td>
<td>Urban HIV clinic, North Carolina, USA</td>
<td>HIV patients with access to SMS (n = 52, male = 39, female = 13, mean age = 44)</td>
<td>RCT</td>
<td>SMS reminder 1 day prior to appointment plus standard care VS standard care (automated phone reminder when home phone is available)</td>
<td>Rate of clinic attendance</td>
<td>Intervention: 72.0%, Control: 81.0% (p = 0.42) No effect</td>
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<tr>
<td>Odeny (2014)</td>
<td>5 health facilities, Nyanza, Kenya</td>
<td>Pregnant women with HIV, &gt; 18 years old (n = 388, median age = 28)</td>
<td>2 arm, unblinded RCT</td>
<td>14 weekly, automated SMS prenatal and post-partum</td>
<td>Rate of women attending maternal postpartum clinic &amp;</td>
<td>Intervention: 19.6%, Control: 11.8% (relative risk = 1.66, 95% CI = 1.02–2.70)</td>
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group (n = 27) received the standard care procedure, an automated reminder phone call to a landline. The study had a high participant refusal rate (45%) at screening and a high attrition rate (28%) in the intervention group. This resulted in small sample size and low statistical power; this RCT did not detect efficacy of the mobile text message reminder to improve retention to care. 28

The efficacy of mobile phone reminders was established among patients attending primary care clinics in Geneva 27 and a sexual health clinic in London. 29 Overall missed appointment rates dropped by four percent (p < 0.005) in the clinic after the intervention. Male sexual health clinic attendants were more likely to return to care than females and PLWH (10%, p < 0.05). 29 For the total sample, the missed appointment rate was lower (7.8%) among the intervention group, compared to 11.4% (p < 0.005) in the usual care group. 27 However, when sub-group analysis was performed with PLWH, the intervention did not improve clinic attendance. 27, 29

Five studies used mobile phone reminders to target mothers with HIV to improve retention to a prevention of mother to child transmission program (PMTCT) or to follow up with babies who were exposed to HIV during birth. 30 All five of the studies are from Africa and targeted retention to postnatal care and early diagnosis of HIV of the babies exposed to HIV. Four studies concluded that mobile phone reminders significantly improved the outcomes (See Table 1, Figure 4). Schwartz and colleagues’ before and after controlled study did not find that weekly mobile phone reminders significantly improved postnatal women’s returning to care. 34

Based on our systematic review, four studies were excluded from the meta-analysis because they enrolled participants at risk for HIV, but who did not have HIV. Three studies 35–37 were similar to each other in study design, settings and population and were conducted in large, urban sexual health clinics in developed countries (Table 2). The samples were drawn from populations at high risk for HIV based on their sexual health history, and mainly consisted of young men who had sex with men. Odeny et al. (2012) conducted a two-arm RCT in Kenya that we also excluded because the study targeted adult males who underwent circumcision as a measure of HIV prevention. The intervention group received daily informative text messages on post-circumcision care and reminders to return for

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<td>Schwartz (2015)</td>
<td>Primary care clinic, South Africa (n = 100, median age = 28)</td>
<td>Pregnant women with HIV (&gt; 36 weeks of gestation)</td>
<td>Weekly, prescribed text messages for 8 weeks plus 2 phone calls (1 pre and 1 postpartum care and reminder to return to care with baby at 6 weeks)</td>
<td>Proportion of women retaining at ART pick-up at 10 weeks and 12 months</td>
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Table 1: Review of the Studies
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<td>Before and after operational study</td>
<td>SMS reminder to return for retesting STIs/HIV after 3–6 months</td>
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<td>Burton (2014)</td>
<td>STI clinic, United Kingdom</td>
<td>At higher risk of STIs and HIV (n = 539), male = 243 (45.5%), female = 296 (54.5%)</td>
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<td>Young adults (n (cases) = 3,717), No demographic information</td>
<td>Before and after study</td>
<td>SMS reminder 2 days prior to pre-booked appointments</td>
<td>Intervention: 76%, Control: 72% (p &lt; 0.05)</td>
<td>Not meeting inclusion criteria</td>
</tr>
<tr>
<td>Odeny (2012)</td>
<td>12 male circumcision sites, Nyanza province, Kenya</td>
<td>Male undergoing circumcision for HIV prevention (n = 1,200), Age: mean 25 years</td>
<td>Two-arm, RCT</td>
<td>Automated daily SMS reminder for 7 post-op days in patients preferred languages</td>
<td>Not meeting inclusion criteria</td>
<td>Primary care clinic attendees or Risk for STI/HIV not PLWH</td>
</tr>
<tr>
<td>Perron (2010)</td>
<td>Urban primary ambulatory clinic, Switzerland</td>
<td>Vulnerable population (n = 2,123), male = 55.5%, female = 44.5%, Age: mean (SD) 46 years (18.2)</td>
<td>Randomized Controlled Trial (RCT)</td>
<td>Sequential reminders: phone call &gt; SMS &gt; postal reminders VS no reminders 2 days prior to the appointment</td>
<td>Intervention: 93.2%, Control: 88.6% (p &lt; 0.05)</td>
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</tr>
<tr>
<td>Zou (2013)</td>
<td>Public sexual health clinic, Australia</td>
<td>MSM (n = 2,397), No demographic information</td>
<td>Retrospective, controlled before and after study</td>
<td>SMS or email (or both) reminder for retesting STIs at 3,6,12 months per participants’ request by Computer Assisted Self-Interview (CASI) system</td>
<td>Intervention: 88.9%, Control: 70.8% (p &lt; 0.05)</td>
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Table 2: Review of excluded studies with reasons
follow-up appointment. Although the study result did not reach statistical significance, the intervention group was more likely to return to care (RR = 1.09, 95% CI = 1.00–1.20, P < 0.05) compared to those men who didn’t receive an SMS message.13

The Effectiveness of Mobile Phone Reminders
A random effects model was used to present the overall effect of the mobile phone reminder intervention among PLWH in 9 studies (Figure 2). Mobile phone reminders improved clinic attendance at follow-up appointments compared to usual care among PLWH (pooled OR = 2.04, 95% CI: 0.97–4.27), however, this result was not statistically significant.

Figure 3 shows a funnel plot of the nine studies. There is no evidence of publication bias but a small study effect exists (Eger’s p = 0.647, Begg’s p = 0.835).

Sub-group analysis
A sub-group analysis was conducted with the six studies (four RCTs and two before and after controlled studies) from Africa (n = 2,182). Ninety percent of the pooled sample were women, because five out the six studies were carried out at PMTCT or post-natal clinic settings. PLWH who received mobile phone reminders were about three times more likely to return to care than those in usual care (pooled OR = 2.92, 95% CI: 1.13–7.53) (see Figure 4). The analysis with three studies (two RCTs and one before and after study) from UK, U.S., and Switzerland (n = 822) did not show a statistically significant difference between groups who received mobile phone reminders and those who received standard care (pooled OR = 1.16, 95% CI: 0.95–1.42).

Another subgroup analysis was conducted after excluding the 4 before and after studies (Figure 5). The pooled sample for the five RCTs is 1,135.27,28,31,33,38 Mobile phone reminders significantly improved clinic attendance compared to usual care (pooled OR = 2.04, 95% CI: 1.11–3.74).

Discussion
This is the first systematic review and meta-analysis to assess the efficacy of mobile phone reminders to improve retention to care among PLWH in both high- and low-income countries. We found that PLWH who received mobile phone reminders for their follow-up appointments were two times more likely to return to care than those who didn’t receive reminders; however, this estimate was not statistically significant. Our sub-group analysis of 5 RCTs showed a significant effect of mobile phone reminders and 6 studies in Africa found that PLWH, mostly women with HIV who received mobile phone reminders were three times more likely to return to care.
return to care than those who received no reminders, and these findings were statistically significant.

Mobile phone reminders are an effective intervention in resource-limited settings. Our study findings are consistent with the Cochrane review of mobile phone reminders on follow-up appointments among a general population. The review included four RCTs conducted in various health care settings ranging from health promotion centers, primary care clinics, and ENT clinics from four mid- to high-income countries. The review concluded that mobile phone reminders had a low to moderate effect in improving clinic attendance, based on three RCTs of moderate quality (RR: 1.10; 95% CI = 1.03, 1.17).18

Mobile phone reminders address ‘patient forgetfulness’, and may mitigate LTFU by providing simple reminders using mobile phones. However, LTFU, or poor retention to care, is multi-factorial, and these reasons differ depending on whether PLWH live

Figure 3: Funnel plot with pseudo 95% confidence limits.

Figure 4: Forest plot for 6 studies from Africa.
in high- or low-income countries. In Swaziland, patients who were eligible to start ART tended to return for follow-up because of the symptoms they experienced. In Ethiopia, Bezabhe and colleagues used qualitative interviews among 24 patients and identified three facilitators of retention to care — disclosure of HIV status, social support, and use of reminder aids. Therefore, mobile phone reminders will be more effective when they address multifaceted issues, such as signs and symptoms that prompt a clinic visit.

None of the reviewed studies reported use of theoretical frameworks to guide the intervention. Despite usefulness of theory to guide interventions, research study design, and data collection and analysis, studies often underestimate how theory can increase understanding of why an effect is occurring or not. Coomes et al. proposed a conceptual framework for ‘integrating the communication functionality of SMS with important psychosocial factors that could mediate the impact of SMS communication on health outcomes’. This model suggests that the SMS intervention is a helpful tool to improve healthcare quality, as well as patient health outcomes, when SMS is interactive, when content is personalized, and when timing of the SMS is factored into to the intervention. Similarly, Finitsis and colleagues’ meta-analysis found that SMS interventions had larger effects when messages were sent less frequently than daily, allowed for bidirectional communication, and were personalized messages tailored to patients’ needs.

There are several limitations to the present analysis. First, the analysis was not limited to RCTs, which limits our ability to state that the SMS intervention, in and of itself, improves retention to HIV care. Second, the sample size (n = 9) is small and studies were heterogeneous. Finally, every study required mobile phone ownership in order to be eligible for study participation. Thus, findings are not generalizable to the non-mobile phone owners, who may be the most marginalized and most likely to be non-adherent to clinic visits. It is important to note that the pooled analysis is mainly based on women with HIV from resource-limited settings. Therefore, our findings may not generalize to men with HIV or PLWH in high-income countries.

There are several studies from South Africa, Kenya, Swaziland, Mozambique, Malawi and United States that are currently testing mobile phone reminders on retention to HIV care. A two-armed RCT in the US is currently testing SMS reminders boosted with informational, supportive, and motivational messages on retention to care and virological suppression of HIV. This study is based on behavioral theory and it testing cost-effectiveness of the intervention. All of these studies will add to the body of literature on SMS on retention to care.
To date, most research on mobile technologies in resource-limited settings has been in the area of HIV management. In addition, one study from Bangladesh tests a mobile phone intervention to improve type 2 diabetes management in an urban setting.47 SMS reminders are also being tested in Nigeria to manage hypertension.48 Although some studies are being done in resource-limited settings on the efficacy of mobile technologies in chronic disease management, the majority of this work has been limited to developed countries.49,50 More research is needed from resource-limited settings to test mobile technologies for conditions beyond HIV.

Conclusion

Sub-optimal adherence to HIV care can lead to ART drug resistance, and this has become a threat to the health of PLWH.23,51 Mobile phone reminders are a relatively new and innovative approach in HIV care, but the body of evidence to date is inconclusive about the impact of SMS on clinic attendance and HIV health outcomes across settings. We found a strong effect of mobile phone reminders to improve PLWH’s attendance to care in resource limited settings, mostly among women with young infants.

With the ubiquitous ownership of mobile phones globally, including among people living in low-income countries, mobile phone reminders to return to clinic for care are feasible. Future studies should examine the impact of incentivized SMS reminder interventions on access to health services and improved HIV health outcomes. Messages should be designed to allow for bidirectional conversations, be tailored for individual needs and should serve as a bridge to other healthcare and social support resources. The ultimate goal of SMS reminders is not only to improve retention to HIV care, but to improve the quality of life of people living with HIV around the world.

References


5. Aranda-Jan CB, Mohutsiwa-Dibe N, Loukanova S. Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa. BMC Public Health 2014 Feb 21;14:188.


34. Schwartz SR, Clouse K, Yende N, Van Rie A, Bassett J, Ratshewo M, et al. Acceptability and Feasibility of a Mobile Phone-Based Case Management Intervention to Retain Mothers and Infants from an Option...


OBJECTIVES: Many health telemedicine applications (apps) have been released in the clinical-care setting. There is limited information regarding the utility of ICT-based maternity data collection and a comprehensive home-based model of care for high risk pregnant women. The aim of our study was to assess the feasibility of a tablet-based real-time bidirectional telecommunication of self-reported maternal condition in normal and high risk pregnant women.

METHODS: The study included eighteen pregnant women (13 normal pregnant women [the Cohort 1 study] and 5 high risk pregnant women [the Cohort 2 study]) who expressed their interest in participating in the study. Participants were supplied with a tablet computer installed with the “MaternityCare” service program. Each user recorded physical information (body weight and blood pressure) and answered the multiple questions on obstetrical symptoms daily for 30 days.

RESULTS: The median value of individual compliance with practice (individual patient-level reporting rates) was 76.7% in the Cohort 1 study and 100% in the Cohort 2 study. Self-reporting data were transmitted on 65.8% for the Cohort 1 study, and 218.9% for the Cohort 2 study of subject days (subject day = 1 subject × 1 day). 66.7% (10/15) of participants affirmed applications’ ease of use, and 60% (9/15) desired to implement the app into practice after the study.

DISCUSSION: In conclusion, high risk pregnant women had a positive attitude about home-based self-monitoring and expressed a strong desire to receive this app. A dynamic, real-time, bidirectional and interactive mobile maternity health system with a tablet app may support information sharing, quick consultation and initiation of the prophylaxis and treatment at the patient, pre-hospital healthcare provider and physician levels.
education, professional education, or patient monitoring.\textsuperscript{3,4} With the advances in ICT, many health telemedicine applications (apps) have been released in the clinical-care setting in recent years.\textsuperscript{4} The speed of development in internet technology for telemedicine in patients with chronic diseases has been rapidly accelerating. However, to the best of our knowledge, through literature reviews, there is limited information regarding the utility of ICT-based maternity data collection and a comprehensive home-based model of care for high risk pregnant women who want to identify obstetric problems earlier and increasing demand for their need and care, implemented through an e-healthcare software.\textsuperscript{5,6} We have developed a new model for maternity e-healthcare devices using a tablet-based application that provides a bidirectional communication through e-mails and mobile text messages between pregnant women and trained coordinators/obstetricians and offers medical advice. The objectives of this study were 1) to determine the usability, feasibility, preliminary efficacy and safety of a tablet-based real-time bidirectional telecommunication of self-reported maternal condition such as body weight, blood pressure and daily symptom questionnaire for 30 days in normal and high risk pregnant women, and 2) to evaluate the effect of a bidirectional and multi-group telemedicine system on satisfaction in these pregnant women.

Methods

Study population

A single-center, prospective, pilot study evaluated overall satisfaction, ease of use, flexibility, accuracy, stimulation and information contents of the telemonitoring system in order to determine the impact of the maternal data on self-care and clinical management. A Cohort 1 study initially targeted normal pregnant women who visited an obstetric outpatient clinic of Nara Medical University Hospital, Kashihara, Japan, from January 2014 to June 2014. Only those pregnant women who met the following maternal inclusion criteria were selected: singleton pregnant women, 20 years of age or older, their first prenatal visit in our hospital before 12 weeks 0 days of gestation, ability to speak and read in Japanese and ambulatory patients diagnosed without any obstetric complications. Women were excluded from the Cohort 1 study if they have any of the following risk factors or conditions: pregnancy-induced hypertension, history of gestational diabetes mellitus (GDM) or pre-existing DM, body mass index (BMI) >30 kg/m\textsuperscript{2}, or any medications. Participants not willing to have a series of prenatal care visits, with an unknown number of prenatal visits, or no prenatal care were excluded from the study. Furthermore, in a prospective Cohort 2 study, recently discharged high risk pregnant women hospitalized for pregnancy-induced hypertension were invited to participate in the feasibility study between July 2014 and December 2014. The inclusion criteria were the same for Cohorts 1 and 2. The exclusion criteria of Cohort 2: history of GDM or pre-existing DM, BMI >30 kg/m\textsuperscript{2}, and participants not willing to have a series of prenatal care visits, with an unknown number of prenatal visits, or no prenatal care. Owing to small sample sizes, descriptive statistics using the sample size estimation method were not presented.

Participants were invited to receive information from the study coordinator regarding participation in the feasibility study and recruited during face-to-face visits. All eligible patients who agreed to participate in the study were interviewed by trained study coordinators. Two certified midwives were trained as the study coordinator. Eighteen pregnant women (the Cohort 1 study, n = 13; and the Cohort 2 study, n = 5) were initially eligible for participation. Ethical approval was obtained from the Ethics Committee at Nara Medical University. Informed consent was required for participation in this study.

Daily Collection via the App

Participants were provided with a medical app for tablet computers (SHARP Tablet-type, RW-T110, http://www.sharp.co.jp/business/tablet/products/rwt110.html) installed with a “MaternityCare” app for the personal use. They received the medical app free of charge and no longer received any reimbursement of expenses for extra data usage caused by the app utilization. After launching and downloading the app, the authentication of a legal user could be exercised by username ID and password. A 15-minute negotiated interview with each participant on enrollment in the Cohort studies included the following items: instructions on how to log in to the app; entering baseline demographics such as socio-demographic variables (name, age, marital status, and husband’s occupation), obstetrical situation (parity, history of abortion, type of previous delivery) and physical information (height, weight and blood pressure) into the app. Participants were presented with all of the functional components of the app in a tab-accessible format at any time from the day following provision of written consent and could start reporting their maternal condition and vital data via the app (Figure 1). Figure 1A presents a
The individuals recorded body weight and blood pressure (Figure 1B). The self-measurement of blood pressure was obtained by each individual as a home blood pressure monitoring. Once-daily measurements are recommended, usually in the morning. When blood pressure measurements are at least >90 mm Hg diastolic or >140 mm Hg systolic, the app recommends repeating measurements. Data were confirmed after repeating measurement to prevent false readings. If repeating measurements were blood pressure >140/90 mmHg, the app sends an automatic email to a study coordinator. Furthermore, each user was asked to complete a tablet-based self-report screening questionnaire about the maternal condition in order to determine the feasibility and acceptance of the implementation of novel technology. The maternity information was assessed using established questionnaires in Japanese on current status that included items on vaginal discharge, vaginal bleeding, emesis, vomiting, abdominal pain, uterine contraction, fetal movement, edema and questions for measuring self-care and quality of life (Figure 1C, left column). Symptoms were entered daily using on-screen radio button selection of information related to symptoms. The questionnaires in the practice and attitude sections consist of 6 categories (overall satisfaction, ease of use, flexibility, accuracy, stimulation and information contents) containing 12 questions that use a 4-5-point Likert scale based on a ‘yes or no’ response or ‘mild, moderate or severe’ to a question. The daily physical measurements took...
about 5 minutes each morning or evening. After the questions were answered without missing values and outlier data, the user could send validated self-reported physical information and obstetrical symptoms daily, and then received electronic assessment, advice and alerts via an automated search algorithm by our clinical decision support system. Data were captured wirelessly and stored in a secure database. The app provides participants and the study coordinator the ability to view multiple summary graphs of the maternal condition data (Figure 1C, right column). The technological (feedback on automated electronic assessment and health status via the app) and non-technological interventions (via the coordinators/obstetricians) are essential to ensure fail-safe electronic communication and follow-up of critical alert notifications and to reduce missed test results of tracking processes. Scores of ≥ moderate or severe on either questionnaire generated an automated electronic referral to the study coordinator in real time.

Participants were also advised to report their symptoms through the tablet computer if they suffer from specific or non-specific ill-health during that day. They can also send text messages and numerical obstetrical data to the study coordinator using the electronic keypad. If the study coordinator would likely seek consultation from an obstetrician, text messages from participants will be emailed from the study coordinator to the obstetrician’s mobile phone. If the obstetrician determined contacting the patient was warranted, a final message or alert was sent from the obstetrician to the mobile phones of the patient via the study coordinator. The study coordinator can use the visual data in the tablet app to view multiple summary graphs of the maternal conditions in clinical practice; to retake the measurements of physical information if the patient feels ill-health, to high priority alarms; to be a potential referral to the emergency department, or to call their home in the event of an important or late pregnancy complication. The alerts from the study coordinator to the obstetrician range from low priority health status via the app) and non-technological interventions (via the coordinators) are essential to ensure fail-safe electronic communication and follow-up of critical alert notifications and to reduce missed test results of tracking processes. Scores of ≥ moderate or severe on either questionnaire generated an automated electronic referral to the study coordinator in real time.

System design and development have been guided by an expert steering committee. The “MaternityCare” app was developed by Rastec Co. Ltd., Nara, Japan. This app was based on two preliminary frameworks: 1) “My physical self-monitoring”: a calendar feature for recording body weight and blood pressure, and 2) “My obstetrical self-reporting”: a tablet-based screening questionnaire for bidirectional telecommunication between participants and study coordinator. The study coordinator can use the visual data in real time to provide better health care services to target user.

Data analysis
Box-and-whisker plot analysis was performed for data on reporting rates to determine quartiles and interquartile ranges. The box plot contains a central rectangle with lines that extend from both ends. It provides the information about the smallest value, first quartile, median, third quartile, and the largest value.

Results
Total volume of data transfers between server and subject
Figure 2 shows participant flow diagram over inclusion/exclusion process. Thirteen normal pregnant women expressed their interest in participating in the Cohort 1 study. After informed consent, one woman refused to participate in the study due to lack of interest. Thus, 12 cases (median age 31 years; range 24–38 years) were selected to enter the Cohort 1 study. Of the 12 eligible participants, 2 did not start to use the app or did not report self-reporting symptoms at all, although they did not feel technical problems in using their tablet (Table 1, cases 7 and 12). Among the 5 high risk pregnant women initially enrolled in the Cohort 2 study, two were excluded for the following reasons: incompatibility between the app and a tablet (n=1) and lack of interest in the study (n=1). A total of 3 patients (median age 32 years; range 26–39 years) were evaluated in the Cohort 2 study. The cumulative probability of dropout showed 23.5% (4/17) of all participants during the study. Finally, the survey was completed by 13 (13/17, 76.5%) individuals.

The median value of individual participant-level reporting rates in the Cohort 1 and Cohort 2 study was 76.7% (range 0–93.3%) and 100% (range 96.7–100%), respectively (Table 1 and Figure 3). As shown in Table 1 and Figure 4, 237 and 197 self-reporting data were collected via their tablets for 30 days, respectively (overall self-reporting rate = 65.8%, 237/12 × 30 for the Cohort 1 study and overall self-reporting rate = 218.9%, 197/3 × 30 in the Cohort 2 study). During the current study, none had criterion for uncontrolled symptoms or adverse effects.

2) “My obstetrical self-reporting”: a tablet-based screening questionnaire for bidirectional telecommunication between participants and study coordinator. The study coordinator can use the visual data in real time to provide better health care services to target user.
obstetric outcome that require additional intervention, including abnormal uterine hemorrhage, preterm premature rupture of membrane, preterm birth, pregnancy-induced hypertension, preeclampsia, HELLP syndrome, gestational diabetes mellitus and uterine abruption.

Satisfaction questionnaire for the application: primary reasons for missing self-reporting data

The results of the patient’s perceptions of this system are shown in Table 2. They were evaluated for satisfaction questionnaire for the application from 6 categories. Despite being at different cohorts of pregnancy (normal and high risk), the results and discussion were centered around both groups together owing to small sample size. Of the 15 respondents, 10 users expressed overall satisfaction in fulfilling the required task and expectations. More than half (66.7%, 10/15) affirmed applications’ ease of use, and 9 women desired to implement the “Maternity-Care” app into practice after the study. The remaining 5 patients expressed dissatisfaction accompanied with problems, practical drawbacks and complaints.

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Table 1: The value of self-reporting data in the Cohort 1 and Cohort 2 study
The most common reason for missing self-reporting, which accounted for 60.0% (3/5) of all responses, was “lack of experience in the use of technology”. Other reasons included “inconsistent usage” and “Password login errors, Data transfer errors, Network errors”. No missing data were due to “I was too busy”.

Discussion
We designed and developed a mobile telemedicine application as health interventions for self-monitoring, reporting and management for normal and high risk pregnant women. This system contains two algorithms: one is to instigate warnings to the mother if there are premonitory signs or symptoms of a potential adverse event; and the other is that the data is independently reviewed by trained study coordinators and/or obstetricians. The current bidirectional telemedicine system can transmit physical information and obstetric complications/symptoms to the coordinators, and deliver real-time information with risk-reduction advice back to the user from the study coordinators and/or obstetricians. We aimed to assess the feasibility of a prototype “MaternityCare” tablet app in normal and high risk pregnant women. 76.5% (13/17) of the participants used the tablet app. Subjects accepted the tablet app were satisfied with its functionality and ease of use and 60% of participants desired to continue using it beyond the pilot. Women who are at high risk of pregnancy complications were more likely to use the tablet app compared to normal pregnant women. Preliminary results of this study indicated the general acceptance by pregnant women in using this system (Figures 3 and 4). However, the findings showed that the research model had poor explanatory power.

Most telemedicine and e-health self-care apps have focused on fields such as chronic conditions. There are many studies on intensive and extensive bidirectional telemedicine research into the obstetrical area. Despite the advance of e-health technologies through electronic devices, there are relatively few studies that have evaluated the management of high risk pregnant women. There may be an increased demand for bidirectional e-health self-care telemedicine using a smartphone app in high risk pregnant women.

The results of the present study should be interpreted with caution. First, these results have limited generalizability because of the enrollment only of Japanese pregnant women at a single tertiary center.
Second, the apparent limitation of the study is a small number of patients. We have to be careful in making the conclusion that the use of the app is “feasible” in the high-risk pregnancy group as only 3 patients were included in this group. Finally, this study is limited by its non-randomized nature. Therefore, we cannot exclude the possibility of bias in our evaluation because of a lack of a control group.

In conclusion, this telemedicine provided the e-healthcare system of care for normal and high risk pregnant women to send automated and manual feedback through trained study coordinators and/or obstetricians. A dynamic, real-time, bidirectional and interactive mobile e-health system with a tablet app may support physical and obstetric information sharing, knowledge translation, quick consultation and initiation of the prophylaxis in the high risk pregnant women. Further research should focus on high risk pregnant women for mobile e-health care: how to facilitate the promotion of self-management and how to sustain compliance for a longer time.

Conclusions
We assessed the feasibility of a tablet-based real-time bidirectional telecommunication of self-reported maternity data in normal and high risk pregnant women. This study found that high risk pregnant women had a positive attitude about home-based self-monitoring and expressed a strong desire to receive this app. A dynamic, real-time, bidirectional and interactive mobile maternity health system with a tablet app may support information sharing, quick consultation and initiation of the prophylaxis and treatment at the patient, prehospital healthcare provider and physician levels.

Funding
The financial support was used to cover the expenses incurred by utilization of the app. This study was funded by Ministry of Economy, Trade, and Industry, Japan as a part of “Program to support prototype development by manufacturing SMEs and micro-enterprises”.

Conflict of interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References
PRELIMINARY VALIDATION STUDY OF CONSUMER-LEVEL ACTIVITY MONITORS AND MOBILE APPLICATIONS FOR STEP COUNTING UNDER FREE LIVING CONDITIONS

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Background: The last decade’s technological advances have spurred a continuously increasing interest in objective monitoring of physical activity with the use of wearable devices. Even though an increased accuracy is important in some lines of research, a balance between precision, feasibility and low-cost monitoring technologies is clearly needed.

Aims: The purpose of this study was to compare the accuracy for step counting between one spring-levered pedometer, two piezo-electric pedometers and two free of charge pedometer applications for Android smartphones, under free-living conditions.

Methods: Eleven healthy adults, ranging in BMI from 20.20 to 24.77 kg/m², volunteered to participate in the study. They wore the selected criterion pedometer Yamax SW-200 (SW), which is considered the “gold standard”, the Garmin Vivofit (GV), Medisana ViFit (MV), Accupedo application (AC) and Pedometer 2.0 application (PD), for a 24-h period, under free-living settings. Data were analyzed using descriptive and inferential statistics.

Results: All devices and applications demonstrated strong correlations with the SW reference pedometer (IC = 0.86 – 0.94), but often large mean differences Significant differences were observed among the five pedometers (F = 5.21, p = 0.01). Only the PD counted almost similar steps as the SW (F = 0.57, p = 0.47), even though it had high Mean Absolute Percent Error (MAPE). The 3 remaining pedometers significantly overestimated counted steps, with the AC application been the least accurate [F = 11.92, p < 0.01; MAPE = 36.15%].

Conclusions: The results of the present study showed favorable outcomes for the estimation of steps per day for the PD application in healthy and normal weight people. The two piezo-electric pedometers (GV - MV) appeared to give similar values, however these values constantly overestimated step counting compared with the criterion pedometer. Taking into account the free cost and feasibility of the PD application, the results demonstrate good potential for future use in free-living settings.

Introduction
Regular aerobic physical activity increases exercise capacity and physical fitness, which can lead to many health benefits and overall health improvement. Twenty minutes of daily fast walking has the ability to reduce the risk of premature death by 16%
to 30% for both healthy and overweight adults. In order to assist people increasing their physical activity, low-cost techniques are required.

The last decade’s technological advances have spurred a continuously increasing interest in objective monitoring of physical activity with the use of wearable devices. Even though an increased accuracy is important in some lines of research, a balance between precision, feasibility and low-cost monitoring technologies is recommended.

Pedometers and consumer-level activity trackers have been an effective, low-cost tool used by many practitioners and scientists. Smart wearable sensors are adequate for preventive methods in many facets of medicine, such as cardiopulmonary, vascular, endocrine, rehabilitation and for monitoring health. Furthermore recent researches on mobile phone technology have reported on the feasibility and efficacy of phone applications in interventions for weight management, through behavior change of physical activity and dietary habits. However, for the majority of these new monitors and smartphone applications limited evidence exists regarding their validity and reliability.

A systematic review of 22 studies on the validity and reliability of Fitbit and Jawbone activity trackers indicated high validity for step counting and lower validity for energy expenditure and sleep estimation. A recent research compared the validity of Fitbit Ultra, Nike Fuelband and Yamax SW-701 during a two minute walk test. It was found that Fitbit Ultra was the most accurate device (5% error), followed by Yamax (15% error), while Nike Fuelband was the least accurate (34% error). Lee, Kim and Welk examined the validity of eight consumer-level devices during a 69 minute laboratory protocol. They concluded that BodyMedia Fit was the most accurate device in estimating energy expenditure, followed by Fitbit Zip and Fitbit Ultra. Under free-living conditions, Ferguson and colleagues have recently published their results regarding the validity of seven activity monitors, worn by 21 adults who went about their daily life for 48 hours. They concluded that validity ranged widely between devices and the most accurate ones were Fitbit One, Fitbit Zip and Withings Pulse, especially in step counting with very strong correlations (r = 0.94–0.99).

Nowadays these monitors, coupled with smartphone devices equipped with in-built accelerometer and the appropriate applications, have a vast potential to enhance user experience and utility. They are intended for individuals to log, record, track and evaluate their general fitness, health or wellness. According to the Food and Drug Administration (FDA), these mobile applications are categorized as mobile Health (mHealth) applications. However they may meet the definition of medical device but FDA intends to exercise enforcement discretion for these applications because they pose lower risk to the public. The report of Research2Guidance stated that mHealth and fitness applications in 2012 were almost 97,000, while between the 300 most downloaded applications, 102 were related to exercise and physical fitness. Fitness and wellness applications are the most rapidly growing mobile sector in the U.S.A., with a 134% rise of users between 2010 and 2011. Furthermore their use may be a powerful tool to encourage and promote physical activity and health.

Smartphone technology and mobile applications have recently been reviewed in physical activity and health promotion. Hekler and colleagues tested three Android smartphones (HTC MyTouch, Nexus One and Motorola Cliq) and concluded that they can provide comparable physical activity estimates to an ActiGraph, both in laboratory-based and free-living context, regardless of the activity classification algorithm used. On the other hand, Boyce, Padmasekara and Blum compared three pedometer iOS applications (iSteps Lite, Pedometer Lite and Lyr Free) with a conventional Yamax pedometer and found that they were inaccurate in step count and speed estimate at varying intensities of activity. Lastly, Bergman, Spellman, Hall and Bergman compared an iOS application (iPodometer) with a StepWatch 3 and direct observation and found similar results regarding the inaccuracy of the application, concluding that this is not a valid instrument for monitoring activity. Till nowadays, little evidence exist regarding the validity of Android physical activity applications and, as Bort-Roig and colleagues stated, ‘well designed studies are needed that comprehensively assess physical activity measurement accuracy’.

The purpose of this preliminary study was to compare the convergent validity for step counting between a spring-levered ‘golden standard’ pedometer, two piezo-electric pedometers and two free of charge pedometer applications for Android smartphones equipped with an accelerometer, under free-living conditions.
Method

Study population

Participants were eligible for inclusion if they were aged 18 years or over, lived in metropolitan Athens, Greece, had an average BMI, were healthy, did not use medication that would affect their body weight or metabolism, were nonsmokers and could ambulate without walking aids. A convenience sample of seven males and four females, with an average age 32.45 years (SD 3.62 years), ranging in Body Mass Index (BMI) from 20.20 to 24.77 kg\(\text{m}^2\), volunteered to participate in the study. Prior to data collection, each individual provided informed consent in order to participate.

Consumer-level pedometers

Two consumer-level physical activity monitors and two freeware Android applications, running in a Samsung Galaxy S4 smartphone, were examined. The Samsung device was selected because nowadays it is considered the primary Android phone manufacturer.\(^1\) According to Del Rosario, Redmond and Lovell,\(^2\) Samsung S4 is equipped with an accelerometer of resolution \(\pm 0.61 \text{ m s}^{-2}\), gyroscope \(\pm 0.06 ^\circ\text{s}^{-1}\), magnetometer \(\pm 0.15 \mu\text{T (x/y axis)}, \pm 0.30 \mu\text{T (z axis)}\) and barometer \(\pm 1 \text{ hPa}\).

Garmin Vivofit (GV): The GV (Garmin Ltd., USA), software version 3.7, is a wrist-worn triaxial accelerometer that can measure steps taken, distance traveled, calories burned and can assess sleep patterns. This monitor is small (21 mm \(\times\) 10.5 mm) and lightweight (25.5 gr). It is also water resistant up to 50 m and has an extended battery lifespan of one year. GV can store data for one month and has a wireless function through a USB ANT\textsuperscript{TM} Stick that makes it possible to upload data to the Garmin Connect\textsuperscript{TM} (Web site) database, in order to store, analyze and compare trainings sessions. No research has been published on the GV.

Medisana ViFit (MV): The MV (Medisana AG, Neuss, Germany) is a triaxial accelerometer that can measure steps taken, distance traveled, total activity time, calories burned, percent of daily target achieved and can also assess sleep patterns. This monitor is smaller (5.8 \(\times\) 2.1 \(\times\) 1.5 cm) and lighter (11.5 gr) than GV. Its battery life span is significantly smaller, about 10 days, and is less expensive. MV can synchronize data to the VitaDock Online (Web site) via a USB cable or the accompanying VitaDock application for iOS and Android devices. No research has been published on the MV.

Smartphone applications

An internet search for all free pedometer applications was conducted on the Samsung Galaxy S4 smartphone using the standard ‘Play Store’ application. The Android OS operating system was chosen because it was the most widely used operating system\(^2\) and had the most freeware applications.\(^3\)

Inclusion criteria for pedometer applications were:

1. Free of charge indefinitely after download. Applications with a free trial period of finite length were excluded.
2. Full and efficient functionality after downloading, without additional software download being necessary.
3. Functionality only through the built-in accelerometer and not using GPS or 3G signal.
4. Able to record the number of steps taken, average speed, total distance and energy expenditure.
5. Adjustable sensitivity settings.
7. Among the most popular and downloadable applications, according to users’ ratings and number of downloads from the Google Play Store (as mentioned in the Store on the 23 March 2015).

Accupedo (AC): The AC application (Corusen LLC; http://www.accupedo.com), software version 5.0.9, of 2.64 MB size, is one of the most widely used pedometer applications and in 2011 was rated by the users as the best pedometer (Consumer Reports, 2011). It had been downloaded 5,000,000 to 10,000,000 times and 28,034 users had rated it with 3.8 in a five-point scale, from whom 12,771 users rated it with 5. It was available for both Android and iOS devices. The application met all inclusion criteria and could record in real-time average speed, total distance, number of steps taken and activity energy expenditure. No validation research has been published on the AC.

Pedometer 2.0 (PD): The PD application (DSD; https://play.google.com/store/apps/details?id=step.counter.pedometer), software version 3.1.9, of 2.39 MB size, had been downloaded 500,000 to 1,000,000 times and 6,829 users had rated it with 3.9 in a
five-point scale, from whom 3,419 users rated it with 5. It was available only for Android devices. The application met all inclusion criteria and could record in real-time average speed, total distance, number of steps taken and activity energy expenditure. Furthermore, it was the only application with a self calibration capability, which was used in order to determine the appropriate sensitivity settings for every participant separately. No research has been published on the PD.

All devices could measure various physical activity parameters, however in the present study only the accuracy of counted steps for each device was examined. None of the devices had been previously validated.

Reference device

The consumer-level devices were compared with the selected criterion spring-levered pedometer Yamax SW-200 (SW). This pedometer is considered the ‘gold standard’ instrument of measuring physical activity levels and steps taken in field settings and has been used as a criterion device in many studies. Furthermore, this device’s accuracy is not affected by the BMI of the participants.

Study protocol

All participants attended an appointment at which demographic data were obtained, with mass, height and step length measured following standardized procedures. Anthropometric measures were obtained at the beginning of the data collection session. Standing height was measured to the nearest 0.1 cm using a wall mounted Harpenden stadiometer (Harpenden, London, UK). Body mass was measured with participants in light clothes and bare feet on an electronic scale (Omron BF-511) to the nearest 0.1 kg.

Before data collection, all batteries were changed and a series of shake tests were performed in order to ensure correct calibration of SW. For the calibration of the pedometer applications and the selection of the appropriate sensitivity level, the in-built function of the PD application was used, following application’s recommendations.

The GV was fitted on the left wrist, while the smartphone and MV were placed in an elastic belt fitted tight around the waist. For every participant, demographic and somatometric data were entered manually in the smartphone applications and with the use of proprietary software in the pedometers, prior to data collection.

Participants were instructed to leave all devices on simultaneously for approximately 24 hours, excluding sleeping and showering. The wear period was not limited to a particular period of the week and no guidelines or restrictions on activity levels were provided, in order to ensure the study broadly represented free-living steps. Data collection took place in June–July 2015.

Statistical analyses

Data were extracted using the proprietary software for all consumer devices, in the same fashion that a consumer would utilize the software and were processed according to the manufacturers’ instructions. Participants were asked about any non-wear periods, and all indicated full compliance (that is, removal only for sleeping and bathing).

Participants’ demographic data were analyzed descriptively. Step count was determined by comparing the pedometers and applications with the SW. Descriptive analyses were conducted to examine the associations with the criterion measure. Intraclass correlations were computed to examine overall group-level associations. Mean absolute percent errors (MAPE) were also calculated to provide an indicator of overall measurement error. MAPE were computed as the average of absolute differences between the activity monitors and the SW value divided by the SW value, multiplied by 100. Validity on step counting was quantified using one-way repeated measures ANOVA, followed by Bonferroni corrections. To further evaluate individual variations in a more systematic way, Bland–Altman plots with corresponding 95% limits of agreement and fitted lines (from regression analyses between mean and difference) with their corresponding parameters (i.e., intercept and slope) were presented. All statistical analyses were computed with SPSS 21.0 and MedCalc 12.7.

Results

Participants took an average of 7,707 steps·day−1 according to the criterion pedometer.

Table 1 shows the indicators of agreement Intraclass correlation coefficients (ICC) between SW and all activity monitors. Overall associations across the whole duration were consistently high with all
methods yielding large ($> 0.86$) and significant correlations with SW.

The MAPE values for the overall group comparisons (Figure 1) were lowest for MV (21.69%) and GV (22.91%), higher for PD (26.18%), and highest for AC (36.15%).

Significant differences were observed between the five pedometers ($F = 5.21$, $p = 0.01$, $\eta^2 = 0.34$). Only the PD did not differ significantly from the criterion SW ($F = 0.57$, $p = 0.47$, $\eta^2 = 0.05$). The three remaining pedometers significantly overestimated counted steps. More specifically, GV ($M = 9140$, SD = 4561 steps) differed significantly from the criterion pedometer ($F = 8.88$, $p = 0.01$, $\eta^2 = 0.47$), as well as MV ($M = 9032$, SD = 5051 steps; $F = 5.49$, $p = 0.04$, $\eta^2 = 0.35$) and AC ($M = 10298$, SD = 5610 steps), which was the least accurate ($F = 11.92$, $p = 0.01$, $\eta^2 = 0.54$).

The Bland Altman plots (Figure 2) suggested that all devices and applications over-counted steps, revealing the narrowest 95% limits of agreement for AC (difference = 2592 steps; 95% CI = −4264 to −919 steps), lower values for GV (difference = 1433 steps; 95% CI = −2504 to −362 steps) and MV (difference = 1325 steps; 95% CI = −2589 to −60 steps), and the lowest values for PD (difference = 517 steps; 95% CI = −2043 to 1008 steps). The slopes for the fitted lines were not significant for GV (slope = −0.20, $p = 0.102$) and PD (slope = 0.04, $p = 0.847$), which suggests no significant patterns of proportional systematic bias with these devices. However, significant bias was observed for the MV (slope = −0.30, $p = 0.016$) and AC (slope = −0.41, $p = 0.001$).

**Discussion**

This preliminary study aimed to examine the convergent validity of two consumer-level pedometers and two Android smartphone applications for step counting, under free-living conditions in healthy and normal weight adults. To our knowledge, this is the first study which has tried to compare the accuracy of commercial pedometers and freeware smartphone applications under free-living settings. Furthermore no previous studies have assessed the validity of GV and MV. The monitors tested in the present study were not marketed as research-grade monitors, as in Lee, Kim and Welk’s study; however the present study partially supports the relative accuracy of the various monitoring technologies.

All devices and applications demonstrated strong correlations with the SW reference pedometer ($IC = 0.86 – 0.94$), but often large mean differences. The results showed favorable outcomes for the estimation of steps per day from the PD Android application, which may not have the smallest MAPE from SW (26.18%), however it did over count on average only 517 steps and had the highest limits of agreement in the Bland Altman plots. The AC application provided the largest error for estimation for step counting, showing on average 2592 more steps, the largest MAPE (36.15%) and the lowest correlation, showing in general poor validity.

The two piezo-electric pedometers (GV and MV) appeared to give similar values, however these values constantly overestimated step counting compared to the criterion pedometer and their MAPE of about 22% was almost the same as that of PD’s application. On the other hand, these two monitors had the highest correlations with the SW. It is hard to reconcile how monitors can produce high correlations and still have inaccurate group-level estimates.
Therefore, caution should be used when interpreting these findings with the GV and MV.

Furthermore, the slopes of the Bland Altman plots showed significant systematic bias for the MV pedometer device and the AC application. This result further reinforces the validity of the PD application, whose slope was within the accepted limits of non systematic bias pattern. The GV also provided evidence of non proportional systematic bias pattern, rendering it a more valid alternative than MV.

Overall, the performance of these consumer-level monitors and applications is not very impressive, as none of the monitors and applications under examination had MAPE near the upper acceptable limit of 3% used in previous studies. The MAPE of GV, MV and PD could be considered acceptable, considering the diverse range of activities a normal adult performs in a single day. It is possible that monitors overestimated some activities and underestimated others, as in Lee, Kim and Welk’s study. The two activity monitors and PD application may be suitable for consumer use, however they are not yet valid for use in research settings, due to large MAPEs.

Finally, results must be viewed with caution, because larger datasets and more diverse samples are needed. The sample population of the present preliminary study was small and included only healthy, young individuals within the normal range of body weight. Therefore, we cannot generalize these findings to other age groups or body sizes. A further limitation was the use of free pedometer programs, while paid programs may be more valid or more functional. Further research is needed to examine these devices and applications across various activities and intensities. We also believe that FDA should consider these applications as primary medical ones and establish more strict rules regarding their production and use, seeing the mass penetration they have in consumers’ downloading preferences. In future studies advanced piezo-electric pedometers should be used as reference devices, such as Fitbit Withings Pulse, because they tend to be more valid and accurate than spring-levered ones. A different methodological approach in free-living validation studies could also be to perform a validity test on the various devices under examination in semi-structured conditions and use later on, with the same sample, the most accurate device as the reference tool.

Figure 2. Bland Altman plots for step estimation.
Conclusion
In conclusion, the present study offers preliminary evidence for the validity of a freeware Android application in measuring total steps per day under free-living conditions. As suggested by Hekler and colleagues,18 Android smartphones may be an acceptable alternative for tracking everyday physical activity of individuals. Taking into account the free cost and feasibility of the PD application, the results demonstrated good potential for its future use. The two physical activity monitors provided similar estimates for step counting, however these estimates were inaccurate comparing to the criterion measure. More research is clearly needed to establish the validity not only in step counting but also in energy expenditure estimation of these monitors and applications under various settings and diverse samples. However, people who own Android smartphones and would like to track their everyday physical activity have the opportunity to use this freeware application, while this may not be yet suitable for use in clinical and research settings.

No competing interests
All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

References


**mHealth: Vehicle for Health System Strengthening in Sri Lanka**

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Sri Lanka has a unique primary healthcare system with diverse community based healthcare services. Emerging health challengers in sustainable development era needs to be addressed with special emphasis on universal health coverage.

mHealth technology is an evidence based intervention to cater the novel healthcare priorities. mHealth needs to be integrated into the existing health system functions, rather stand-alone resolutions. mHealth applications are used for behaviour change communication, point-of-care diagnosis, vital event registration, data collection, electronic health records, provider-to-provider communication, human resource management and supply chain management initiatives. Incorporating these mHealth interventions at community level are essential in resolving future health challengers in Sri Lanka.


**Introduction**

Health challenges in the modern world require different kinds of solutions. The use of new technology is one key element to fight against the global health burden. Innovative technologies are particularly useful in resource constrained settings, which provide cost effective resolutions. The discovery and rapid spread of mobile phone and wireless technology has the potential to change the mode of service delivery in healthcare.¹ Incorporation of novel technologies into health system can gain maximum results. The objective of this paper is to identify mHealth technologies that can be used to strengthen the health system in Sri Lanka.

Health system is defined as “all the activities whose primary purpose is to promote, restore and/or maintain health”.² It includes service delivery, patient safety, human resource, information system, medical products/ vaccine, technology and health financing. Increase demand of public health issues have made health system function more complex and challenging. Shortages of qualified staff and narrow budget lines have given health systems to select robust, cost effective evidence based interventions to overcome this contest. Mobile health or mHealth is an element of electronic Health (eHealth) and it is one such component that has the capacity to have an impact on community health services.³ Countries within the South-East Asian Region such as Bangladesh has already developed and enforced national health information technology policy with a main focus on mHealth initiatives to standardize and interoperate public health data collection with multisectoral approach.⁴

**Country Profile**

Sri Lanka is an island situated off the southern coast of India with a total population of 20.36 million.⁵ Sri Lanka is classified as a lower middle income country with a Gross National Income of US$ 3440 in 2014⁶ and it has achieved good health indicators despite being
a lower income country compared to other nations globally. Of the total government expenditure 4.9% was spent on health, or 1.43% of the Gross National Product. The Human Development Index for Sri Lanka was 0.702 in 2013. Sri Lanka has a unique preventive primary healthcare system that goes down to the community level. The success behind good health indicators with a relatively low health budget was mainly due to the strong preventive health system. The system is managed by qualified health professionals from national level to the grass root level and it is further strengthened with inherently built health information management system coupled with quality monitoring and evaluation system. The focus was mainly given to the community based health services. These services are provided by two main community health workers at grass root level, i.e. Public Health Midwife (PHM) and Public Health Inspector (PHI). Public Health Midwife is a front line health worker whose primary responsibility is to provide maternal and child health services at community level. Public Health Inspector (PHI) also works at grass root level, and responsible for environmental, sanitation, disease surveillance and control of communicable disease activities in a defined community health area.

Global Challenge
The United Nations General Assembly held in September 2015 has declared new sustainable development agenda for all countries from 2015 – 2030. Health is well positioned in the Sustainable Development Goals with a broad intention to “ensure healthy lives and promote well-being for all at all stages”. It highlights the importance of social determinants, where equity plays a key role with shifting health priorities. Health challengers for Sri Lanka in the next decade require different kinds of solutions. Rapidly increasing Non-Communicable Disease (NCD) burden, growing mental healthcare needs, rehabilitation/palliative care services and remodelling the traditional maternal and child health services to meet the quality and equity parameters need a comprehensive integrated approach. The main emphasis should be to achieve ‘Universal Health Coverage’ by providing equitable quality health service, including promotive, preventive, curative, rehabilitative and palliative care without any financial suffering to anyone and special attention to most vulnerable.

mHealth
mHealth is defined as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices”. Mobile phone and wireless technology is growing rapidly in Sri Lanka with high mobile cellular penetration from 27% in 2006 to 87% in 2011. Mobile cellular subscriptions have increased to 103 per 100 people at the end of 2015. The mobile phone technology has deeply grounded into the Sri Lankan socio-cultural context and reached well beyond health boundaries compared to other technologies and health infrastructure. Mobile health services range from conventional call centres, emergency toll-free telephone service to modern mobile telemedicine, mobile patient records, patient monitoring, community mobilization/health promotion and decision support systems. All these mobile solutions have to be considered in a broader health system perspective rather than as isolated interventions. It is the duty of the policy maker to explore the fundamental public health principles of mHealth interventions and improve health system performance in the areas of coverage, quality, equity and efficiency.

mHealth is useful for different health services in different aspects and it can be used to strengthen the prevailing tasks more accurately with less time and add new tasks to expand services at ground level. The use of mHealth in developing countries range from education, data collection, communication, outbreak tracing and treatment support. Twelve mHealth innovations were identified among reproductive, maternal and child health arena to reinforce health systems with sound evidence. The community health workers have to be utilized to deliver health interventions using this mHealth technology and these interventions can be readily modified according to the Sri Lankan context.

mHealth as a Health System Strengthening Tool
mHealth technology is a useful tool for client education and behaviour change communication. Community health workers can send appropriate and timely mobile health messages for their clients including pregnant mothers, patients with non-communicable diseases, family planning recipients and even to adolescent/youth groups. The short message service based behavioural change campaigns such as smoking cessation interventions have a proven efficacy compared to traditional methods in developed world. It is the exact time to initiate mobile cessation interventions and motivational messages for good health habits through community health workers in Sri Lanka. Point of care diagnostics using mobile technology can be easily applied to diagnose HIV by
interpreting CD4 cell counts through mobile phones. Since HIV is regarded as a disease with stigma and discrimination it will be helpful to use community health workers to manage them within the community. Assessment of drug compliance is crucial, not only for HIV; but also for tuberculosis, malaria and chronic NCDs. Evidence from South India has shown the value of mHealth adherence interventions among HIV patients.16

The health information management at ground level is entirely paper based with complicated registers, records and returns. Community health workers devote much of their valuable time for paper based work resulting concerns on quality, completeness and timeliness of the data. Electronic data management using mobile phone by primary healthcare workers can drastically reduce the turnaround time for reporting at divisional, district and national level. This could be coupled with a digital vital registration system and electronic health record to build a longitudinal population information system.4

Community health workers are an essential resource to collect data for household surveys and demographic health surveys. The use of tables will provide opportunity for them to simultaneously upload the data during data collection without any time delay. Development of a unique electronic health record for each and every individual is essential and community health workers should have the ability to feed the relevant data at field level to this database. This can be further evolved to generate an attractive mobile application (app) that reminds key health related activities to respective individuals. Community health worker will be able to send a reminder regarding child’s vaccination due date to their parents through this electronic system. This will enhance the compliance, improve coverage and minimize inequity. Evidence from Indonesia suggests that the electronic medical record system is useful in collecting data for scientific research and had increased treatment protocol adherence.17

Population screening and detecting high risk clients for NCD at community level can be done through PHMs/PHIs using mobile phone decision support protocols and checklists. These cost effective point-of-care decision support tools ensure standard quality care at community level. A study conducted in rural India has shown that mobile-based, point-of-care clinical decision support instruments are useful to identify cardiovascular disease risk in advance.18 Under-utilization of primary healthcare centres and over-utilization of tertiary care centres is a concern for the health system in Sri Lanka. Lack of laboratory and diagnostic facilities at primary care level encourage people to bypass these institutions and directly access tertiary care hospitals. This can be minimized by introducing provider-to-provider communication using mobile applications by establishing a connection between community clinics and central laboratories/diagnostic centres at national level. This will minimize the cost and time for patients between testing and reporting results. Health workers at primary care level can interpret the test results sent by central level through electronic applications and can initiate appropriate referrals or treatment schedules according to national guidelines. The use of Tele-medicine in intensive care units in Thailand (Tele-ICU) connects the intensivist and critically ill patients in rural areas and act as a mediator to provide quality service coverage.19 Scheduling of community services such as antenatal, postnatal home visits and field clinic visits through mobile devices according to priority needs is essential to provide accountable service delivery. This will save time for community workers and provide the opportunity for policy makers to re-orient their services according to national priority needs in a scientific manner. Providing voice messages, health promotion messages, audio or video clips, multi-media messages and relevant updates to health workers through mHealth technology is a useful training and educational guide for them. This can even be designed as a mode of continuous professional development programme.

Web based dashboards permit supervisory officers to analyse the progress of their subordinates at all levels. With global positioning system in place, it facilitates to trace field officers at community level, minimizing unnecessary field visits. Incorporating mHealth strategy to supply chain management allows smooth functioning of primary healthcare with daily stock updates (medicines, materials). Drug shortages can be minimized by allocating responsible health workers at health facility level and encourage timely ordering with regular electronic updates.4 Hotlines and toll free call centres should be established 24 hours per day to enable clients to directly consult their health professionals for urgent matters.

Private health sector in Sri Lanka has made a step forward on mHealth initiative with assessing the effectiveness of monitoring patients with cardiac abnormalities outside hospital premises. The monitoring was conducted with an ECG belt, pulse oximeter.
and blood pressure monitor. The results were encouraging that 60% of patients have identified that mHealth technology is useful and provided additional sense of security for them during monitoring. There is wealth of evidence to suggest the effectiveness of mHealth in the advancement of public health as a health system strengthening device.

Conclusion
mHealth interventions are dynamic ground-breaking approaches that can be used at community level through grass root community health workers. The lessons learnt from private sector will enhance the ability of service provision at primary healthcare through mHealth technology with efficient, equitable service delivery for everyone at all levels. It is the right time for the Ministry of Health in Sri Lanka to implement these mHealth innovations at community level to encounter the upcoming challengers within health sector with strong determination and effort.

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References


“THE BUS FRAMEWORK: A COMPREHENSIVE TOOL IN CREATING AN MHEALTH APP UTILIZING BEHAVIOR CHANGE THEORIES, USER-CENTERED DESIGN, AND SOCIAL MARKETING”

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INTRODUCTION

Despite the explosion of health-related mobile applications (apps) – now numbering more than 43,0001 – few are widely used. One quarter of all apps downloaded are only used once.2 Amongst apps that help people manage their health, most are only downloaded fewer than 500 times, and only five apps account for 15% of all health app downloads.2 However, research has shown that when they are used, health apps are successful at improving the user’s health outcomes and preventing disease.3,4 Despite these successes of health apps, they are still not used to their fullest potential. A national survey found that while 58% of adults own a smart phone only half of these adults have apps on their phones.5,6 In fact, only one in three app users has ever downloaded an app that helps track or manage health.6 While health apps are not currently widely used, they are growing in popularity and could be an opportune platform to deliver health promotion campaigns. For this health promotion platform to be optimized, it is important that end-users are engaged in the health app development process to date.3

KEY INGREDIENTS FOR SUCCESSFUL UPTAKE AND USE OF HEALTH APPS

There may be several reasons that health app uptake has been disappointingly low. It is possible that the low uptake and use of health apps may be due to deficiencies in app design and a lack of app evaluation. Muessig suggests there is a lack of use of social marketing principles in app development.7 Additionally, Riley highlights the limited use of principles of behavior change theories in app development.8 Lastly, McCurdie notes that app development does not always use principles of user-centered design.3 Using these principles synergistically could help create a health app that focuses on and engages the end-user while successfully affecting health behavior change.

Behavior Change Theories

Health promotion specialists use behavior change theories to develop health campaigns for target audiences. These theories evaluate environmental, social, and personal factors (e.g. norms, attitudes, and beliefs) that may be influencing health behaviors.9 There are many different theories; each has its own set of constructs that influence behavior change. Three commonly used theories are Health Belief Model, Theory of Planned Behavior, and Social Cognitive Theory (See Table 1).9 Each theory can stand alone or constructs from multiple theories can be combined and tailored to best fit the campaign’s and the audience’s needs.
User-Centered Design

User-centered design (UCD) is an iterative design process that engages the end-users throughout product development. UCD analyzes the usability, usefulness, and fit of a technology in the end-user’s everyday life. When using this design process, the designer must ensure that the end-user is able to use the final product as intended, and can learn how to use it with minimal effort. Interventions that use UCD have a greater likelihood of achieving end-user engagement and being effective. UCD ensures the product creates sustained and positive behavior change. UCD can be especially beneficial in creating usable and sustainable health apps that account for end-users’ needs and preferences. See Figure 1 for a UCD model.

Social Marketing

Social marketing adopts traditional marketing principles to influence behaviors that improve health. It is most successful when used as a research-driven process that utilizes end-user feedback to create a tailored campaign for a specific audience. Social marketing is critical when planning health campaigns because it examines the viewpoint of the audience by incorporating the “Four P’s of Marketing.” These Four P’s are: product, price, place, and promotion. See Table 2 for how the Four P’s could be operationalized for health apps.

THE BUS FRAMEWORK: A COMPREHENSIVE TOOL FOR CREATING HEALTH APPS

The success of health apps may be improved by utilizing the BUS Framework, which incorporates principles from Behavior change theories, UCD, and Social marketing, or BUS. Figure 2 illustrates an app development framework incorporating all three of these to maximize app effectiveness. App creation should employ both quantitative and qualitative research methods. For example, quantitative methods could include surveying end-users about their health needs and their existing health knowledge, attitudes, and behaviors. Qualitative methods could include end-user interviews or focus groups for more in-depth feedback on health app prototypes.

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<tr>
<th>Theory</th>
<th>Explanation</th>
<th>Key Theory Constructs</th>
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<tr>
<td>Health Belief Model</td>
<td>Focuses on an individual’s perceptions of the threat posed by a health problem, the benefits of avoiding the threat, and factors that influence an individual’s decision to avoid the threat</td>
<td>• Perceived susceptibility of a condition&lt;br&gt;• Perceived severity of the condition&lt;br&gt;• Perceived benefits of taking action to reduce risk or seriousness of the condition&lt;br&gt;• Perceived barriers to performing the action&lt;br&gt;• Cues to action&lt;br&gt;• Self-efficacy or confidence in one’s own ability to take action</td>
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<td>Theory of Planned Behavior</td>
<td>Addresses the relations between an individual’s beliefs, attitudes, intentions, behavior, and perceived control over the behavior</td>
<td>• Intention to perform a behavior&lt;br&gt;• Attitude towards the behavior&lt;br&gt;• Perceptions of norms related to the behavior&lt;br&gt;• Perceived control over performing the behavior</td>
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<td>Social Cognitive Theory</td>
<td>Examines the process by which personal factors, environmental factors, and human behavior influence each other. This theory states that self-efficacy, goals, and outcome expectations affect the likelihood that a person will change a health behavior.</td>
<td>• Behavioral capability or knowledge and skill to perform a given behavior&lt;br&gt;• Expectation or anticipated outcomes of a behavior&lt;br&gt;• Reinforcements or responses to a behavior that increase or decrease the likelihood of occurrence</td>
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Table 1: Behavior change theories and their constructs, adapted from Theory at a Glance: A Guide for Health Promotion Practice.
Steps for Health App Creation

1) Situational Analysis
Performing situational analysis is the first step in app development. This analysis includes identifying the health problem, the target population (i.e., the campaign end-users), the behavioral determinants of the health problem, and the campaign partners and stakeholders. Identification of the health problem includes reviewing existing data on the health of a specific population and understanding aspects of the health problem.\(^\text{13}\) The target population should be narrowed down to a group of people with common characteristics (i.e. attitudes, demographics, patterns of behavior).\(^\text{13}\) Such audience segmentation is necessary to create a more homogenous target population with more similar needs. Campaigns that target broad populations, such as “adults”, are less successful because of the diversity of knowledge, attitudes and health behaviors in this large of a population.\(^\text{13}\) Also, successful campaigns should target determinants of behaviors (i.e. barriers and facilitators) that influence the health problem of interest in the target population.\(^\text{14,15}\) As noted in the Institute of Medicine report, Speaking of Health: Assessing Health Communication Strategies for Diverse Populations, “the more one knows about the determinants of a given behavior, the more likely it is that one can develop an effective communication intervention to reinforce or change that behavior.”\(^\text{11,16}\)

After identifying the target audience and specifying the targeted health problem, it is important to identify and include partners and stakeholders to ensure that successful app creation and buy-in will occur. Partners are those who will support and promote the health campaign and may be advocates for the health issue. For example, the American Sexual Health Association could be a partner for a sexually transmitted disease (STD) testing campaign encouraging testing among female college freshmen. Stakeholders are third-party entities who may benefit from the campaign’s success. For example, stakeholders could be pharmaceutical companies who market drugs to treat STDs, university health centers that provide STD testing to college students, and financial investors in the app.

2) Concept Generation and Prototype Design
After the health problem has been identified through situational analysis, the concept for the campaign should be selected. For the example given above, the campaign's concept would be increasing STD testing. The campaign developers should conduct surveys and interviews or focus groups with members of the target audience to understand their barriers and facilitators to STD testing. Based on these findings, constructs of behavior change theories can be utilized to design a prototype – a preliminary version of the final app – that meets the needs of the end-users. For example, if end-users are not being STD tested because they forget, the “cue to action” construct from the Health Belief Model could be incorporated in the app design to address this barrier. This could include the app sending the user a notification for her annual STD test. If end-users do not know where to get an STD test, the construct of “perceived control” from the Theory of Planned Behavior could be applied, and the app could use geo-sensing to show the user a map with nearby STD testing facilities.
Finally, if end-users do not know if they should be STD tested, “behavioral knowledge” from Social Cognitive Theory can guide the app developers in designing the app to provide users with the latest STD testing recommendations that are specific to them. The end result of this step could include picture mock-ups of the app screens and an outline of intended app functions.

3) Prototype Development

The app prototype should be created using the design framework created in Step 2. End-users should be engaged to test progressive versions of the prototype through walk-throughs and usability testing. Walk-throughs entail guiding a small sample of end-users through all aspects of the prototype. The developers should present the app to the end-users to “find anomalies, improve the software product, [and] consider alternative implementations.” For example, in the STD testing app users would give developers feedback on whether the app should have its own calendar for testing reminders or if the app should connect to the existing calendar on the user’s phone. End-user feedback could also reveal end-user preferences on the size of the radius of nearby STD testing clinics in the app’s STD testing facilities map. Finally, usability testing should be done. This involves giving the prototype to the end-user and observing their ability to navigate it without aid from the developers.

4) Pilot Testing

The app should be given to a sample population of the end-users. These end-users should be given access to the app and use it in their everyday life

Table 2: The Four P’s of Social Marketing applied to a health app

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<tr>
<th>Social Marketing Principle</th>
<th>Definition</th>
<th>Principle applied to a health app</th>
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<td>Product</td>
<td>• Actual product: the specific behavior promoted by the marketing campaign.&lt;br&gt;• Core product: the benefit expected by the audience in exchange for performing the behavior.&lt;br&gt;• Augmented product: any tangible product or service that is created to assist in behavior change.</td>
<td>A health app would serve as the augmented product.</td>
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<td>Price</td>
<td>• Shows the advantages of the behavior change by pointing out the increased nonmonetary benefits for the desired behavior or the decreased nonmonetary cost for the desired behavior.&lt;br&gt;• The benefits may be intangible, or achieved years later, or both.</td>
<td>An exercise app could tell the user what weight loss would be achieved by performing a certain exercise. By combining encouraged behavior (i.e. exercise) and the positive end result (i.e. weight loss), the app could show how the benefits outweigh the cost of the behavior.</td>
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<td>Place</td>
<td>• Where and when the audience performs the behavior change.&lt;br&gt;• The place should be at a time and place that makes the behavior change convenient for the target audience.</td>
<td>A health app could encourage particular behavior changes by using a global positioning system (GPS) sensor. For example, when the end-user enters a grocery store, a healthy eating app could alert the user with a healthy recipe and a list of ingredients to buy. A health app could also use an alarm system to notify users to take their medications when they wake up. For a health app the channel would be the mobile phone.</td>
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<tr>
<td>Promotion</td>
<td>• The promotion strategy refers to the message of the campaign and the communication channel through which this message is delivered.</td>
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for a defined period of time. This would allow the developers to ensure that the app is applicable in the end-users’ natural environments. At the end of this period, end-users would give feedback to the campaign developers about their experience using the app and any input they have on improving it. This feedback can be gathered through surveys, interviews, and/or focus groups. End-user feedback allows the development team to see which aspects of the health app are working and which need to be changed to be more effective. Based on the results of the feedback, further iterations of the prototype can be created if necessary.

5) Campaign Launch

Once the final functioning app has been created and successfully pilot tested, it should be pitched to the stakeholders and partners in order to create buy-in for the final product. Should the stakeholders buy into the app, they will be more likely to provide support for the campaign, which could result in additional resources to launch the campaign to a wider audience and to make the campaign successful. At this point, the campaign can be launched and made accessible to the target audience through advertising, promotion by stakeholders and partners, and media reporting.

6) Evaluation

The final, and often overlooked, step is campaign evaluation. There are three types of evaluation – process, outcome, and impact – all of which could use quantitative and qualitative methods to obtain feedback from all parties involved throughout the campaign development process (i.e., target audience, campaign developers, stakeholders, and partners). Process evaluation assesses if the health app was developed and implemented successfully. This evaluation should determine if the project was completed in the allotted timeframe, if the selected stakeholders and partners were actively involved in the project, if the app was developed within the budget, if the app was sufficiently publicized, if the target audience successfully downloaded the app, and if the target audience used the app. Outcome evaluation focuses on end-users’ perceptions and interpretations of the campaign and the immediate behavior change that resulted from the health app. This evaluation should include assessing changes in knowledge, attitudes, and behaviors related to the targeted health problem. For example, outcome evaluation of the STD testing app would include determining if STD knowledge improved because of the app, if end-users were encouraged to get STD tested because of the app, and if end-users had any barriers to using the app (e.g. the end-user was embarrassed about receiving calendar reminders about STD testing). Finally, impact evaluation measures the long-term, broader effect the campaign has on the end-users. This could include getting periodic STD testing data from university health centers over the duration of the campaign.

CONCLUSION

Smartphones and mobile applications are increasing in popularity. However, this technology is being underutilized for health, despite its potential to engage patients and influence positive health behavior changes. Successful health apps should be designed using the principles of behavior change theories, user-centered design, and social marketing as illustrated
in the BUS Framework. Doing so would also help achieve the U.S. Department of Health and Human Services Healthy People 2020 objective of increasing the use of mobile technologies for health. Designing campaigns based on the BUS Framework could be a way to effectively use this burgeoning technology for creating positive behavior change and improving patient health.

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References


The development and application of new technology has long been an integral part of healthcare. The desire to improve quality of care while lowering cost leads to a constant search for new devices and methods that can leverage recent technological advances to assess more accurately, study more informatively, and treat more effectively. Behavioral health interventions that leverage digital health technology have been lauded as a means to help remedy patient burden, treatment expense, and variable adherence found in traditional interventions (Pagoto & Bennett, 2013). The so-called “digital revolution” has produced powerful devices with unprecedented portability and, in the process, opened a new world of opportunities for the use of technology in healthcare. This “revolution” has resulted in a multi-billion dollar market that parallels the increasing global demand for fast and readily accessible health information to facilitate clinical care (Chakrabarti, 2012). However, despite these seemingly parallel movements, there is an ongoing disconnect between the commercial enterprise and clinical evidence-base of digital health technology.

Behavioral scientists may be particularly well-positioned to capitalize on recent health technology developments given the tremendous capacity of mobile devices and other technology to track key health behaviors, provide psychoeducation, and deliver timely interventions to promote health (Cushing & Steele, 2010; Palermo & Wilson, 2009). As a result, the development and testing of mobile health technology has been a “hot topic” in behavioral medicine. Leaders in the field have noted the potential of new technology to improve both research and practice by facilitating measurement of health-related symptoms, remotely examining adherence and self-management behaviors, assessing functioning and outcomes, and delivering therapeutic interventions (Palermo, 2008). Despite this enthusiasm, the use of innovative health technology in daily practice is still in its infancy, and paradigm-shifting developments remain a hope for the future rather than a current reality. Furthermore, we contend that some of the traditional methods used in behavioral medicine may have real limitations when applied to digital health technology. Consequently, new approaches may be needed to realize the potential of this area. In this commentary, we discuss some of the most formidable challenges in the development and dissemination of digital health technologies, and recommendations for overcoming these obstacles using newer approaches. Our commentary focuses specifically on digital health technology, which encompasses the broader landscape of health technology and includes, but is not limited to, patient internet portals, wearable mobile sensors, smartphone and other handheld applications, electronic event monitors, health information technology (IT), telemedicine, and healthcare software.

The first unique challenge of digital health technology development comes in terms of the expertise needed to develop clinically useful applications. Although behavioral scientists bring expertise in behavior change, we may lack sufficient technical and design expertise necessary to bring functional technologies to full fruition. Indeed, the development health technology has, understandably, focused on the hardware and software design and engineering requirements. Yet, many have failed commercially in part due to poorly defined target behaviors and the lack of validity of the data they provide. Rather than individuals working in isolation, a team science
A second challenge of mobile health technology for psychologists is that traditional funding mechanisms (e.g., NIH R- or K-awards) may be ill-suited and incompatible with the fast-paced technology environment. Technology changes so rapidly that in some cases, the devices used in clinical research studies may be obsolete by the time the study findings are published. Moreover, this duration precedes the research-to-practice translation gap, which underscores the challenge of testing and implementing effective technologies in clinical care. To put this into perspective, the process of a typical NIH R01 grant from initiation to completion of the study would mirror the industry-based iteration of the first iPhone device to the iPhone 5s. Thus, the typical NIH R01 mechanism, requiring substantial pilot work before a five-year evaluation period, may not be realistic for the development and dissemination of new clinically-validated health technologies. Instead, alternative sources of funding, such as SBIR/STTR, foundation grants, and investment from industry partners may be needed to develop and validate various health technologies for widespread dissemination. Relatedly, the evaluation of digital health technologies presents new challenges that may not be well-addressed in traditional randomized controlled trial (RCT) designs. Because of constant changes in devices and operating systems, a more flexible and iterative approach to development and evaluation is needed (i.e., agile development process, see Abrahamsson, Salo, Ronkainen, & Warsta, 2002). For example, in order to maximize clinical relevance and patient engagement, digital health technology must be able to evolve over time (e.g., including updated software versions), involve input from both the developer and user, and be adaptive (i.e., allow for frequent changes). Issues of ongoing development and modification are not unknown to existing behavioral medicine interventions, but the dramatically accelerated pace of change with mobile health technologies demands a particularly flexible approach. Validated versions of the technology can then be scaled-up for widespread dissemination, clinical integration, and commercialization.

Unfortunately, the proliferation of health technology applications as a whole in recent years has far outpaced the evaluation of these applications, resulting in an abundance of technology-based options, but a dearth of data supporting their efficacy. This has resulted in some questioning whether there is more hype than hope for digital health technology (Labrique, Vasudevan, Chang, & Mehl, 2013). Moreover, very few mobile applications include psychosocial principles or behavioral theory methods employed in traditional face-to-face interventions, and thus may limit their impact on health behavior change (e.g., Brannon & Cushing, in press; Pagoto, Schneider, Jojic, DeBiaisse & Mann, 2013; Schoffman, Turner-McGrievy, Jones, & Wilcox, 2013). For behavioral scientists, untested applications represent a conundrum as the principles of evidence-based practice require that our services be based on “best available research evidence,” and the promise of a technology may be offset by the lack of rigorous evidence to support its use. Ultimately, this will likely impede the integration of digital health technology into clinical practice and thus undermine its potential health impact (Pagoto & Bennet, 2013).
Finally, the landscape of mobile health technology poses a challenge in terms of informing clinicians of new technologies and keeping up-to-date on emerging evidence for effectiveness. Such evidence has a major impact on treatment selection, and clinicians will be rightfully hesitant to adopt new technologies without knowledge of their effectiveness. However, the volume of applications likely to be developed in the coming years makes it extremely challenging for any professional to keep abreast of the latest developments. The issue is exacerbated by the typical lag between evaluation research and publication of results, necessitating new mechanisms for disseminating findings quickly and in a format that is accessible to busy clinicians. In addition to maintaining up-to-date lists of new technologies and available evidence, opportunities to demonstrate new products and provide support for clinician implementation will be needed. Given the importance of clinician adoption of new technologies, it is crucial to involve these professionals from the beginning and then disseminate strategically to maximize impact.

Digital health technologies in behavioral medicine represent a confluence of staggering opportunities and formidable challenges. Realizing the potential of this area will require a combination of well-established behavioral medicine principles (i.e., rigorous evaluation, interdisciplinary team work) and new strategies that meet the unique challenges of a rapidly changing technology landscape. While there may be a general distrust or slow adoption into practice by some, increasing the evidence base of digital health technology has the potential to shift these views and unearth the true potential for improving health outcomes. Behavioral scientists/clinicians will be forced out of their comfort zone—working with previously unfamiliar partners in an environment that requires agile development and creativity in seeking funding. The potential rewards for this work are considerable and adopting a broader team science approach and adding some of these “new” experts (e.g., commercial developers and designers, engineers) to the table will dramatically enhance our ability to promote the health and psychological well-being of individuals.

References