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Evaluation of an Android-based mHealth System for Population Surveillance in Developing Countries

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Abstract

In parts of the developing world up to 80% of persons infected with human immunodeficiency virus (HIV) are unaware they are infected, leaving themselves and the population around them at risk of further illness. Approaches that depend on patients presenting for screening have failed to be utilized by these populations. It is imperative that screening services instead be delivered to these patients at their convenience. We describe the development of a system to support such services using Android-based mobile phones running Open Data Kit. We also describe a use of this system supporting screening efforts for a population of 2 million persons in Western Kenya. Users of the system felt it was easy to use, and facilitated their home visits. It is more cost effective than pen-and-paper alternatives. Additionally, electronic data collection facilitated earlier reporting. We have implemented a viable solution at scale for collecting electronic data during household visits.

INTRODUCTION

Traditional health care delivery paradigms where patients present to health care providers for care have proven inadequate in many developing country settings. In one observational study from Nigeria, over half of pregnant women delivered outside of hospital facilities and 82% of these women had no skilled attendants at delivery. [i] In Ethiopia, over half of patients diagnosed with pulmonary tuberculosis waited an average of 30 days before presenting to a public health facility[ii]. Even worse, many patients who have particular medical conditions never get diagnosed (or receive late diagnosis) simply because they rarely interact with the health care system. As an example, it is estimated that nearly 80% of HIV-infected adults in sub-Saharan Africa are unaware of their status[iii]. The problem of accessing health care in these settings is two-fold: "On the supply side, good quality, effective health care may not be offered. On the demand side, individuals may not utilize services from which they could benefit."[iv]

As an alternative to waiting for patients to present to health facilities for screening and care, many health care delivery systems in developing countries have initiated efforts to get care out of the physician's office and into communities. One such care system is the USAID-Academic Model Providing Access to Health care (USAID-AMPATH) Partnership[v] in Western Kenya. This program has embarked on an effort to conduct home visits to all two million individuals in its catchment area. The goal of the Home-based Counseling and Testing (HCT) program is to collect basic health information, offer rapid HIV testing, collect sputum for individuals at risk for TB, and offer focused care services where needed. Most HCT tasks are performed by several hundred government-trained community-based health workers. Data from the HCT encounters was initially collected using Personal Data Assistants (PDAs) physically tethered to separate Global Positioning Service (GPS) units. The community-based health workers who used this initial data-collection system felt that this solution was faster, easier to use, and produced higher quality data than using paper-based data collection forms.[vi] These findings are comparable to those from previous studies comparing PDA and paper-based systems.[vii]

Despite its advantages over a paper-based system, this initial data-collection approach had several significant shortcomings. First, although costs were significantly lower than paper-based data collection methods the costs were still substantial. [vi] Second, the data collected could not be directly integrated into the electronic medical record system which was already in use at the USAID-AMPATH clinics – integration required dedicated time by several experienced data managers. Third, the cable connection between the PDA and GPS devices was not always reliable, and GPS information had to occasionally be entered manually into the PDA devices. Fourth, the use of the proprietary Pendragon Forms Software (Pendragon Software Corporation, Illinois, USA) on the PDA devices limited flexibility to incorporate some functionality into the data collection software – some of these functionality included advanced barcode scanning and check-digit algorithms.

In response to these shortcomings, we developed a second generation tool to support the HCT program, with a specific eye on reliability and scalability. We set out to develop an open source mHealth solution that would work on a variety of affordable handheld devices with inbuilt GPS capability. A requirement of this new system was that it had to seamlessly integrate with a widely used open source medical record system, so that the tool could be extended to other settings in the future. [viii,ix] We hypothesized that revising our implementation with these goals would yield reduced costs at comparable effectiveness and end-user satisfaction to our previous efforts. In this paper, we present the development and implementation of this system.

METHODS

Setting

The HCT program is being conducted in Western Kenya, within the catchment area served by the USAID-AMPATH partnership. This partnership is comprised of Moi University School of Medicine and a consortium of North American universities led by Indiana University School of Medicine. The partnership has provided comprehensive HIV care to individuals in Western Kenya since 2001 and is now transitioning to providing comprehensive primary care.[v] The HCT program, including the research reported in this brief, were approved by both the Institutional Review Board at Indiana University as well as the Independent Review Commission of Moi University in Kenya.

The HCT System – Technical Details

We selected the Android operating system (Google, Inc. Mountain View, CA USA) for mobile devices due to several factors. Android was chosen because it is open source. Android is now the most popular smartphone operating system and runs on the widest selection of smartphones whose costs are rapidly declining[x]. To implement the HCT mobile data collection functionality, we took advantage of an existing Android-based tool called 'Open Data Kit (ODK) Collect'[xi] developed by members of this project's team. ODK Collect is freely available on the Android Market, uses forms written in the XForms standard, and displays these to users on phones running Android (Figure 1). ODK Collect can support multiple types of questions including text entry, multiple choice, and check boxes. In addition, it can easily handle multiple data types such as text, GPS location information, photos, videos, audio, and barcodes. Functionality within ODK Collect can also be extended to take advantage of thousands of other available Android Apps.

The Xforms created for the HCT program allowed collection of household information (including GPS), individual demographics, HIV and tuberculosis (TB) histories, testing result information, and follow-up appointments. Contents of these forms were based on direct input by the end-users, with particular attention paid to the workflow for the health workers. The HCT application used almost all ODK Collect's functionalities, and had user authentication, branching logic, and basic decision support. We used ODK Collect's extensibility by incorporating a customized check-digit algorithm for Patient IDs. In addition, we used a freely available barcode scanning application from the Android Market to scan individual ID card barcode numbers with the smartphone's camera, and incorporated these into the collected HCT data. The HTC Dream (HTC America, Inc. Bellevue, WA USA) smartphone was used for the initial implementation as it had an GPS system and a camera. We are currently in the process of implementing the Huawei IDEOS (Huawei North American Headquarters, Plano, TX USA).

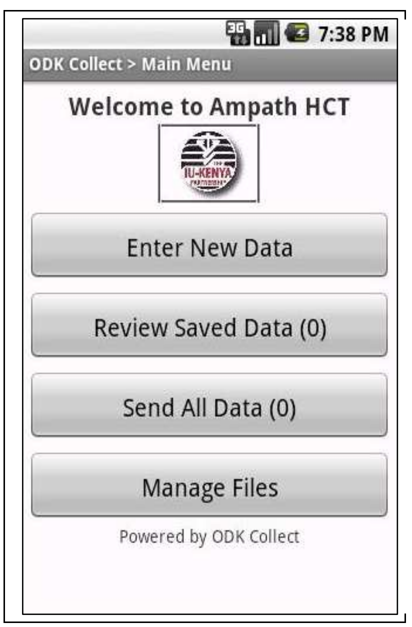

Figure 1. Screen shot of the first screen for Open Data Kit (ODK) Collect.

Data collected on the smartphones was exported into an instance of OpenMRS. OpenMRS is a freely–available, java-based, open source electronic health record system (HER) that can be installed on many different operating systems including Linux, Windows, or Mac OS X. [viii] OpenMRS has been in use at USAID-AMPATH clinics since 2006, and is currently also deployed in over 15 other African countries. [xii] HCT data collected on smartphones was transferred as XML files into OpenMRS using an existing XForms module within the EHRs. Synchronization of the mobile HCT program and the EHRs was done by the community health workers, who used direct USB or wireless network connections - functionality for wireless network transmission was available in our application but was not used because of cost and security considerations. The downloaded data were stored in a specific directory in the OpenMRS server's file system. We built a custom OpenMRS module which scanned this directory to determine if any new XML data files had been downloaded. Data contained in the identified files was then parsed and stored in relevant tables within the OpenMRS database – either as person or location attributes, or as observations that corresponded to particular concepts in the USAID-AMPATH's concept dictionary.

Usability Testing

We conducted two rounds of formal field-based usability testing of the application. In the first round, we involved five pairs of two community counselor end users - Nielsen has shown that about 80% of usability issues can be uncovered with about five subjects, with diminishing returns using more subjects.[xiii] One member of this pair was given an Android-based device with the HCT software installed, while the other member used the existing PDA/GPS solution. The pairs of end users conducted HCT home visits for one day, at which time notes were taken on their actions and verbalizations ('think aloud' technique). These notes were analyzed for critical incidents (i.e. usability issues) and difficulty meeting tasks. Conclusions were drawn from erroneous assumptions and actions, and from tasks taking longer than anticipated. At the end of the session, a brief semi-structured interview and a group discussion were conducted. The content of these interviews covered the strengths and weaknesses of the Android-based system when compared to the existing PDA/GPS solution. End users were also invited to contribute corrections and comments on the interface design. After we incorporated feedback from the first round into the application, we conducted a second round of usability testing and debriefing interviews in a similar fashion to the first round, and with the same number of providers. Major usability issues uncovered during this assessment were addressed prior to deployment of the application.

Data Collection

Prior to deployment of the Android-base application, formal training of end users and data managers for the HCT program was conducted over two days. Each end user was assigned responsibility for a specific device. These end users carried the devices with them during home visits and recorded all data into our customized HCT forms after seeking consent from each individual. Collected data was synchronized to the OpenMRS server as described above.

Data Security

To maintain the highest levels of security possible during this project, several measures were undertaken. Despite the capability for data transmission over wireless networks, we elected to only allow direct connections to our data repositories. Collected data was stored on the mobile devices in field, and after transmission to our servers these files were then deleted from the device's memory. Counselors were made personally reponsible for their devices and took great care to protect them from theft and loss. As of the time of this writing, no devices have been lost or stolen.

User Survey

To assess end-user attitudes towards the new Android-based data collection tool, we conducted an anonymous, self-administered survey of end users who had used both the previous PDA/GPS solution as well as the current Android-based solution. Respondents were asked to evaluate the reliability of the solution as well as their satisfaction compared to the previously available tool. (Appendix A)

Cost Calculations
We calculated costs of using the Android-based solution to allow for direct comparison with costs of using PDA/GPS devices ($0.15 per individual) or a pen-and-paper based system ($0.21 per individual) which had been determined in a previous study.[vi] Our model also included estimates for device breakdown, development of the system, maintenance costs, and training.

RESULTS

Usability Testing
Several issues were uncovered during the first round of usability testing. End users found the font too small and difficult to read in either high light (under direct sunlight) or low light conditions. They also felt that the navigation was not intuitive. Android-devices acquired GPS coordinates more slowly than the previous solution, but the fact that end users did not have to use a separate GPS device was a positive with the Android setup. Furthermore, providers felt that navigation between screens was not very intuitive. To address these problems, we increased the font and taught the end users how to adjust the contrast of the display with considerations of the battery life. We improved our programming to make GPS acquisition happen in the background, and to allow the 'Enter' key to make a selection and move to the next screen. The 'Shift-Enter' key combination returned to the previous screen. The changes were implemented prior to the second round of testing.

Feedback received from the second round of usability testing largely centered on features to make the interface more intelligent and user-friendly. For example, end users suggested that information about the administrative locations should be displayed in an order based on the location hierarchy (i.e. sub-location, location, division, and district) and not alphabetically as we had done. The end users also suggested adding several other functionality, namely features to: (a) allow for direct navigation to the end of the form, (b) to allow the user to save forms as in progress or incomplete, and(c) to review saved forms before transmission. Based on the day's experiences, we also added options to keep track of household in which no one was found at home during the visit, and functionality to allow for return dates to be entered if the household requested a later date for interview. Finally, we improved the logic in many fields on the form such as disallowing non-sensible values for age, sex, or identification number. These changes were implemented for the final version of the Android application.

Data Collection and Analysis
Between March and August 2010, end users visited 18,850 households in the Ainabkoi and Kesses Division in Western Kenya to conduct HCT, with data from these encounters recorded using the Android-based application. end users were allowed entry into 18,108 (96%) households, and they on average visited two to eight households per day.

Counseling and testing was completed for 63,470 persons. Persons were eligible for testing if they were adults over 13 years of age – adults already known to be HIV-positive were excluded. Individuals under 13 years of age were eligible for testing if their mother's HIV status was positive or unknown, or their mother had died or living status was unknown. Children less than 18 months age were not tested because the rapid HIV ELISA tests used during HCT are typically not used to diagnose individuals below this age.

After applying the exclusion criteria, 40,280 were eligible and 39,071 agreed to testing after being counseled and consented to testing. We found 726 (1.9%) were HIV positive, with 565 being new diagnoses and 161 had known their status but wanted to confirm their status. We were able to refer 491 persons for follow-up but only 168 (28%) presented for further care. Children who were less than 18 months and met criteria for HIV testing were immediately referred to an HIV clinic; 129 children fell into this category and 34 (26.4%) presented for follow-up. Follow-up was provided by the USAID-AMPATH partnership, which has been providing HIV care in Western Kenya with the support of the Kenyan Ministry of Health for nearly a decade.

During home visits, HCT end users identified 993 pregnant women. Of these, 448 women (45%) were not receiving ante-natal care. Of all pregnant women, 986 (99.3%) were counseled regarding the risks and benefits of testing and 963 agreed to be tested for HIV. We identified 20 (2.1%) pregnant women as infected with HIV. All of these were new diagnoses and were referred to a clinic for prevention of mother to child transmission of HIV; 17 of these women presented for follow-up. We referred HIV negative pregnant women not receiving ante-natal care to antenatal clinics; 207 presented for follow-up.

User Survey
At the time of the survey, 70 end users had used both the Android-based HCT program as well as our previous PDA/GPS solution. The survey was administered to a convenience sample of 58 of these end users during a weekly team meeting.

Compared to our previous PDA/GPS solution and on a five-point scale, end users felt the Android system was faster (4.26 +/- 0.83), easier to use (4.43 +/- 0.81), and resulted in higher quality data (4.18 +/- 0.80). end users felt using the smartphone sytem facilitated their interactions during home visits (3.98 +/- 0.88). Users felt that the training they received was adequate (4.21 +/- 0.87), and wished to continue using the Android-based system (4.47 +/- 0.83) as compared to the earlier PDA/GPS system(Table 1).

Question (Compared to using PDA/GPS system)	Number of Respondents for Each Option of a 5-point Likert Scale				
	1	2	3	4	5
How reliable is the Android device in collecting data?[a]	0	2	5	14	30
How reliable is the Android device in collecting GPS coordinates?[a]	0	2	3	8	37
How do you rate the quality of data collected on the Android device?[b]	0	0	12	17	21
How easy is it to use the Android device to collect data?[c]	0	2	4	15	30
How fast can you collect data on the Android device?[d]	1	1	5	20	23
Does the Android device make it easier or harder to interact with individuals?[c]	0	2	4	18	17
Should end users continue to use Android devices?[e]	1	1	2	16	31
How easy is it to use the Android device to collect GPS coordinates?[c]	1	1	2	9	38
Was your training on using the Android device good or poor?[f]	1	2	2	24	19
How much experience do you have using computers?[g]	10	0	30	3	7
How much experience do you have with Android devices?[g]	40	0	6	1	2

[a]Scale: 1-Very Unreliable to 5-Very reliable [d]Scale: 1-Much Slower to 5-Much Faster
[b]Scale: 1-Much Worse to 5-Much Better [e]Scale: 1-Definitely Discontinue to 5-Definitely Continue
[c] Scale: 1-Much harder to 5-Much Easier [f] Scale: 1-Very Poor to 5-Very Good [g]Scale: 1-Never used to 5-Regular Expert User

Table 1: Survey Responses comparing Android-based Smartphone solution with existing PDA/GPS solution.

Cost Calculations
The HCT program is tasked to visit two million people over the course of three years (760 workdays). To meet this goal, the program must visit an average of 2,565 persons per day. During the observation period, counselors were able to visit 10-16 persons per day using the Android-based system. For this calculation, we will take the conservative estimate of 10 persons per day. To meet our need, we must sustain 257 counselors with Android-based devices operating daily for the three year period. We will assume a 25% device breakdown rate as in our previous study. We thus require 322 Android devices over the three year period.

At the time of preparing this manuscript, the HTC Dream can be purchased for anywhere from $250 to $550. This was determined by using the Google search engine (http://www.google.com/products) with the keywords "HTC Dream". The median cost determined from this search is approximately $400. As all software used is open source and freely available, this figure represents the total cost per counselor. Based on the projection of the number of devices we require above, this results in a total cost $128,800. Our previous projected cost for the PDA/GPS solution was $183,360. It should be noted that Android-based mobile devices are now available to us in Kenya for approximately $150.[xiv]

The data collected on the Android-based devices will be synchronized with a desktop computer at each of the USAID-AMPATH clinics; based on our previous work we will assume 18 clinics and $1,500 for a desktop computer at each clinic ($18,000 total). In implementing the Android based solution, we required nine months of support by a mid-level programmer as opposed to one month in our previous PDA/GPS solution. Personnel costs include nine months programming time by a mid-level programmer in Kenya ($1,600 per month, $14,400 total), 50% of an IT person's time ($22,000 for three years), 50% of a data manager's time ($22,000 for three years), and two dedicated data assistants ($45,000 for three years). Training costs will come to $1,000 per day, assuming two day training sessions for counselors in groups of 70 to 80. The total for all fixed costs are $111,400.

Thus, the total projected costs for this project are $294,760. For each of the two million persons surveyed, the cost of using the Android-based solution is approximately $0.15 per person. As in our previous work, we assume that the Android devices will not be resold or used for other purposes at the conclusion of this work. This cost can be compared with our previous estimates of $0.15 per individual for a PDA/GPS solution and $0.21 per individual for the data entry of a pen and paper system alone.

Discussion

Our implementation in Western Kenya remains one of the largest applications of a handheld device based system for performing clinical care during home visits in a resource constrained environment. In conducting a redesign of our solution, we have achieved cost savings over both pen and paper collection solutions and remained comparable with our PDA/GPS solution. Our solution will yield significantly increased cost savings in the near future as the price of Android mobile phones declines. Also, we and others are able to reuse a significant amount of the code generated to support this project, and nine months of a dedicated programmer's time should not be necessary.

At the same time of realizing these cost savings, we preserved the high level of user satisfaction we enjoyed with our previous PDA/GPS solution. We have again demonstrated that users with little to no previous computer or PDA experience can be rapidly trained and used to provide clinical care at the household level while documenting the interaction electronically. Our experiences reiterates previous findings that versus pen and paper based systems, information collected via handheld devices contain less errors, are more complete, require less cleaning, and are not more expensive.[xv]

In this study, we found that 1.9% of persons interviewed eventually tested positive for infection with HIV. This number is significantly lower than previous data which suggests a 5.4% precedence for HIV infection in Western Kenya.[xvi] The reason for this discrepancy is that individuals who were already known to be infected with HIV and receiving care were excluded from our program. In fact, it can be concluded that we may have identified a number of additional people who are infected with HIV, and that actual prevalence may be significantly higher than previously suspected.

The direct capture of electronic records greatly facilitated the expeditious performance of initial analyses and reports prior to the conclusion of the three year HCT program. This matches previous research showing the benefit of electronic information via hand-held devices for use in queries, report generation, case management, and establishment of follow-up.[xvii] Our work has highlighted some of these findings, most notably that only 28% of persons we are identifying as infected with HIV are presenting for follow-up care. We feel compelled to address this finding immediately, as three years is a dangerous period of time to leave HIV untreated. We are currently considering directions in which we can affect this - some of our initial approaches may be similar to text message based reminders that haven been shown effective in previous research.[xviii]

The Ministry of Health in Kenya has been highly supportive of the USAID-AMPATH partnership throughout its history. We are hopeful that the outcomes of this project, when completed, will merit consideration by the Ministry for inclusion in its HIV programmes.

Conclusions

In this brief we have described the development and implementation of an open source, freely available solution for the provision of clinical care at the household level. We have expanded on our previous work by demonstrating increased efficiencies in cost while preserving a high level of user satisfaction and data quality. We also re-demonstrate the usefulness of electronic records in such applications, especially in the area of rapid analysis. We are highly concerned by the follow-up rates we've found in our initial program; in our future efforts we hope to work toward developing and implementing solutions to prevent these individuals from dying with HIV.

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Appendix 1. Survey instrument administered to Home-Based Counseling and Testing end users who had used both the current Android-based system as well as our previous PDA-based solution.

Survey of Android Phones for HCT

This brief survey evaluates the utility of the Android phone compared to the old PDA/GPS tool for collecting HCT data. Your participation is completely voluntary; but we would appreciate your feedback.

1. For about how many individuals (not households) have you used the Android Phone to collect HCT information?(Please check one)

____ Less than 10 **___ 10 - 50** **___ 51 – 100** **___ More than 100**

2-3. How would you rate the reliability of the following? (Circle one for each)

	Very Unreliable	**Somewhat Unreliable**	**Neutral**	**Somewhat Reliable**	**Very Reliable**
2. Reliability of the Android phone for collecting data (compared to PDA/GPS)	1	2	3	4	5
3. Reliability of the Android phone for collecting GPS coordinates (vs. PDA/GPS)	1	2	3	4	5

4. Compared to collecting information via the handheld (PDA), how do you rate the quality of data collected using the Android phone? (Circle one)

Much Worse	**Worse**	**About the Same**	**Better**	**Much Better**
1	2	3	4	5

5. Compared to collecting information via PDA, how easy is it to collect data using the Android phone? (Circle one)

Much Harder	**Harder**	**About the Same**	**Easier**	**Much Easier**
1	2	3	4	5

6. Compared to collecting information via PDA, how fast can you collect HCT data on the Android phone? (Circle one)

Much Slower	**Slower**	**About the Same**	**Faster**	**Much Faster**
1	2	3	4	5

7. Compared to collecting information via PDA, how does using the Android phone affect your overall interaction with individuals during HCT counseling? The Android phone makes it (Circle one)

Much harder	**Harder**	**No effect**	**Easier**	**Much Easier**
1	2	3	4	5

8. Should Counselors continue using Android phones (or switch back to PDA) to collect HCT data in the future (Circle one)

Definitely Discontinue	**Consider Discontinuing**	**Neutral**	**Consider Continuing**	**Definitely Continue**
1	2	3	4	5

9. Compared to transferring GPS data by cable to PDA, how much easier is it to use the Android phone to collect GPS information?

Much Harder	**Harder**	**About the Same**	**Easier**	**Much Easier**
1	2	3	4	5

10. How would you rate your training on using the Android phone program to collect HCT data?

Very Poor	**Poor**	**Neutral**	**Good**	**Very Good**
1	2	3	4	5

11. How much experience do you have using personal computers? (Circle one)

I never use computer		**Occasional User**		**Regular Expert User**
1	2	3	4	5

12. Before HCT, how much experience did you have with Android Phones? (Circle one)

Never used Android Phone		**Occasional User**		**Regular Expert User**
1	2	3	4	5

Your Sex: Male [ ]   Female [ ]   **Your Age:** _____Yrs

List the most negative aspects of the Android Phones for HCT:

List the most positive aspects of the Android Phones for HCT:

Write any other comments:

Appendix 2 - Further data

Indicators	Age < 18 mos	Age 19 mos - 12 yrs	Males > 12 years	Females > 12 years	Total
Total Captured	3299	23161	17441	19569	63470
Eligible for HIV Testing	129	3262 (14%)	17320 (99%)	19569 (100%)	40280 (63%)
Counseled for HIV Testing	N/A	3069 (94%)	17180 (99%)	19659 (100%)	39818 (99%)
Completed HIV Testing	N/A	2952 (90%)	17098 (99%)	19021 (97%)	39071 (97%)
Positive HIV Test Result	N/A	53 (1.6%)	217 (1.3%)	456 (2.4%)	726 (1.8%)

Table A1. Results for Individuals Surveyed in the Home-Based Counseling and Testing (HCT) Program in the Ainabkoi and Kesses District in Eastern Kenya. Numbers in parenthesis are percentages of the previous row's total. All children less than 18 months old and deemed at risk of HIV exposure were immediately referred to tertiary care, and no further testing was performed by the HCT program.

HIV Status	Age 19 mos - 12 yrs	Males > 12 years	Females > 12 years	Total
Newly Identified Positive	42	184	339	565
Previously Known Positive and not Receiving Care	2	7	33	42
Previously Known Positive and Receiving Care	9	26	84	119
Total Positive Eligible for Follow-Up	44	191	372	607
Total Referred	34 (77%)	157 (82%)	300 (81%)	491 (81%)
Total Successfully Enrolled in an HIV Clinic	17 (39%)	45 (24%)	106 (28%)	168 (28%)

Table A2. Results for Individuals identified as positive for HIV infection by the Home-Based Counseling and Testing (HCT) Program in the Ainabkoi and Kesses District in Eastern Kenya. Numbers in parenthesis are percentages of the previous row's total.

References

[i] Olusanya BO, Alakija OP, Inem VA. Non-uptake of facility based maternity services in an inner-city community in Lagos, Nigeria: an observational study. J Biosoc Sci. 2010 May; 42(3):341-58.

[ii] Mesfin MM, Newell JN, Walley JD, Gessessew A, Madeley RJ. Delayed consultation among pulmonary tuberculosis patients: a cross sectional study of 10 DOTS districts of Ethiopia. BMC Public Health. 2009 Feb 9;9:53.

[iii] 'Towards Universal Access: Scaling up Priority HIV/AIDS Interventions in the Health Sector. Geneva: World Health Organization. 2008.

[iv] O'Donell O. Access to health care in developing countries: breaking down demand side barriers. Cad Saude Publica. 2007 Dec;23(12):2820-34.

[v] Inui TS, Nyandiko WM, Kimaiyo SN, et al. AMPATH: living proof that no one has to die from HIV. J Gen Intern Med. 2007;22(12):1745-50.

[vi] Were MC, Kariuki J, Chepng'eno V, et al. Leapfrogging Paper-Based Records Using Handheld Technology: Experience from Western Kenya. Stud Health Technol Inform. 2010;160(Pt 1):525-9.

[vii] Galliher JM, Stewart TV, Pathak PK, Werner JJ, Dickingson LM, Hickner JM. Data collection outcomes comparing paper forms with PDA forms in an office-based patient survey. Ann Fam Med. 2008;6(2):154-60.

[viii] Mamlin BW, Biondich PG, Wolfe BA, et al. Cooking up an open source EMR for developing countries: OpenMRS - a recipe for successful collaboration. AMIA Annu Symp Proc. 2006:529-33.

[ix] OpenMRS LLC. OpenMRS >> Where in the World? Available at http://openmrs.org/about/locations/. Accessed 18 Oct 2010.

[x] Goldman D. "Android passes Blackberry as No 1 on Smartphones." CNNMoney 07 Mar 2011: http://money.cnn.com/2011/03/07/technology/android/. Accessed 14 Mar 2011.

[xi] Hartung C, Anokwa Y, Brunette W, Lerer A, Tseng C, Borriello G. Open Data Kit: Tools to Build Information Services for Developing Regions. Information and Communication Technologies and Development (ICTD) 2010. *In Press*.

[xii] Mamlin BW, Biondich PG. AMPATH Medical Record System (AMRS): collaborating toward an EMR for developing countries. AMIA Annu Symp Proc. 2005:490-4.

[xiii] Nielsen J. Estimating the number of subjects needed for a thinking aloud test. *International Journal of Human-Computer Studies.* 1994;41:35-397.

[xiv] Kinyanjui K. Kenya gets low priced smartphone. Business Daily. 09 Sept 2010. Available at http://www.businessdailyafrica.com/Company%20Industry/Kenya%20gets%20low%20priced%20smartphone/-/539550/1004304/-/rf069lz/-/. Accessed 21 Oct 2010.

[xv] Galliher JM, Stewart TV, Pathak PK, Werner JJ, Dickinson LM, Hickner JM. Data collection outcomes comparing paper forms with PDA forms in an office-based patient survey. Ann Fam Med. 2008 Mar-Apr;6(2):154-60.

[xvi] National AIDS and STI Control Programme, Ministry of Health, Kenya. July 2008. Kenya AIDS Indicator Survey 2007: Preliminary Report. Nairobi, Kenya. Accessed at http://www.aidskenya.org/public_site/webroot/cache/article/file/Official_KAIS_Report_20091.pdf on 18 Oct 2010.

[xvii] Dwolatzky B, Trengove E, Struthers H, McIntyre JA, Martinson NA. Linking the global positioning system (GPS) to a personal digital assistant (PDA) to support tuberculosis control in South Africa: a pilot study.Int J Health Geogr. 2006 Aug 16;5:34.

[xviii] Leong KC, Chen WS, Leong KW, et al. The use of text messaging to improve attendance in primary care: a randomized controlled trial. Fam Pract. 2006 Dec;23(6):699-705. Epub 2006 Aug 17.