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From Evidence to Practice: The implementation of digital health interventions in Africa for achievement of Universal Health Coverage

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Editorial to the HELINA 2019 proceedings

Nicky Mostert
Nelson Mandela University, Port Elizabeth, South Africa
The HELINA 2019 Conference

The 12th HELINA (HEaLth INformatics in Africa) conference was organized from 20 – 22 November 2019 in Gaborone, Botswana. The conference was hosted by the University of Botswana (UB) e-Health Research Unit under the Department of Computer Science, in collaboration with: Ministry of Health and Wellness (MoHW), Ministry of Transport and Communication (MTC), Botswana Institute for Technology Research and Innovation (BITRI), and the Botswana Health Information Management Association (BoHIMA), with Support from Stop TB Partnership in Geneva and Virtual Business Network (VBN) Services.

The conference focused on evidence to practice of digital health interventions to achieve universal health coverage. Digital health is an enabler for equitable health care access, from clinical care to public health. The conference provided a platform to showcase digital health interventions that have not only shown benefits, but are also sustainable.

The Conference Themes

The call for submissions for HELINA 2019 covered a broad range of themes related to the implementation of digital health interventions in Africa under the title “From Evidence to Practice: The implementation of digital health interventions in Africa for achievement of Universal Health Coverage”. Academic research papers, work in progress papers, and case study/experience papers where solicited within the following themes:

- The maturity model approach to implementation of digital health solutions
- Digital Health Learning Systems
- Quality and use of health data and systems
- Big data analytics in health care
- Health Information Systems Interoperability
- Continuous Quality Improvement of health data and systems
- Development of competent human capacity for digital health
- Sustainable ICT-solutions for health service delivery
- Artificial Intelligence and frontier technologies in digital health

Review process

After a call for papers was sent out a total of 133 submissions were received. A double blind peer review process was used for evaluating each full research and work-in-progress paper. These submissions were anonymized before being submitted to at least 2 reviewers according to their area of expertise. The Scientific Programme Committee based their final decision on the acceptance of each submission on the recommendations and comments from reviewers. Accepted submissions were then sent back to the authors for revision according to the reviewers' comments. This review process resulted in the following acceptance rates:
Full research papers: 4.5% (n=8)
Work in progress papers: 6% (n=5)
Case studies and experience papers: 8% (n=11)
Rejected or retracted papers: 82% (n=109)
In order to be included in the conference proceedings, an accepted paper had to be presented at the conference.

Nicky Mostert, HELINA 2019 SPC Chair

JHIA online.org Journal of Health Informatics in Africa

12th Health Informatics in Africa Conference (HELINA 2019)
Peer-reviewed and selected under the responsibility of the Scientific Programme Committee

Assessing Users Involvement in Analysis and Design Tasks of Electronic Health Information Systems: Experiences, Challenges, and Suggestions to Optimise Involvement

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Background: User requirements play a vital role in the development of usable EHIS. For developers to design better quality, relevant and safer EHIS that meet user needs, they are required to actively engage stakeholders especially in the analysis and design tasks of its development life cycle. This is because they provide context appropriate solutions based on their needs. However, in most cases developers ignore health stakeholders' input especially during these tasks due to varying perspectives and expectations, complexity, high cost, and variability in time to complete the tasks. This has resulted into various challenges including difficulty in capturing and interpreting user requirements in an effective and efficient manner, poorly designed and unusable systems, unsatisfied user needs, and high maintenance costs. This study thus aimed at assessing users' involvement in the analysis and design tasks when developing EHIS with a view to understand their experiences, challenges, and suggestions to optimise their involvement.

Methods: We employed a cross-sectional survey to investigate and describe the level of user involvement and challenges faced in the analysis and design tasks of the EHIS development process. A total of 36 health practitioners from 13 Key health institutions located in Uganda were selected as respondents.

Results: The study revealed that majority of the respondents was involved in EHIS development, with a few involved at analysis and design tasks. Increased costs associated with data collection, followed by lack of consensus in clarifying, articulating and defining user requirements were recorded as the biggest challenges faced by users at requirements gathering, analysis and system design tasks. Regards suggestions to optimising users' involvement in EHIS development tasks, the study reported that users were very much interested in being involved at all tasks of EHIS development, and consultation of users was paramount in order to incorporate all their needs in EHIS.

Conclusions: The results from the study demonstrate the value of user involvement at the analysis and design tasks of EHIS development cycle. User involvement offers benefits in form of reduction in costs, improved productivity due to users easily arriving at a common consensus and positive growth in user attitudes. The researchers intend to incorporate suggestions that emerged from this study to conduct long-term evaluations of existing EHIS and investigate how users' involvement changes over time.

Keywords: Keyword: Human Centred Design/User Centred Design, User involvement, User stories Analysis and Design

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1 Introduction

In recent years, many countries have adopted Electronic Health Information Systems (EHIS) with the aim of replacing existing paper-based patient records with electronic information systems to enable better integration, sharing of information, and smoother collaboration amongst different healthcare providers [1]. EHIS have been critically acclaimed for their ability to increase legibility, reduce medical errors, shrink costs and boost the quality of healthcare [2]. An Electronic Health Information System refers to a digital collection of patient information or a computer managed health information system [3] that is designed to improve the quality of healthcare, efficiency, diagnosis, and treatment as well as safety of patients [4], through processing data and knowledge in the health sector environment [2]. It encompasses a wide range of products and services designed to collect, store, exchange and use patient data throughout the clinical practice of medicine for communication and decision-making; examples include; electronic medical records, electronic health records, clinical decision support, computerised physician order entry, administrative, laboratory and radiology health information systems [5].

EHIS development process goes through different iterative tasks of the System Development Life Cycle (SDLC). The first three tasks (user stories collection/requirements gathering, analysis and design) involve identifying and interpreting user requirements in a much more clearer and understandable form [6]. Gathering system requirements and interpreting these requirements, requires one to take into consideration many things including; user needs, user perspectives, available resources, and the budget. This is because if requirements are wrongly specified or interpreted in an ambiguous, incorrect or not complete format from the start, then the developed system is at risk of not working to the expectation of the targeted user. Active user engagement and ownership is very vital for the success of many designed EHIS and tech-enabled projects; this is because they provide context-appropriate solutions based on their needs [7], which leads to better quality, relevant and safer devices that meet users' needs [4] foster ownership [8] successful implementation and quality of the product [4]. However, there still exists a huge disparity between the way developers and stakeholders of the designed health information systems artefacts regard user involvement.

In information systems discipline, the notion of *user involvement* is generally described as the participation of potential users or representatives in the system development process [9]. It is largely related to user perception of system usefulness, which tends to create a sense of ownership and more positive attitude towards computer systems [10] [11]. In most cases developers ignore stakeholders' input, especially during the analysis and design tasks [4] , due to complexity, high cost and variability in time to complete tasks [12] [13]. To a large extent this has contributed towards miscommunication, misunderstanding as well as conflicts between users and the development teams, difficulty in translating user stories into design specifications and time wastage [14] [15]. Consequently, many developers design systems that lack clarity on who the users of the system are, what they need or how their needs differ [16]. As such, many of these poorly designed systems are abandoned by the target users because of their ineffectiveness in meeting user needs [12], limited interoperability [17], and also have other challenges including; 80% of high maintenance costs [18], errors, that could cause patient harm and death [19] [20]. This partly explains why only 61% of the designed systems meet the requirements specifications of the users, and 63% of the design projects surpass their estimated budgets [21].

To avoid such pitfalls, [22] suggests that developers should employ the Human Centred Design (HCD) approach also known as User Centred Design (UCD) approach. *User/Human Centred Design* (UCD/HCD) is an interactive approach to system development that involves studying, understanding and considering user perspectives in all the design tasks and iteratively developing products that works for the intended end users [10] [23] [24]. Additionally, the World Health Organisation (WHO) strongly encourages use of HCD/UCD approach when designing EHIS (UNICEF Designing Digital Interventions for Lasting Impact). This is because this approach follows global principles for digital development (digitalprinciples.org). Among these principles is "design with the user" and "be collaborative" [25] [26] as described in the WHO *collaborative requirements development methodology*. According to [24], *users* can be divided into three broad, categories; these include primary users (person(s) who will regularly use the artefact), secondary user (person(s) who will only occasionally use the artefact), and tertiary user (person(s) who will be affected by the use of the artefact). Examples of users in the health systems include; patients, former patients, care takers, medical device users, advisors, participants, consultants, co-producers, healthcare professionals, community leaders, general public, ultimate end users and organizations with health interest or a specific disease [27] [28] and the power they have over the proposed system range from vendors, policy makers, professionals, to data entry personnel [29].

Following the UCD/HCD approach, during *user stories collection/requirements gathering* phase, users define the system in more detail with regard to its inputs, processes, outputs, and interfaces. Users specify requirements including; key system functionalities, identify the kind of test to be performed, define test procedures or use cases to be used in testing, and traceability back to the requirements [30], to a level of detail sufficient for systems design to proceed. In the *Analysis* phase, users ask themselves three major questions; how does the current system work, what do the users want, and what recommended solutions can work for these users [31]. The phase is therefore important in determining what business needs exist, as well as how they can be met, who will be responsible for individual pieces of the project, and what sort of timeline should be expected. The core activity at this phase is to understand the requirements of the users of the product and to come up with a design that is easily acceptable to the users [32]. While in the *design phase*, end users discuss and determine their specific business information needs for the proposed system [33] as well as consider the essential components, structure, processing and procedures for the system to accomplish its objectives. The necessary specifications, features and operations that will satisfy the functional requirements of the proposed system are identified.

In using the UCD/HCD approach, several *benefits* are advanced to the users. For instance, EHIS developed using this approach, appeals to a wide array of customers, because before proceeding to another phase, all user groups have to be satisfied with the requirements made [34]. Furthermore, user involvement helps designers to manage users' expectations of a new product. When users have been involved in the design of a product, they know from an early stage what to expect from a product and they feel that their ideas and suggestions have been taken into account during the process [10]. This leads to higher customer satisfaction, smoother integration of the product into the environment and a sense of ownership for the final product [35]. User involvement helps the system developers to get fast and easy methodologies of designing and validating the system functionality. System developers can assess and certify data from the secondary sources to identify users' requirements, and thus apply a more appropriate methodology [10].

Notwithstanding the above benefits for users' involvement in the UCD/HCD approach, the users still face various challenges. One of the major challenges of the UCD/HCD is that users with negative attitudes will resist the implementation of the new system or changes in existing system. Others may pose unrealistic expectations from the system [36]. Some users may not wish to participate or get involved in the project while others may not have the right attitude to the workplace thereby causing behavioural problems and ultimately causing delays in the project delivery timelines [37]. Involving users in the development of information systems always requires more time for proper engagement, extra work and also attracts additional costs because of the larger resulting project teams [38]. Effective incorporation of user participation in the design process is also among the challenges. Determination of which voices will be heard and how the users' preferences will be reflected in the design is a values-based decision and is rarely easy [39]. Along with the issue of who gets to participate comes the issue of how to recruit users who will represent the potential target user groups appropriately when those groups are very large or very diverse. When user participation is limited to only a certain stage, the users' role will end up being that of information providers rather than co-designers of the project. [4], asserts that the highest participation rate of users in the four-stage development of the HIS was related to the implementation phase and the lowest participation rate was related to analysis. The study further reveals that established teamwork from end-users and the support of top managers from HIS development as the most important factors in increasing user participation. This calls for the need to focus on the other three stages of EHIS designing, that is, requirements gathering, analysis and design. Further still, [12] also observed that there is limited appreciation of users' input in healthcare system development. Their findings indicate that 60% of the users believed that designers and developers of the system ignore their views and 22% asserted that their recommendations were not applied when modifying the system. This explains the low level of participation of users in the design and evaluation stages. The study recommended that communication between the end users and developers should be improved and better methods for healthcare IT development should be devised. Lastly, a study on user involvement in the co-design of self-care support systems for heart failure patients by [40], revealed that there is a difference between users who work in an organizational setting and users who are patients. Patients as users provide comprehensive ideas that can be used to improve care of other patients in future. However, there is need to explore co-design with the users, so as to approve the ideas that patients have apparent during their encounter with the system, as well as find a balance between a situation understanding of users and the developers.

Given the above benefits and notwithstanding the various challenges faced by the users involved in the UCD/HCD approach in designing EHIS, currently in Uganda's health sector, various users are not involved in the first three tasks of the EHIS development process. To this end, this research sought to establish the magnitude of users' involvement in the user stories collection/requirements gathering, analysis and design tasks when developing EHIS with a view to understand their experiences and the challenges that impede their involvement, as well as to propose suggestions to optimise their involvement

2 Materials and methods

The Cross-sectional survey was used for data collection because it was found to be more suitable in describing the current level of user involvement in the user stories analysis and design tasks of EHIS development, as well as establishing the challenges that impeded users from being adequately involved in these tasks. *Cross-sectional survey* is a method that is used to collect data at a particular point in time [42] [41].Particulary we used the survey questionaires to investigate the level of user involvement in the EHIS development process.

Questionnaire design: All the three authors participated in designing the questionnaire. The design of the questions was based on the review of literature on the challenges of user involvement in analysis and design tasks [37] [21]. Both close-ended and open-ended questions were developed. The questions had two major sections. Section A required the respondents to provide information on the organisation, its location, title of respondent at the organisation, size of organisation. Section B mainly focused on user experience on the different EHIS used in their organisation, how it was acquired, whether the design of the EHIS or not, how they were involved at the different tasks, the challenges they faced in using the systems while not involved in its development. The respondents were also asked to suggest ways in which they would like to be involved in the user stories analysis and design tasks, how they would like to be involved in EHIS development and in what tasks they would like to be involved mostly. A pre-test was first done on the questionaires to verify if they accurately reflected the area of interest, and thereafter questions were futher simplified to make it easily understandable and acceptable to the target respondents.

Sample size: Uganda was used as our case study to better understand the problem under study. A total of 36 health-practitioners were purposively selected from 13 key health institutions located in the Northern and Central regions of the country, that is, Gulu and Kampala, respectively. The limited number of health institutions using EHIS in Uganda, coupled with time and cost constraints informed the rationale for purposive sampling. The roles of the respondents ranged from biostatistician, counsellors, data clerks, health information systems specialist, lab technicians, clinicians, nurses, quality control officers, to monitoring and evaluation officers.

Inclusion Criteria: This study was restricted to medical practitioners' who either used the EHIS on a daily basis or were in charge of developing or monitoring the EHIS.

Data collection: A self-administered questionnaire was sent to respondents. A 95% response rate was achieved. The questionnaire gathered background information about their places of work, their experience while using EHIS as well as their involvement in the EHIS development process.

Data analysis: The raw data transcribed on hard copy questionnaires was entered into Microsoft Excel templates. From Microsoft Excel, data cleaning was undertaken to validate and verify all the collected data. All outliers or missing information were dropped from the final dataset and used for analysis. The raw data was exported to Stata 14 for analysis. Descriptive statistics were then generated using Stata to come up with the summary tables and graphs.

3 Results

3.1 Background characteristics of respondents' institutions

The researchers collected information about the background characteristics of the respondents' institutions. Respondents from AcholiRhites, Gulu Regional Referral hospital and Infectious Diseases Institute accounted for 25%, 22.2% and 19.4% of the respondents, respectively. In terms of size of the organisation, at least 72% of the respondents were from health organisations that employed at least 50 people. Most (38.89%) of the respondents were data clerks. The nurses and HIS Specialists at 19.44% and 13.89% followed the data clerks, respectively. The most commonly EHIS used by respondents' organisations were Open EMRS (44%), Integrated Clinical Enterprise Application (ICEA)(19%)-an in-house developed system at Infectious Diseases Institute, DHIS2 (19%), HMIS (3%), MTRACT (14%). Furthermore, respondents were asked how their respective institutions acquired the EHIS. 44.44% of the respondents mentioned that they were designed in house; the vendors' designed 13.89% and 41.67% mentioned other sources.

3.2 Extent to which the users were involved in the EHIS development

Respondents' were asked to state the magnitude of their involvement in the development of EHIS at their respective institutions**.** Overall, 47% of the respondents were never involved in EHIS development. Among those that were involved, majority of respondents were involved at the implementation task (52%) with only 31%, 22% and 22% being involved at the requirements gathering, analysis and design tasks of the EHIS development cycle respectively. For those that were involved, the breakdown of the tasks at which they were involved is illustrated in figure 1.

Figure 1 below shows that the majority of respondents (52.78%) participated in the implementation task of the EHIS development whereas the least participation rate was recorded at the analysis and design tasks. This agrees with the findings of [4], who revealed that the highest and lowest participation rate of users in the four-stage development of the EHIS was the implementation and analysis stages respectively. [4] attributes this low level of involvement in the analysis and design tasks to the complexity, high cost and variability of time to complete the tasks.

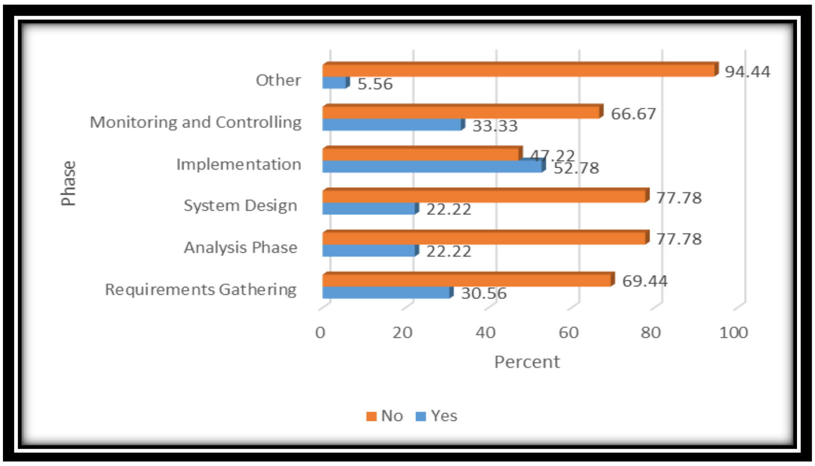

Figure 1. Respondents involvement in the EHIS by Task

3.3 Challenges faced by Users when not involved in the EHIS development at various phases/tasks

The researchers asked respondents about the challenges they faced when not involved in the EHIS development process. Figure 2 below shows that increased costs was recorded as the biggest challenge faced by users at the requirements gathering, analysis and system design tasks at 67%, 44% and 56% respectively. Increased costs referred to the process of data collection in that it requires a lot of resources and a lot of time wasted in transcribing, coding and analysing the narrative of different stakeholders. This was followed by lack of consensus in capturing, clarifying, articulating and defining user requirements due to the communication gap between the users and developers at 54%, 38% and 38% respectively. This results in inadequate initial analysis of user requirements [43].

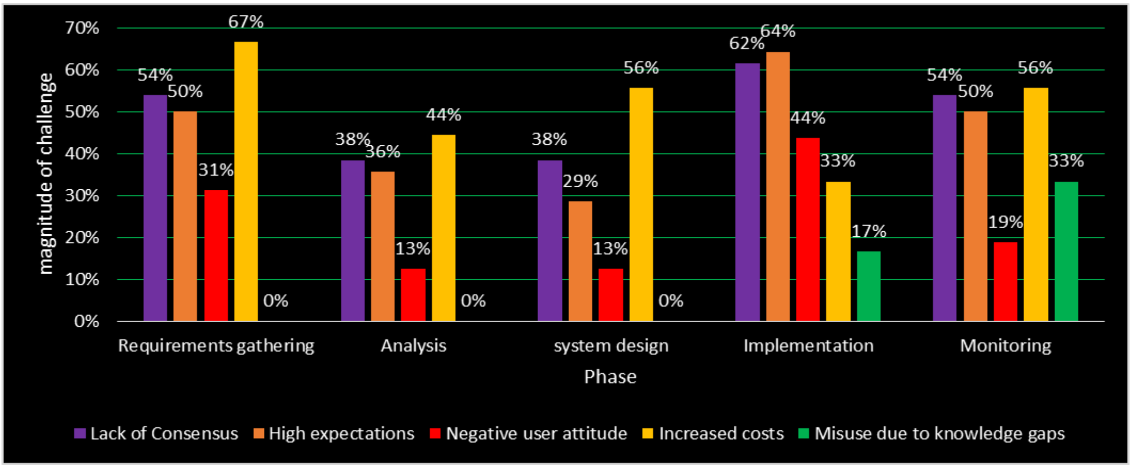

Figure 2. Breakdown of challenges encountered at various tasks of the EHIS development cycle

The above findings are emphasized by several scholars such as [10] who asserts that user involvement helps designers to manage users' expectations of a new product; and [37] who revealed that some users may not have the right attitude to the workplace thereby causing behavioural problems and ultimately causing delays in the project delivery timelines.

3.4 Suggestions to address the challenges and how users wanted to be involved in future EHIS project development

Respondents were asked to make suggestions for addressing challenges faced when not involved in the EHIS development process and how they would like to be involved in future EHIS development projects. The biggest percentage mentioned that they would like the users to be involved at all tasks of the EHIS development, that is, from the initial stage to the final stage (27.78%); these were closely followed by those that mentioned that consultation of users is paramount so as to incorporate all their needs in the EHIS (22.22%). Figure 3 below shows the respondents suggestions.

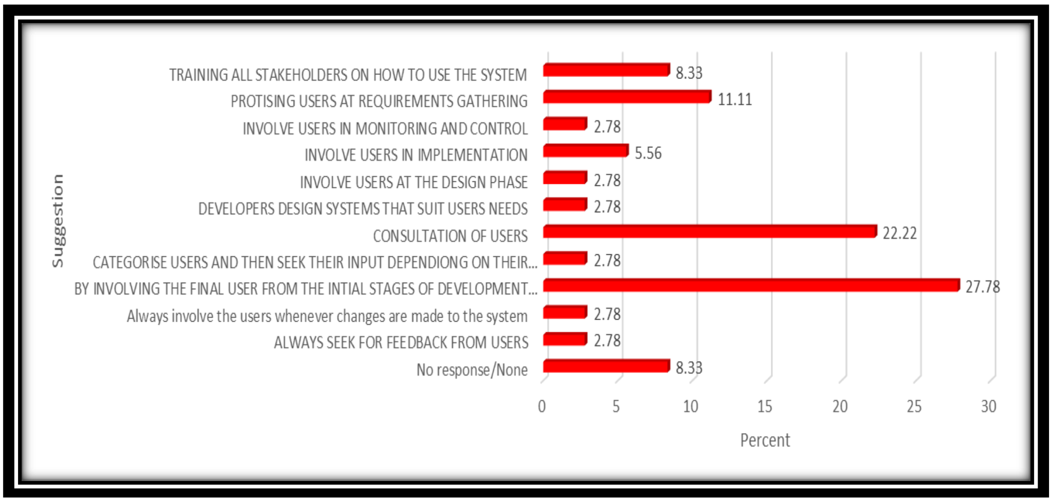

Figure 3. Suggestions to address the challenges in figure above

Furthermore, respondents were asked at what stage of EHIS development they would like to be involved in. Findings revealed that most users (80.56%) would prefer to be involved at the requirements gathering task. This is emphasized by [43] [6] [21], who reveal that system requirements gathering is one of the most ignored tasks by system developers. The fact that the design task attracted the least number of user preference for involvement at 41.67%, is further a testimony to findings from [21] study, which show that unsatisfactory initial analysis of the user requirements by the developers explains why only 61% of systems designed meet the requirements specification of the users.

4 Discussion

From the results above, we observe that the analysis and design tasks are very vital for transcribing user stories into actual system requirements to satisfy user needs. The fact that user involvement in the analysis and design tasks was very low (22.2%), compared to implementation tasks (52.7%), confirms the assertions made by [4] [13], that developers ignore user inputs and design systems that lack clarity on who the users of the system are or how their needs differ [16]. This finding prompted the researchers to question where developers obtain requirements used for designing EHIS systems.

On the issue of challenges faced, 44% of the respondents mentioned that, they were unsatisfied with the current EHIS systems, because they negatively affected their efficiency and effectiveness in work tasks [12]. For example, they wasted a lot of time in trying to access and understand the system functionalities, hence they preferred to use alternative means to achieve their work tasks. Our finding concurs with explanations made by [44] that inadequate initial analysis of user requirements, makes developers design systems that do not cater for user needs [16]. This explains why only 61% of the designed systems meet the requirements specification of the users [21], and why target users abandon 63% of such systems [12].

Further more, based on our findings, there seemed to be an interesting linkage between user involvement in the different EHIS development process and the challenges faced when users are not fully involved in these tasks. The respondents felt that their ideas should be included in all the tasks of EHIS process development, because besides being well acquainted with the business process operation of these health facilities, they were the actual users of these systems. However to their dismay, only small portions of their ideas were actually included in the EHIS design. As such their limited involvement in these tasks led to challenges such as lack of consensus, high expectations of the product, poor/negative user attitude, increased costs and misuse due to knowledge gaps towards the poorly designed EHIS [12].

To address the above challenges, respondents presented the following suggestions; their views should always be considered in all tasks of EHIS process development, feedback from users on the performance of current system, should be considered before designing new ones, prioritise user requirements and provide more training to enlighten them on how to use systems, where they were not involved in the process development, so that they can optimise its use. This study aims to incorporate these suggestions to investigate how user involvement can be optimised in the analysis and design tasks in the development of EHIS, to design better quality, relevant and safer devices that meet users' needs to improve efficiency and effectiveness in the delivery of services as well as to avoid future errors that could cause patient harm and death [4] [7] [8].

5 Conclusion

In this paper the authors investigated the extent to which users were involved in the analysis and design tasks of the electronic health information systems development process and challenges associated with not involving them. Results show that only 22% of users were involved at the analysis and design tasks. Additionally, the biggest challenges faced at these tasks were increased costs, lack of consensus and high expectations. These were recorded at 44% and 56%; 38%; as well as 29% and 36% respectively. To address the above drawbacks, the researchers intend to incorporate the suggestions that emerged from this study to conduct long-term evaluations of existing EHIS and investigate how users' involvement changes over time. In conclusion, despite evaluating a pilot study, the authors feel that the results provide strong justification for the concept of optimising users' involvement at the analysis and design tasks in the development of electronic health information systems following the UCD/HCD approach.

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Not Missing a Step: South Africans Taking Control of their Personal Wellbeing using Wearable Health Devices

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Background and Purpose: Globally, the number of people living with chronic diseases is increasing, with unhealthy lifestyles as major contributing factor. Although the benefits of preventive healthcare is documented, majority of policy makers spend only a fraction of their health budgets on preventive healthcare. There is growing evidence that increasing physical activity contributes to improved personal wellbeing and reduce chances of developing chronic diseases. Consequently, awareness of the importance of good personal wellbeing is increasing. Heightened health-consciousness has also brought along growth in wearable health device market. This study investigated the role of wearable health devices in preventive healthcare and promotion of personal wellbeing.

Methods: We employed the interpretive research paradigm to understand the role of wearable health devices in preventive healthcare and the promotion of personal wellbeing, from users' perspectives. Data was collected through a one-on-one, semi-structured interviews with 30 participants who currently own and use a wearable health device and/or a mobile fitness-tracking application.

Results: Study results showed that the use of wearable health devices can motivate users to increase their physical activity and maintain healthy lifestyle, thus promoting personal wellbeing.

Conclusions: The use of wearable health devices/mobile fitness-tracking applications play significant role in promoting personal wellbeing. Different kinds of rewards by health insurers also provide additional incentives for users to reach their monthly fitness goals. A shift towards primary preventive healthcare, where citizens are encouraged to increase their physical activity, can go a long way in reducing the high rate of chronic diseases.

Keywords: Fitness tracker, Physical activity, Preventive healthcare, Wearable health device.

1 Background and Purpose of Study

Incidence of chronic diseases, such diabetes and hypertension is on the rise across the globe primarily due to unhealthy lifestyles. This has contributed immensely to high costs of healthcare service delivery [1, 2]. As a rule of thumb, prevention is better than cure [3]. However, healthcare systems across the globe have mainly focused on curative healthcare services by providing treatment for disease conditions. Despite the fact that preventive healthcare benefits are broadly recognized, existing health systems invest only a portion of their health budgets on disease prevention initiatives [4].

Preventive healthcare involves steps taken to prevent illnesses, as opposed to treatment of disease conditions [5]. Preventive care can be classified into primary, secondary and tertiary prevention [5]. The focus of primary preventive care is on the promotion of personal wellbeing by preventing or reducing the chances of disease conditions developing. This can be achieved by maintaining healthy lifestyles, the consumption of healthy food, increasing physical activity, and so on [5]. Secondary preventive healthcare entails early detection of disease before the symptoms of the disease appears through regular screening and the treatment of such disease when it is still asymptomatic to prevent the progression of the disease. Tertiary preventive healthcare on the other hand involves the treatment of disease when symptoms are evident so as to avert complications or premature death [5]. The focus of the study reported on in this paper is primary preventive healthcare. There is growing evidence that increasing physical activity has

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paper is primary preventive healthcare. There is growing evidence that increasing physical activity has benefits in preventive healthcare and the promotion of personal wellbeing [6, 7]. Consequently, many people are becoming health conscious due to a growing awareness in preventive healthcare [8].

Associated with heightened health awareness, we have seen an explosive growth in the development and adoption of wearable health devices for monitoring physical activity [9]. Many organizations are also taking advantage of the potential benefits of using wearable health devices in the workplace as part of their employee wellness programs [10].

Globally, research focusing on the application of ubiquitous computing in the healthcare sector, termed "u-health", is on the rise. In South Africa specifically, the focus of u-health research has mainly been on applications and devices that support remote monitoring of elderly patients and the treatment of chronic diseases (for example, see [11, 12]). To address the gap in studies that focus on the use of u-health for preventive healthcare, we investigated the role wearable health devices in primary preventive healthcare and the promotion of personal wellbeing, from the perspectives of users. The research questions for the study were:

- What role can wearable health devices play in preventive healthcare and the promotion of personal wellbeing?
- In what ways do wearable health devices support users in maintaining healthy lifestyles?
- What are the perceived challenges of wearable health devices from users' perspectives?

The structure of the remaining sections of the paper is as follows: Section 2 gives a summary of literatures that are relevant to this study, while section 3 contains the materials and methods. The research results is in section 4. Finally, the discussion and conclusion is presented in section 5.

2 Related literature

In this section, we summarize the literatures that are relevant to this study. This includes an overview of mechanisms that are used in wearable fitness-tracking devices and the features that are provided in them. The section also gives a brief insight into the concept of self-quantification and its role in preventive healthcare. Finally, the benefits and challenges associated with wearable health devices are discussed.

2.1 Overview of wearable health devices

The term 'wearable' implies that such device is worn on the person's body (e.g. the wrist) or clothing. Wearable health devices are non-invasive devices that support monitoring and recording of physiological data, such as, heart rate, sleeping pattern, the level of physical activity, blood sugar levels, and so on [13]. In general, wearable health devices that monitor physical activity uses one or a combination of the following mechanisms:

- **Pedometers**: Pedometers are lightweight devices worn on various body parts to measure the number of steps taken or the distance covered by the wearer [14]. A pedometer is a useful self-monitoring and feedback tool for increasing physical activity and maintaining a healthy lifestyle [15]. One of the limitations of pedometers is their inability to measure energy being exerted accurately [16, 17]. In addition, the steps taken during a physical activity, such as for example cycling, can be inaccurate [16]. The significant growth in the penetration of mobile technology across the globe has seen an upsurge in the development of mobile applications (apps) in general and health apps in particular [18]. Of particular relevance to this study is pedometer apps that count the number of steps taken. Many of these apps are available for downloads on Android and Apple platforms free of charge. Examples of popular pedometer apps include Samsung Health, Google Fit, and Argus. Compared to dedicated wearable health devices which are generally expensive, pedometer apps could be a cheaper alternative for self-monitoring of physical activity particularly for citizens in low- and middle-income countries (LMICs). Many African countries are classified as LMIC by the World Bank [19].
- **Accelerometers:** Accelerometers are tiny wearable devices, worn on the waist, hip or thigh that measures sudden increases in speed in order to determine the amount of energy being expended [14]. Accelerometers work by detecting movement across three planes (side-to-side, up-and-down, or forward-and-backward) [20]. One of the shortcomings of accelerometers is their inability to measure steps taken in physical activities like cycling accurately [16, 20].

- **Heart rate monitor:** Heart rate monitoring provides physiological indication of physical activity and the amount of energy being expended. This is based on the assumption that there is a direct correlation between heart rate and energy being exerted [17]. The accuracy of heart rate monitors can be influenced by factors that have nothing to do with the amount of energy being exerted. These factors include body temperature, weight, muscle mass, effect of medications, stress level, and so on [17]. Heart rate monitoring device can be combined with activity tracking mechanisms like pedometers or accelerometers.
- **Multi-sensor devices:** As the name suggests, multi-sensor devices combine multiple sensors attached on different body parts to enable a more accurate measurement of physical activity and energy being exerted [21]. Because multi-sensor devices monitor many factors at the same time (for example, heart rate, respiration, galvanic skin response, steps taken, and so forth) the accuracy of physical activity and energy being exerted is much better, compared to devices with single sensors like accelerometer [17, 21]. Weaknesses of multi-sensor devices include high cost and complex data processing [17].
- **Global positioning system (GPS):** GPS is a navigation system that can support the monitoring of physical activity. The use of wearable GPS devices for monitoring physical activity is advantageous in that it is capable of detecting the location and duration of physical activity. GPS devices are useful for monitoring outdoor physical activity due to their ability to detect and estimate the position of the wearer, accurate measurement of ground slopes, as well as the speed and distance covered [22].

2.2 Features of wearable health devices

Many of the consumer wearable health devices (for example, Apple Watch, Fitbit Charge, Garmin Vivoactive, Huawei Band Pro, Samsung Gear Fit Pro, and so on) have a range of features that enable individuals to take ownership of their personal wellbeing. These devices also come with mobile phone apps that enable users to keep track of their health and fitness activities over a period. Wearable health devices combine various techniques and strategies, including persuasion, feedback, reward, social influence, and gamification to promote positive health habits [23]. This section gives an overview of common features on wearable health devices for promoting personal wellbeing.

- **Goal setting:** Consumer wearable health devices allow users to set up personal fitness goals. Simply stated, goal setting involves providing a detailed plan of health and fitness activities, including their frequency, duration, and how to achieve the goal [24]. Goal setting is an important aspect of starting or maintaining health and fitness activities. On purchasing a new wearable health device, the owner is prompted to set up goals for daily steps, food and water consumption, weight loss, and so on [25].
- **Self-monitoring:** Wearable health devices are capable of collecting data about a user's physical activity as well as physiological data like heart and pulse rates, body temperature, blood sugar level, calories burnt, and body fat percentage, to keep track of health and fitness activities [26].
- **Performance measurement:** Wearable health devices allow users to keep track of, or count the amount of physical activity they do. Different aspects of physical activity, such as the number of steps taken, distance covered, activity duration and frequency, as well as biological data (such as, heart and pulse rates, body temperature, calories burnt, and the amount of weight lost/gained) can be measured automatically using wearable health devices [27]. For example, an associated app on a mobile phone can keep track of physical activity data over a period of time and compare the data with set goals, and compare a week's activities with the previous week's performance. Alternatively, manually tracking this type of data could be difficult, if not impossible.
- **Personalized feedback:** Feedback involves the provision of data on recorded health and fitness activities. This may include assessment of health and fitness activity against specific goals [24]. To ensure successful change in behaviour, it is important to provide relevant feedback to users. Feedback from wearable health devices and/or associated mobile phone apps can be text, tactile, or graphic. Receiving feedback about their health and fitness activity can motivate users to improve so they can attain their goals [23]. In their study on the effect of feedback on physical activity behaviour and awareness, Van Hoye et al. [28] postulate that participants that received some form of feedback will be more likely to increase their physical activity outcome than those who did not receive any form of feedback.
- **Rewards:** Another technique that is often used to promote positive health habits using wearable health device is by providing some form of reward [23]. Rewards for meeting a set target can be monetary or non-monetary (for example, vibration, sound, and images). Studies have shown that offering rewards

can motivate people to increase their physical activity [29, 30]. However, Patel et al. [30] found that monetary reward that is framed as a loss can be more effective in motivating users to increase their physical activity. Health insurers often use monetary and non-monetary rewards to motivate their members to increase their physical activity [31]. One example of this kind of reward is the Discovery Vitality Active reward programme in South Africa, where members earn Vitality points that can be used to purchase goods and services at discounted rates at the company's partner organizations [32].

- **Virtual fitness trainers:** A virtual fitness trainer is often implemented in mobile fitness apps by incorporating the knowledge, motivation and monitoring capabilities of a personal fitness coach to encourage users to engage in physical activity [33]. Virtual fitness trainers can discover a user's strengths and weaknesses, set up an appropriate exercise plan, motivate, and assist the user to reach her/his goal [34]. Mobile apps like Nike's NRC, Endomondo, and Runtastic can be used as a stand-alone virtual fitness trainer or may be integrated with compatible wearable health device.

2.3 The role of self-quantification in preventive healthcare

The "Quantified self" is becoming a new catchphrase in the consumer wearable health device environment. Quantified self refers to continuous self-tracking of different kinds of data. This can be about physical activities, biological metrics, dietary intake, behavioural, psychological or environmental data [35]. In addition to data acquisition, users can act on the data [8, 35].

Wearable health device has the potential to motivate individuals to track and improve on their daily physical activity. For example, alerts can remind users that they have been inactive for a while and need to engage in physical activity [36]. Self-quantification is set to become the future of personalized healthcare, where individuals assume personal responsibility for their health and wellbeing [37].

One of the benefits of self-tracking is the fact that the vast amount of data generated can be used for research purposes. Furthermore, the data can enhance clinical decision making [37]. However, self-quantification is not without shortcomings. One of the criticism of self-tracking relates to lack of concrete guidance to inexperienced users on how to interpret and use the enormous data that is collected in a meaningful way. For example, Rapp and Cena [38] found that their study participants lost interest in self-tracking due to difficulty in wading through, and interpreting the large amount of data generated.

2.4 Benefits and challenges of consumer wearable health devices

In this section, we summarize the benefits and challenges of consumer wearable health devices for preventive healthcare and promotion of personal wellbeing.

As stated in section 2.2, wearable health devices enable individuals to take personal control of their wellbeing. With the aid of a wearable health technology, it is easier to keep track of physical activity and biological data automatically. Wearable health devices have the potential to help users improve their physical activity and adopt healthy behaviour [23]. Through features like goal setting, performance monitoring and personalized feedback, individuals can set up fitness goals that meet their needs, track activities against set goals, and adjust their targets as required [23, 26]. The virtual fitness trainer feature in mobile apps, often linked to a wearable health device, is capable of mimicking a personal fitness coach or trainer by showing users the correct body movements for specific exercise [33]. The benefits of virtual coach include the ability to demonstrate the correct body movements for a given exercise, targeted exercise suggestions based on a user's requirements, and motivating the user to follow a fitness program [39]. This feature is particularly beneficial in the South African context, where many people do not have the financial means to use the services of a professional fitness trainer.

Despite the highlighted benefits, wearable health devices are not without drawbacks. One of the challenges relates to privacy and security concerns [40]. Data collected by wearable health devices is often transmitted to cloud storage by means of the associated mobile app. This data is at risk of unauthorized access by people with malicious intent on the device itself, whilst the data is in transit and /or on cloud storage [41].

Health data is arguably more personal than biographical data like name, date of birth, or telephone number. The move towards self-quantification and automatic collection of health data, such as, weight, blood glucose level, calorie consumption, body fat percentage, and so on, could have negative impact if this data is linked to the owner of the data positively [41]. For example, intercepted data could be used for blackmail purposes. Another concern relates to manufacturers of these devices using data collected from multitude of users for purposes other than which users explicitly gave their consent [27].

3 Materials and methods

This study employed the interpretive research paradigm to understand the role of wearable health devices in preventive healthcare and the promotion of personal wellbeing, from users' perspectives. Data was collected through a one-on-one, semi-structured interviews. An important participation inclusion criterion was that potential study participants should be using a wearable health device and / or a mobile fitness-tracking app at the time of data collection. We employed a non-probabilistic, snowball sampling technique [42], where we started with three people that met our inclusion criterion to participate in the study. We then requested these participants to refer us to other people that could participate in the study. In total, 30 people participated (21 females and nine males). Each interview session lasted approximately 30 minutes. The interview sessions consisted of closed and open-ended questions. Due to page number limitation, the interview questions is not included in this paper.

Our higher education institution (HEI) granted ethical approval for the research. We explained the purpose of the study to participants and participation was voluntary. All participants signed an informed consent form as there was no identifiable risk present in them participation in the study.

4 Results

4.1 Ownership and usage of wearable health devices and / or mobile fitness apps

As stated in section 3, 30 people participated in the study. Of the 30 participants, 15 own and use a wearable health device, another 15 use one or more mobile fitness-tracking app(s), while 10 use a wearable health device and an accompanying mobile health app. Wearable health devices owned by participants include Apple Smart Watch (three people), Fitbit Charge 2 (five), Garmin device (four), Polar H10 heart rate sensor (two), and Samsung Gear S2 (one). With regard to mobile fitness-tracking apps, five participants use the Huawei Health app, four use Samsung SHealth with another four using Nike NCR app, a participant uses Google Fit app while another participant uses the Runtastic app.

Fourteen participants use their wearable health device / mobile fitness-tracking app every day, while the remaining 16 do so at least three times per week. The mean ownership duration was 20 months; one participant had been using her wearable health device for 60 months, while the shortest usage period was three months. Study participants engaged in different types of physical activities, including walking, aerobics, running, workouts at the gym, cycling, and racing. We asked participant about the types of information they got from their wearable health device and / or fitness-tracking apps. Their responses included the number of steps taken, distance covered, calories burnt, and reminders. Participants also used their mobile health apps to record their heart rates, water and food intake, and sleeping patterns.

4.2 Usage of wearable health device and / or mobile fitness apps to support healthy lifestyles

We asked study participants to share with us the ways in which their wearable health device and / or fitness-tracking apps support them to track their physical activity and maintain healthy lifestyles. The responses from participants showed that all participants were of the view that the use of wearable health device and / or a fitness-tracking app is a vital tool to their journey to healthy behaviours and disease prevention. For instance, one of the participants said, *"it motivates me, I can see how far I ran the previous day and can improve on that"*. Another participant remarked, *"For me, this is a psychological boost. When I look at my mobile app and see my workout results, I feel good"*. Yet for another respondent, *"It helps me to know when I am slacking and improve on my running activities and motivates me to be more active"*.

Eleven participants indicated that they get incentives from their medical aid by linking their wearable device to their health insurance profiles so that their physical activity is automatically tracked. A participant said, *"It keeps me focus and motivated through data records and link to Discovery Health Vitality rewards"*. Another participant remarked, *"I have certain number of active days, on average four* *days per week. My active days amount to ten thousand steps then I get discount from my medical insurance".* The use of wearable health device and / or fitness tracking apps played an important role in enabling participants that are Discovery Vitality members to reach their goals by reminding them when they are not active and providing tips on how many steps should be taken per day in order to reach weekly goals. Some of the study participants also stated that they made use of the virtual coach feature on their fitness-tracking apps. The virtual coach suggests the number of kilometres to run per day, the type of workouts to engage in, and the time intervals between workouts. Responses from two participants are quoted verbatim as follows:

"Sometimes ago when I started running I wanted to be a sprinter like Caster Semenya and I got injured. Thereafter, the app guides me on the number of minutes to run per kilometre to avoid injury".

"You can sprint and injure yourself after which you cannot run for three weeks, but with the app you get guided on how you should conduct yourself".

The preceding discussions showed that the use of wearable health device and / or a fitness-tracking app enabled respondents to be active participants in maintaining their personal wellbeing, thereby supporting the goal of preventive healthcare.

4.3 Challenges related to the use of wearable health device and / or mobile fitness apps

Participants were asked about the kind of challenges they encountered with their wearable health device / fitness-tracking apps. One of the challenges identified by participants was high data cost. Participants stated that there were times when they would abandon a planned workout simply because they do not have the funds to purchase data for their mobile phones. Without data, they could not connect to the internet to log their workouts. Some fitness tracking apps require users to connect to the internet in order for it to track physical activity automatically. This sometimes demotivates these participants, especially the ones that get incentives from their health insurers for meeting specific fitness targets. Participants' responses about high data costs was unexpected. In the last few years, many South Africans have raised concern about high data costs. This has result in campaigns like #datamustfall.

Two participants raised concern about the accuracy of data collected by their mobile fitness-tracking apps. They indicated that in some instances, the data was not the same as the one on Discovery Health's system, which could lead to increase in monthly health insurance premium. One participant expressed his concern thus, *"I worry that the information I log on my app but it did not log on Discovery will increase my monthly premiums because Discovery checks your BMI to ensure that you are not overweight or obese".* The second participant noted "*you find that you run a long distance and when you check the log on the device or app it gives you a different number*"

Another concern raised by a majority of participants relates to safety and security of their health information. Some of the safety and security issues raised by participants include the following: *"I worry and wonder about the information collected by my device and app, people are very silly, when sharing the information from the app you would share the location where you jog, which might not be safe for people you don't even know in real life"*; *"I wonder whether people will not use the information I log against me"*; and *"sometimes it has virus and it does not function well*". Participants' concerns on the accuracy, safety and security of data collected by wearable health devices and mobile fitness-tracking apps mirror the ones reported in the literature. As stated in section 2.4, health data are vulnerable to unauthorized access on the wearable device, during transmission and on cloud storage.

5 Discussion and conclusion

In this study, we investigated the role of wearable health devices and fitness-tracking apps in preventive healthcare and the promotion of personal wellbeing. Wearable fitness-tracking devices and mobile health apps can motivate users to improve their physical activity. Using automatic reminders, users can increase physical activity when they have been inactive for a specific time. Users can track the number of steps they have taken, distance covered, calories burnt, monitor heart rate and blood pressure, as well as food and water intake. Abnormal physiological data can be detected and medical help can be sought before it is too late. The different features implemented in fitness-tracking devices and / or mobile health apps support study participants in reaching and maintaining their personal fitness goals. The use of rewards by health insurers also provided additional incentives for participants to reach their monthly fitness goals. All study participants were unanimous in their view that using wearable health devices and / or fitness-tracking apps have had positive influence on their lifestyles and health behaviours. However, some of the concerns highlighted by participants included high data cost, discrepancies in data collected by wearable health devices and fitness-tracking apps, as well as safety and security of health data.

The results reported in this paper has implications for health policy makers. The majority of health policy makers across the globe, including South Africa, spend a significant amount of their health budget on curative healthcare. Chronic diseases form part of the quadruple burden of diseases that weigh heavily on the South African healthcare system. One of the contributing factors to high incidence of chronic disease is unhealthy lifestyles. Although the budget allocations to healthcare increases annually, the health outcomes are not commensurate with budget allocations. A shift towards primary preventive healthcare, where citizens are encouraged to increase their physical activity can go a long way in halting the high rate of chronic disease. The use of wearable fitness-trackers and apps can motivate citizens to adopt and maintain healthy lifestyles.

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Development and Implementation of an mHealth-based Mentoring Application for Use in Resource-Constrained Settings

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Background and Purpose: Clinical mentoring remains important in improving the quantity and quality of human resources for health (HRH) within low- and middle-income countries (LMIC). Few digital health solutions exist to support in-field mentoring. We herein describe the development and implementation of a robust HRH mentoring application for use within LMIC care settings. Our objective was to improve the quality of health care services through the collection of high-quality mentoring information that could be utilized expeditiously to improve programming.

Methods: We adopted a user-centered approach to gather key features needed for the mHealth mentoring application, and internally developed the system leveraging agile approaches. Usability testing was conducted, and system improvements were made prior to wider-scale implementation of the mentoring application.

Results: The developed mentoring application had three key components: (1) an android-based mHealth application for mentors, (2) a server-side application, and (3) a web-based front-end for platform administration. The mHealth application was used during routine mentoring sessions through smartphone devices capacitating users to collect mentoring session data, synchronize collected data to a secure server, and view individualized summary mentoring reports. The application was successfully implemented at health facilities supported by Friends in Global Health in Zambézia Province, Mozambique. By June 2019, 172 mentors were using the application and over 5,500 mentoring sessions were recorded into the system.

Conclusions: An HRH mentoring mHealth application extends the reach of conventional solutions to support the provision of continuous provider education by placing digital technology in the hands of mentors performing on-site mentoring activities.

Keywords: Mentoring, mHealth, Capacity building, Point-of-care, Mozambique

1 Introduction

In 2014, UNAIDS released the 90-90-90 targets. These targets state that by 2020, 90% of all people living with HIV will know their HIV status, 90% of all HIV-positive people will receive sustained combination antiretroviral therapy (ART), and that 90% of all people receiving ART will be virally suppressed[1]. Achieving these ambitious 90-90-90 goals requires well-trained and sufficient numbers of health care personnel at multiple levels, and well-functioning care systems. Unfortunately, for low and middle-income countries (LMICs), where most persons living with HIV reside, the numbers and qualifications of healthcare providers remain inadequate to meet the population's care needs [2]. In fact, human resources

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for health (HRH) has been identified by the World Health Organization (WHO) as being essential to the scale-up and sustainability of comprehensive HIV care [3], and approaches are urgently needed to address this constraint within LMICs [4].

One of the approaches recommended to improve HRH in LMICs is the utilization of clinical mentoring approaches for existing personnel. The WHO recommends clinical mentoring to assist in the scale-up of comprehensive HIV services, and to address "ongoing professional development to yield sustainable high-quality clinical care outcomes" [5]. Clinical mentoring is "a system of practical training and consultation that fosters ongoing professional development to yield sustainable high-quality clinical care outcomes" [5]. There is robust evidence that widely adopted clinical mentoring approaches can improve patient care, and address professional development needs for providers to ensure the provision of high quality care [6]. In addition, clinical mentoring has been demonstrated to improve the knowledge, confidence, satisfaction and retention of health providers [7].

As in any health system strengthening initiative, the performance of clinical mentoring programs needs to be monitored closely and improvements made in a timely fashion. It is important to track the number of sessions provided by mentors and determine whether these achieve set quantitative as well as qualitative targets. There is also a pressing need to examine whether mentees are being adequately mentored, and whether they are able to demonstrate the requisite level of competence required as part of their professional development. Over the longer-term, it is important to systematically quantify the health outcome impacts of clinical mentoring, by linking the provision of clinical mentoring sessions to select patient outcomes.

In most HIV-care programs in LMICs, clinical mentoring sessions are either not rigorously and systematically tracked, or they are manually captured but only on paper-based forms. This presents a challenge to easily aggregating and the collected data and using the mentoring data to inform decision-making for quality improvement of mentoring programs in real-time. The timely collection of high-quality health information forms an integral component of the WHO framework [8, 9], and innovative approaches that improve the use of clinical mentoring data are essential to ensure continued quality improvement within existing national programs. A core role of health information technology (HIT) is to strengthen the health system and HIT offers an opportunity to enhance the collection and utilization of mentoring data for decision-making. In fact, the increasing adoption of mobile technology within LMICs make it an ideal technology in settings where clinical mentoring sessions are offered in geographically dispersed settings, many of which are very rural and have limited internet connectivity.

We herein describe the development and implementation of a robust mobile point-of-care (POC) HRH mentoring application for use within an HIV care and treatment program, as a proof of concept of the potential of HIT to strengthen systems focused on clinical mentoring and to improve the overall quality of patient care and associated outcomes.

2 Materials and methods

2.1 Setting

The HRH mentoring mobile application was developed by the Friends in Global Health (FGH) program [23], Mozambique, in collaboration with colleagues at Vanderbilt University Medical Center (VUMC). VUMC/FGH, with U.S. government funding support from CDC/PEPFAR, presently supports the provision of comprehensive HIV services at 195 health facilities in 17 districts within Zambézia province in Mozambique. As of June 2019, greater than 190,000 patients were receiving potentially life-saving ART at FGH-supported health facilities, where in addition to the provision of ART services ranging from adult HIV care and treatment, pediatric HIV care and treatment, HIV prevention (including the prevention of mother-to-child HIV transmission (PMTCT)), HIV testing and counseling (HTC), family planning services, care for HIV/tuberculosis (TB) co-infected persons, care and treatment of additional opportunistic infections (i.e. Kaposi's sarcoma, cervical cancer, etc.), amongst others. VUMC/FGH currently employs more than 200 trained mentors to support health facilities across several key HIV care domains including adult and pediatric care and treatment (including early infant diagnosis), adult care & treatment (including 2nd line ART, etc.), pediatric care & treatment (including early infant diagnosis (EID), child-at-risk (CCR) services, etc.), laboratory, pharmacy, monitoring and evaluation (M&E), HIV testing and counseling (HTC), HIV/TB co-infection, TB screening and treatment (including multi-drug

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resistant (MDR) TB), HIV prevention (including PMTCT, Pre-exposure prophylaxis (PrEP), etc.), other opportunistic infections (i.e. Kaposi's sarcoma, cervical cancer screening, etc.) and nutritional counseling/services.

Existing Mentoring Workflow & Tools: Consistent with the vast majority of other clinical implementing partners within Mozambique providing comprehensive HIV care services, FGH originally employed a traditional paper-based approach to track clinical mentoring activities. At the beginning of every week, each mentor was given a schedule of mentoring sessions they needed to conduct. The mentor would then travel to a health facility, equipped with Ministry of Health (MoH)-mandated clinical mentoring data capture forms to complete. During each clinical mentoring session, the mentor would manually complete the relevant sections on the paper-based form, and at the time of return to FGH headquarters, they would share these forms with their supervisors. In subsequent years, the mentors manually entered completed forms into a REDCap^{TM} [10] database developed by the VUMC/FGH team. This paper-based system, however, had multiple challenges including: (1) an inability to easily track completed mentoring sessions, (2) time consuming data entry (done retrospectively), (3) data quality issues for the retrospectively entered data that often had associated data entry errors, (4) the inability for mentors to access their historical data real-time during mentoring sessions, and (5) the lack of the mentoring data availability in timely fashion for managers and decision-makers.

2.2 Application Development

Preliminary data collection/needs assessment: We began by engaging an interdisciplinary team to identify the key attributes, optimal flow, essential data elements and reporting functionality that the majority of key stakeholders desired for the HRH mentoring application to possess. This team included clinical mentors from multiple departments, managers, monitoring and evaluation (M&E) personnel, strategic information (SI) and quality improvement (QI) team personnel, and they were all overseen by a project steering committee. Once the essential functional requirements had been identified, the team also helped to prioritize the order of attributes including the creation of a timeline for mobile mentoring application development, field testing, and eventual implementation.

Application Development & Testing: A team of VUMC/FGH strategic information personnel with experience in mobile health and server-side application development was selected to develop and implement the application, with project workflow being coordinated by a technical project manager. This team adopted an agile practical methodology including daily scrums and weekly sprints. During the development phase, the team involved end-users to help identify bugs, ensure that the system requirements were being met, and to evaluate the adequacy of the interface, user experience and workflow. Once the first version of the system was adequately developed and refined, we deployed it in a real-world setting with a new set of users on three devices over a two-month period. During this period, the development team got a chance to get direct feedback from the end-users, to fix bugs, and to implement suggested relevant improvements.

2.3 Implementation

The developed application was implemented within clinics at VUMC/FGH-supported health facilities, with various clinical mentoring domains and health facilities sequentially enrolled.

3 Results

3.1 Systems Architecture

The developed clinical mentoring application platform had three main components, namely: (1) mobile, (2) server-side, and (3) web-based manager front-end (Figure 1).

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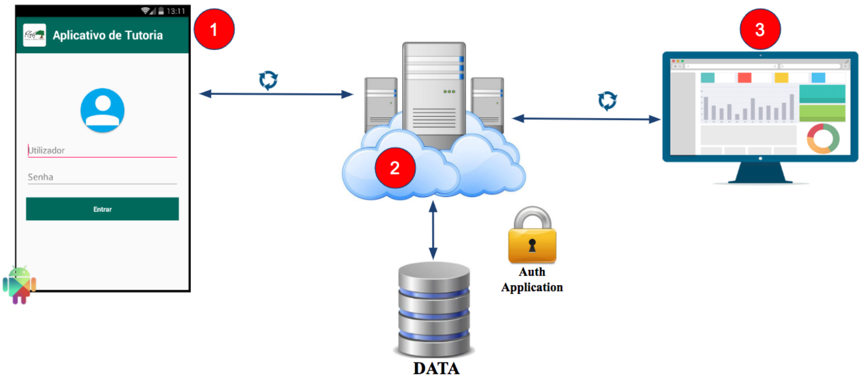

Figure 1. Mentoring Application Architecture

(1) *Mobile*: The mobile application was the one used by mentors to collect data during routine clinical mentoring sessions and worked in both online and offline modalities. Some of the features within the mobile application included: (a) the ability to add and delete mentees; (b) the ability to collect data in pre-populated forms for mentoring activities; (c) ability to synchronize data from completed forms to a secure server, and (d) ready viewable access to individualized mentoring activity summaries for the provider. The mobile mentoring application also had several security features, ensuring protection of the collected data. The application did not collect any protected health information.

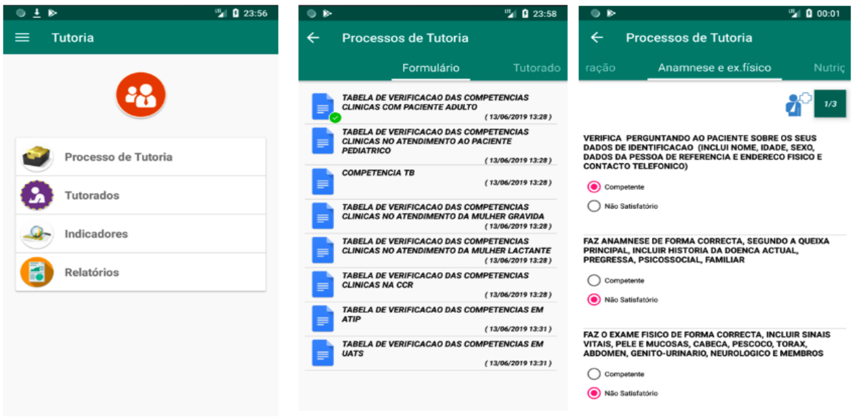

TABELA DE VERIFICACAO DAS COMPETENCIAS CLINICAS COM PACIENTE ADULTO (13/06/2019 13:28)

TABELA DE VERIFICACAO DAS COMPETENCIAS CLINICAS NO ATENDIMENTO AO PACIENTE PEDIATRICO (13/06/2019 13:28)

COMPETENCIA TB (13/06/2019 13:28)

TABELA DE VERIFICACAO DAS COMPETENCIAS CLINICAS NO ATENDIMENTO DA MULHER GRAVIDA (13/06/2019 13:28)

TABELA DE VERIFICACAO DAS COMPETENCIAS CLINICAS NO ATENDIMENTO DA MULHER LACTANTE (13/06/2019 13:28)

TABELA DE VERIFICACAO DAS COMPETENCIAS CLINICAS NA CCR (13/06/2019 13:28)

TABELA DE VERIFICACAO DAS COMPETENCIAS EM ATIP (13/06/2019 13:31)

TABELA DE VERIFICACAO DAS COMPETENCIAS EM UATS (13/06/2019 13:31)

VERIFICA PERGUNTANDO AO PACIENTE SOBRE OS SEUS DADOS DE IDENTIFICACAO (INCLUI NOME, IDADE, SEXO, DADOS DA PESSOA DE REFERENCIA E ENDERECO FISICO E CONTACTO TELEFONICO)

● Competente
○ Não Satisfatório

FAZ ANAMNESE DE FORMA CORRECTA, SEGUNDO A QUEIXA PRINCIPAL, INCLUIR HISTORIA DA DOENCA ACTUAL, PREGRESSA, PSICOSSOCIAL, FAMILIAR

○ Competente
● Não Satisfatório

FAZ O EXAME FISICO DE FORMA CORRECTA, INCLUIR SINAIS VITAIS, PELE E MUCOSAS, CABECA, PESCOCO, TORAX, ABDOMEN, GENITO-URINARIO, NEUROLOGICO E MEMBROS

○ Competente
● Não Satisfatório

Figure 2. Mentoring mHealth application screenshots

(2*) Server-side*

The server-side application was responsible for handling the whole business logic defined in the requirements gathering and expose the data to the other clients (front-end and mobile). This server-side application was developed in Java and the data was stored in a MySQL™ database. Features supported on the server-side included the ability to: (a) add and update programmatic areas for mentoring; (b) add and update mentors and mentees; (c) map mentors according to their programmatic area to enable mentoring forms relevant to their specific area to be pushed to the mobile application; (d) add and update forms; (e) add and update questions within forms; and (f) generate mentoring reports.

(3) *Web application*

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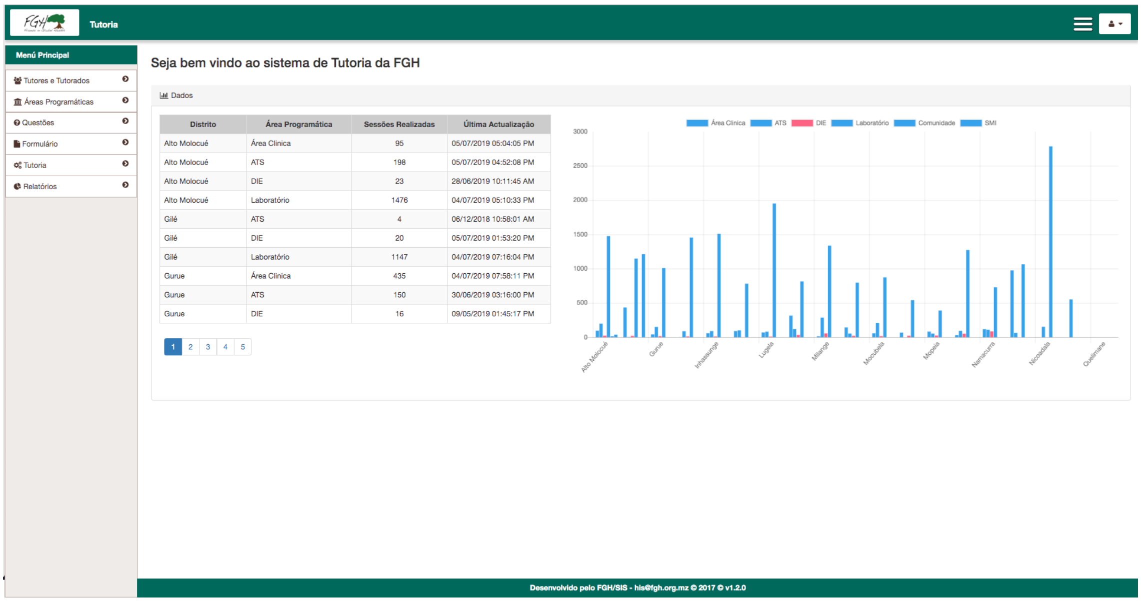
A web-based front-end was developed for use by system administrators and managers to help access and perform the functions supported by the server-side application. The front-end was written in JavaScript™ using the AngularJs™ framework.



Seja bem vindo ao sistema de Tutoria da FGH

Distrito	Área Programática	Sessões Realizadas	Última Actualização
Alto Molocué	Área Clinica	95	05/07/2019 05:04:05 PM
Alto Molocué	ATS	198	05/07/2019 04:52:08 PM
Alto Molocué	DIE	23	28/06/2019 10:11:45 AM
Alto Molocué	Laboratório	1476	04/07/2019 05:10:33 PM
Gilé	ATS	4	06/12/2018 10:58:01 AM
Gilé	DIE	20	05/07/2019 01:53:20 PM
Gilé	Laboratório	1147	04/07/2019 07:16:04 PM
Gurue	Área Clinica	435	04/07/2019 07:58:11 PM
Gurue	ATS	150	30/06/2019 03:16:00 PM
Gurue	DIE	16	09/05/2019 01:45:17 PM

Desenvolvido pelo FGH/SIS - his@fgh.org.mz © 2017 © v1.2.0

Figure 3. Mentoring web application screenshots

3.2 Implementation Data

The initial implementation of the mentoring application was with the monitoring and evaluation (M&E) team in June 2017. To date, 35 mentors from the M&E team provided their clinical mentoring sessions using the mobile app. Subsequently, two additional mentoring domains were added including laboratory and clinical mentoring domains (MCH, Pharmacy, HTC and Community). Currently, 40 laboratory mentors and 97 clinical mentors use the application to record their mentoring sessions, for a total of 172 active users of the application.

There is active use of the application as demonstrated in Table 1. In three months between April and June 2019, a total of 5,561 mentoring sessions have been performed using the application.

	Mentoring Domain	April	May	June	Total
1	Monitoring & Evaluation	25	47	98	170
2	Laboratory	1506	1507	1351	4364
3	Clinical Area	271	312	444	1027
Totals		**1,802**	**1,866**	**1,893**	**5,561**

Table 1. Number of mentoring sessions performed in the last 3 months

4 Discussion

One of the key impacts of health information technology is in health systems strengthening. In LMICs, there has been little use of digital technologies to track the performance of field-based clinical mentors and their mentees, to evaluate the quality of field-based mentoring sessions, and to inform decisions around approaches to optimize the impact of mentoring sessions. Use of digital technologies for HRH in these settings have largely been focused on developing and implementing interoperable health worker registries, with systems like iHRIS being widely utilized [11]. Existing mechanisms to track continued provider education have also largely relied on traditional tracking approaches with class-based courses registered within the digital system and trainee participation recorded following delivery of the course. Examples of such systems include the Training System Monitoring and Reporting Tool (TrainSMART™) [12]. To our knowledge, our group is the first to describe the development and real-world implementation of a system to track field-based clinical mentoring activities to support HIV care and treatment within an LMIC setting. The development and implementation of our mobile application significantly extends the reach of digital health technologies to support HRH development outside the classroom.

We adopted a user-centered approach to inform the development of the HRH mentoring system, taking into account key considerations within resource-constrained settings. As such, the system functions fully offline, is highly customizable to support different types of clinical mentoring domains and possesses the necessary security features while avoiding the use of protected health information. With implementation of this clinical mentoring system, mentors no longer have to retrospectively enter paper-based data into electronic systems, saving time and reducing data entry errors. With this system, it is also easy to track when clinical mentoring sessions are actually being conducted so managers/decision makers have the ability to monitor performance of individual mentors (i.e. tracking how many sessions they performed) and to identify gaps in the quality and timeliness of mentoring activities.

In addition to extending the HRH system to cover more HIV care and treatment-specific domains, our future plans also include enabling our system to be compatible with other HRH and data aggregation systems used within LMIC settings. We also plan to incorporate gamification into the app by incorporating rewards, specifically leaderboards, points and badges, etc. for various clinical mentoring milestones and achievements. Beyond evaluating performance of individual clinical mentors and their mentees, we eventually plan to evaluate the impact of digitally-facilitated clinical mentoring sessions on select patient outcomes and program indicators. Our current system is only being implemented in one care system in one setting and it is our hope that it can be scaled-up to cover more care programs across multiple countries, especially after enhancements to its functionality have been made.

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Statement on conflicts of interest

There are no conflicts of interests associated with this work.

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Managing Patient Identification in Uganda's Health Facilities: Examining Challenges and Defining Requirements for a National Client Registry

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Background and Purpose: Managing accuracy to identify any patient is very crucial in ensuring continuity, quality and coordination of their healthcare over time. Patient identification management (PIM) in healthcare is still a challenge in Uganda for both public and private healthcare institutions including insurance companies using different mechanisms to uniquely identify clients. This deters PIM and individual health data linkage across healthcare organizations. An integral part of individual health data linkage and health information exchange (HIE) process across healthcare organizations is verification and/or validation of a client's identity. This vital service can be provided by an administrative electronic health information system known as a client registry (CR). A *CR* is a central electronic database that holds patient identifying information and demographics with a mechanism to uniquely identify each of them using select identifying information such as unique identifiers within a given territory. Consequently, in preparation for the establishment of a National CR (NCR), we needed to first examine the current mechanisms used and the challenges faced in PIM in Uganda's health facilities. The NCR is envisaged to facilitate and harmonize PIM and HIE in Uganda's healthcare system.

Methods: A cross-sectional study was conducted to document the mechanisms used for and challenges facing PIM in Uganda and define NCR requirements. The Design Science Research (DSR) approach was employed to achieve the overall study aim with a much broader goal beyond this paper. Specific to this paper, the research question for which the methods and results presented was formulated under stage two of the DSR six-step process model.

35 key informant interviews with purposively selected representatives from select organizations and health facilities were conducted.

Results: Majority of health facilities use either paper-based or a combination of both paper-based and electronic tools to register clients, manage their identities and data. Key challenges reported facing PIM relate to data storage, retrieval, client identity verification, and tracking. These translated into four key NCR requirements that can facilitate PIM and HIE in Uganda's healthcare system.

Conclusions: The study proves that there is need to address the various PIM challenges; as such our next steps are to establish actual NCR requirements/services in order to harmonize PIM across Uganda's health facilities.

Keywords: Client Registry, Patient Identity Management, Health Information Exchange, Health Information Systems, Disease Management

1 Introduction

Managing accuracy in the identity of any patient is very crucial in ensuring quality, continuity and coordination of their healthcare over time. Being able to accurately and consistently identify a client who accesses healthcare services at any point of care helps to enhance provision of timely care, ease retrieval

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of individual medical records to aid informed treatment and forms a basis for developing a Shared Health Record (SHR) that can aid coordination of care between providers (1, 2). Managing accuracy in identities of clients who access healthcare services also has a big role to play in the quality of health data that is reported at health facility, regional and national levels (3). In low-and-middle-income countries (LMICs) scaling up of health services directed to combat endemic communicable diseases like HIV/AIDS, Tuberculosis and Malaria is more evident. This has however come with the need for increased data collection in order to create an individual longitudinal health record to aid monitoring and evaluating of the efficiency, effectiveness, equity and acceptability of healthcare at health facility, subnational and national levels; planning and coordination of healthcare service delivery; and accountability to donors and/or development partners (3).

Uganda currently lacks a standard mechanism to manage patient identities within and across its healthcare institutions, as such affecting the reliability of data, and realistic population denominators (4). Particularly, the healthcare facilities, institutes and vertical health programs use diverse identification schemes and patient number formats intended to identify each patient and manage internal patient identification (5). For instance, the current situation is characterized by the assignment of varying serial numbers to the same client who may access outpatient services from more than one unit (TB, HIV/ART, Diabetes, Malaria, Antenatal, Maternity, Postnatal, and so forth) within a health facility; assignment of varying inpatient service numbers to the same client across health facilities; assignment of varying vertical health program numbers (ART number, Unit TB Number, Antenatal Number, PMTCT Number, Child Number, and so forth) for a co-morbidity client or a client diagnosed with two or more conditions requiring careful monitoring to ensure timely intervention and subsequent better health outcomes.

However, it is challenging to use the aforementioned facility-, unit-, and program-specific numbers outside the respective precincts and thus cannot be used to track a client and the healthcare services they use across healthcare facilities they visit. This is true regardless of whether eHealth applications (like UgandaEMR and Clinic Master) or paper-based systems (HMIS tools) are used for data collection and management, yet several conditions fought against in Uganda are longitudinal in nature (6). A disease or condition is longitudinal in nature if it requires careful monitoring or follow-up of a patient to ensure better treatment adherence and outcomes (3). Additionally, in some MoH technical working group meetings, a proposal to use the National Identification Number (NIN) to uniquely identify individuals at the point of care has been made. The NIN is however challenged with various gaps including; not all people who live in Uganda have NINs such as the children from zero months to 17 years of age, alien (non-citizens), and refugees. The NIN is serially generated without accounting for the fields / attributes' combination (what they mean or represent). Worse still, capturing of the NIN differs in varying institutions depending on the space / length of values in a given Information System; for example the Immigrations and International Interpol institutions do capture only the nine numeric values which are the "card number", while embassies do capture the NIN itself, so to say the NIN actually constitutes of fourteen alpha-numeric values; and its use for patient identification may minimize and/or compromise privacy and confidentiality of patients' health information. These gaps have negative implications on patient identification and matching efforts across healthcare organizations in Uganda directed to improve quality, continuity and coordination of patient care.

Based on the above situation, it is clear that Uganda's healthcare system lacks a standard mechanism to uniquely identify patients for ease of healthcare management and service provision. In other words, there is absence of a universal, ubiquitous and unique way of identifying patients and managing their identity across healthcare organizations in Uganda (3, 5, 7). Without proper identification of clients, it is difficult to manage client/patient identities within and across healthcare facilities; a vital aspect or backbone of a Share Health Record; proposed to facilitate consolidation of individual patient data collected during various encounters within and across different health service points to aid quality, continuity and coordination of healthcare (3, 8). To this end, this study aimed at examining the challenges facing mechanisms used for patient identification management; from which these could be used to inform requirements that a National Client Registry (NCR) should have in order to aid HIE in Uganda's healthcare system. A *NCR* is a central electronic database that holds patient or client identifying information and demographics with a mechanism to uniquely identify each of them using select identifying information such as unique identifiers within a country or nation.

2 Materials and Methods

A cross-sectional study was designed to be conducted between April and November 2018 in seven regions across Uganda including Northern, West Nile, Karamoja, Eastern, Central, Western and South Western regions; particularly, within the Districts of Gulu, Adjumani, Moroto, Mbale, Kampala, Kabarole and Kabale Districts, respectively. The select study sites included Ministry of Health, National Information Technology Authority - Uganda, National Identification and Registration Authoriy, two development and/or implementing partner organizations; and 30 health facilities across the seven select regions. Study participants comprised mainly those from Ministry of Health, Partners and health facilities including health informaticians, monitoring and evaluation specialists, clinicians, data managers, nurses, midwives, among others. The Design Science Research (DSR) approach was employed to achieve the overall study aim with a much broader goal beyond this paper. The basis for using DSR approach stemmed from its ability to provide a rigorous process leading to elicitation and specification of essential NCR requirements and development of design models. Under stage one of the DSR six-step process model, the problem driving the much bigger study was identified. Specific to this paper, the research question for which the methods and results presented was formulated under stage two of the DSR six-step process model.

The purposive sampling technique was employed to select the study sites and key informants. This was because subject matter experts on key aspects such as patient data management, patient identity management and health information exchange were required at both national and sub-national levels to answer the research questions. Thus, the key informants that were purposively selected possessed enormous experience in healthcare, health information systems and health data management. Purposive sampling is a non-probabilistic sampling technique used when there is need to concentrate on people with certain characteristics who are better placed to contribute to a given research study (9, 10). The purposive sampling criteria included the organizational mandate, knowledge and experience, region, level of health facility, information system tool or mechanism type, end-user type and technical area.

Qualitative data collection methods were employed to document mechanisms used for and challenges facing patient identification management in Uganda's healthcare system. A semi-structured interview protocol and an interview guide were designed to collect data from select study participants at sub-national and national levels, respectively. This study obtained ethical approval from Makerere University School of Public Health Institutional Review Board (IRB). Additionally, permission was sought from the stakeholder organizations that were selected as study sites for this research before any data collection was done. Thirty-five key informant interviews with purposively selected representatives from select organizations and health facilities were conducted. That is, nine at national level and twenty-six at sub-national level). An inductive approach was used to analyse the collected data. The data collected was transcribed verbatim, manually analysed and coded by two coders (researchers) independently. The coding was compared and discussed before deriving themes from the data and categorizing results into final themes by the two independent researchers. The coded data were categorized into three key themes namely, process / workflow, technology and organizational (people) challenges.

3 Results

In summary, 78% (22/28) of the health facilities visited were Government-owned, while 11% (3/28) and 11% (3/28 were PNFP and PFP respectively. It was reported that about 50% (15/28) use both paper-based and electronic HIS while only 39% (11/28) and 2.8% (2/28) use paper-based and electronic HIS, respectively. In addition, close to 90% (25/28) health facilities use HMIS tools which have provision for recording client numbers like the ART number, Child number, TB number, ANC number, etc., assigned to clients during their first visit at health facilities for ease of identification on subsequent visits. Slightly over 30% (10/28) health facilities use both HMIS tools and UgandaEMR system, particularly for ART care clients, and only 3% are using any of; PARAS Healthcare MIS, Butabika Medical Records System, ICEA or Microsoft Dynamics Navision.

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Region	**Health Facilities**								**Total**
	Clinic	**HCII**	**HCIII**	**HCIV**	**GH**	**RRH**	**NRH**	**HMO**	
Northern	0	1	1	1	0	1	0	0	4
Eastern	0	1	1	1	0	1	0	0	4
Central	1	0	1	0	1	1	2	1	7
Western	0	0	1	1	2	1	0	0	5
South Western	0	1	1	1	1	1	0	0	5
West Nile	0	0	0	0	1	0	0	0	1
Karamoja	0	1	0	0	0	1	0	0	2
Total	1	4	5	4	5	6	2	1	28

HC – Health Center; GH – General Hospital; RRH – Regional Referral Hospital; NRH – National Referral Hospital; HMO – Health Management Organization

Table 1. Health facilities that participated in the study by region and level

3.1 Overview of Mechanisms

	Mechanism	**Description of Purpose & Functionality of Mechanism**	**How Patient Identity is Managed**
1.	Health Management Information System (HMIS)	HMIS is a paper-based routine health information system used to monitor and evaluate the health sector as well as provide warning signals of events like epidemics (surveillance), and health facility commodity stock-outs. It enables health workers offer better care and manage health facility supplies and resources; supporting health workers in their efforts to organize and supervise health development work in their communities; and provides data to the health sector and partners for decision making.	Patients' identifying data are recorded in the paper-based registers and pre-primary tools such as client cards. Patient number formats are used to identify clients. However, these number formats do not effectively serve the purpose of managing patient identities within and across health facilities.
2.	UgandaEMR System	UgandaEMR is an electronic health information system (eHIS) built on an open source platform (OpenMRS). It is used to register HIV positive clients and their clinical information such as their vitals, viral load, CD4 count, regimens prescribed, drug allergies, among others, based on the paper based HMIS form called the HIV Care / ART Card, as well as scheduling appointments and report generation based on the national HMIS standard reports.	System-generated medical records numbers are used to identify patients. However, the system-generated medical records numbers are known only within the ART clinic of a given health facility. Thus, a medical records number assigned to a patient may be rendered useless when a patient say moves across other units within the same health facility and/or visits other health facilities for care (other than HIV care).
3.	Integrated Clinic Enterprise Application (ICEA)	ICEA is a proprietary, modular ART/HIV centric system that supports patient registration, consultation, prescription, lab, counselling, TB management, referral data capture; Clinical Decision Support; Order Entry Prescribing; and report generation. It also tags each clinician to the patients they handle on a routine basis.	System-generated medical records numbers are used to identify patients. However, the system-generated medical records numbers are known only within the Infectious Disease Clinic. Thus, a medical records number

			assigned to a patient may be rendered useless when a patient say, visits other health facilities for care (both HIV and other care).
4.	Butabika Medical Records System (MRS)	Butabika MRS is a proprietary EMR system built on Microsoft Access to enable registration of mental health clients, coding of client illnesses based on ICD-10, capturing of their history, storage of mental health client data, capturing clinical data including drugs being administered to client, allergies and report generation.	System-generated medical records numbers are used to identify patients. However, the system-generated medical record number is known only within a given unit of the National Referral Hospital and has no meaning attributed to it. Thus, a medical records number assigned to a patient may be rendered useless when a patient say moves across other units within the referral hospital and/or visits other health facilities for care (other than mental care).
5.	Microsoft Dynamics Navision	This is a proprietary integrated hospital Management Information System customized to enable registration of clients, prescribing drugs, patient billing and inventory information management. It is generally an Enterprise Resource Planning tool that several private healthcare facilities in Uganda have customized to enable client registration and related clinical and administrative patient data, such as clinical notes capturing, drug prescription, patient billing, and drug inventory information management.	System-generated medical records numbers are used to identify patients. However, the system-generated medical record number is known only within a given unit of the Hospital and has no meaning attributed to it. Thus, a medical records number assigned to a patient may be rendered useless when a patient say moves across other units within the referral hospital and/or visits other health facilities for care.
6.	PARAS Healthcare Management Information System	PARAS Healthcare Management Information System is a proprietary patient-centric comprehensive and integrated healthcare delivery application that covers a complete spectrum of patient care designed to suit the needs of all kinds of health care providers such as hospitals, clinics, laboratories, day care centers, diagnostics, etc. Its key functionalities include client registration, appointment scheduling, dashboards, e-prescription, alerts and notifications, inventory and stock management, and system administration.	System-generated medical records numbers are used to identify patients. However, the system-generated medical record number is known only within a given unit of the Hospital and has no meaning attributed to it. Thus, a medical records number assigned to a patient may be rendered useless when a patient say moves across other units within the referral hospital and/or visits other health facilities for care.

3.2 Challenges Facing Mechanisms Used for Patient Identification Management

This section presents the general challenges faced by the mechanisms used for patient identification management described above. They are categorized as process (workflow), technology, organization and other challenges.

Process / Workflow Challenges.

Data Entry: Regarding data entry, it was reported that some of the HMIS tools did not have all the required data elements to enable capturing of client identifying information and other important data as may deem necessary. For instance, some respondents reported that these tools often lacked provision for entry of new data elements due to the time it took to request for effecting these changes by the mandated Division, and transition from the old to new tools. Also, some health programs (not mentioned here) lacked unique identifiers for clients.

Data Storage: Health facilities especially those that use mainly paper-based information systems and/or both electronic and paper-based systems lacked proper ways to store client's health information. A respondent from one of the National Referral Hospitals said this regarding storage, '…t*he issue is about storage where the shelves get full and some records are kept on the floor. You sort them today, tomorrow as you retrieve, they get mixed up. You have to again re-sort*".

Data Retrieval: Majority of the participants attributed the challenge of retrieving client records to lack of EHIS and the tedious nature the paper-based tools pause to health workers when trying to access past medical records. A respondent at a regional referral hospital said, "…*you know this thing of opening, opening… it takes a lot of time looking for something. If at all it was electronic it would be easier. Because sometimes patients are many and you must look for them individually, and update such that we isolate those people who missed appointments yet have to adhere to treatment prescriptions.*"

Client Identity Verification: Difficulty to validate and/or verify client identity were reported by health facilities that have ART clinics, TB clinics and those that handle clients with health insurance. For example, for ART clinics, there was difficulty in accounting for the incentives given to HIV clients due to lack of verification means. A respondent said, *"Seriously every insurance company and hospital has a different identifier they assign to a client, this brings lots of confusion for us. I mean ... now for us with several ART care clinics, the clients test for HIV and access ART care. When they hear of another clinic dispensing porridge as an incentive, they seek care from that clinic and abandon the previous one where they were first initiated on treatment, do not tell the truth regards their medical history and there is no referral form for reference. So, we always register the client afresh and miss all the medical history that might have been collected before and don't get to know the last regimen received".*

Client Tracking: Lack of ability to track clients was also mostly reported especially by health facilities that deal with clients who have chronic illnesses like TB, HIV and services that require continuity of care like immunization and antenatal care. At health facility level, a respondent from one of the refugee hosting Districts in West Nile said, *"...the current HMIS tools do not allow us to capture the identity of infants who present for immunization. So, there is no way of telling the true identity of an infant, where they live or come from and whether they are a refugee or not, for us to follow up if they got immunized or not"*. A national level respondent said, *"In TB care, the biggest problem we have is during TB client follow-up periods where accountability of cohorts in terms of whether a client got cured or died or was lost to follow-up is very much required. Overtime we have realized that loss-to-follow-up is meaningless especially because a client may be accounted for as lost-to-follow-up, yet they continue receiving services from another facility with no way of telling that due to lack of streamlined client identity management across healthcare facilities in the country".*

Duplicate Client Records: Majority of the respondents also reported duplication of client records, particularly due to lack of a unique identifier that could consistently and uniquely identify a client. In other health facilities, respondents mentioned that they were not able to determine duplicate client records and that such aspects are never discussed or prioritized.

Technology Challenges

Lack of effective data validation rules: Health facilities that use both electronic and paper-based information systems especially in the HIV clinics, were concerned about the data validation rules customized by developers; these sometimes were overridden by data entrants who simply appended punctuation marks e.g. full-stops or commas to clients' names if the systems rejected the entries.

Lack of better effective ways to identify and control duplicates: Respondents were greatly concerned about information inaccuracy in EHIS, e.g. during client searching, there are no means of differentiating between two clients who may have similar data elements; worse still the EHIS do not indicate data wrongly entered by health data clerks or managers to prompt correction through edits and updates. A respondent from one of the urban hospitals in Kampala said this about data entry challenges faced using electronic information systems: *"Electronic system has information accuracy issues. For example, before registration I search a client by name and when I finds two or more people with the exact names am never sure of who this person is, first or second entry. I normally use the phone number to differentiate the two although sometimes there is no phone number recorded. Also, there are data entrants who are never kin and therefore end up appending details to a wrong client record which may result into one client's medical history falling under another's client's demographics which may not be easy to change because the system is not intelligent enough to flag it for resolution."*

Absence of well-configured EHIS to generate national-level HMIS reports: Respondents also reported that the electronic health information systems deployed and used at the health facility are not configured to generate standard national-level HMIS reports, and yet manual report compilation is one of the major pain points in health data management. A respondent from a Health Center IV in Western region where the Case-Based Surveillance Project has been implemented said, *"We still cannot generate the quarterly report perfectly…the Form 106a. The figures or data are often overlapping or incorrectly placed in the provided spaces whenever we try to generate it electronically. So, we still have to manually compile this report."*

Organizational Challenges

The national-level respondents majorly reported the organizational challenges including;

Lack of governance and coordination of the mechanisms used to collect patient data; as a result, several uncoordinated mechanisms have mushroomed across the country, worse still unknown to the Government.

Lack of defined needs for health data management in health facilities. Health workers, data entrants and records assistants simply do not know why they collect this data apart from reporting it to the higher levels, thus do not attach importance to the aspect of data management.

Low usability of the PIM mechanisms. Some of the tools/mechanisms used for PIM are somewhat complex or seem a burden for the health workers to use; as such they refrain from using them for patient data collection. This leads to missed opportunities to collect important health data. For example, some end-users mentioned that they found it hard to construct logical commands to generate reports using cohort builder. The majority mentioned that it was a burden to record data in both paper based HMIS forms and the electronic systems and so they always ended up recording in only one of them.

Difficulty interpreting data elements that constitute the tools/mechanisms; health workers nationwide lack uniformity in interpretation of the data elements that constitute the HMIS tools. This impacts negatively on the quality of data that is collected.

Lack of inclusiveness of frontline health workers during the development of some of these EHIS tools/mechanisms, as well as Standard Operating Procedures.

Other Findings and Challenges

Data Analysis: Majority of the respondents at the health facility level mentioned that the paper based HMIS tools made it so difficult for them to analyse data; this required one to first enter the data into an

EHIS leading to somewhat double work or burden. Additionally, a data analysis skills gap and definition of the bare minimum for health workers to analyse was reported.

Reporting: Reporting gaps were also reported at health facilities that use mainly paper-based and both systems. Particularly, it was tedious to sift through all registers to ably count all clients who visited the health facility at all entry care points during the reporting period (monthly or quarterly). Worse still, there were no means of generating standard HMIS periodic reports for those facilities that use electronic mechanisms.

Target Population Estimation: The issue of population denominators was raised by respondents mainly working on the Immunization program in refugee-hosting, borderline districts and Kampala where the population is always fluctuating. It was reported that it was difficult to generate accurate denominator estimations for health facility catchment areas, yet these estimates guide ordering for vaccines and other injectable materials. Specifically, the figures provided to health facilities are centrally based and generated from occasional surveys, thus they do not give a true reflection of the actual children numbers that come to outreaches or health facilities for immunization. Quoting verbatim from Adjumani District respondent *"For us here, these target population estimates from the District do not help because any time we receive refugees from South Sudan. We have no way of knowing when it will happen and so the number of vaccines sometimes is not enough…".*

Weak security, confidentiality and privacy measures: The way some of the electronic information systems deployed in health facilities are designed compromises the privacy and confidentiality of patient health information. For instance, for some mechanisms a health data clerk is able to see all of a client's data information (both identifying and clinical information). Furthermore, majority of the health facilities using electronic mechanisms had no defined standard procedures on use of login credentials like user passwords. For some electronic health information systems deployed at health facilities, respondents mentioned that there was no way of telling who and what a user did or changed in the system at any point in time. Lastly, several respondents especially those from facilities in central region (Kampala) mentioned client perceptions and organizational culture with regard to security, privacy and confidentiality of person health data in healthcare institutions as a challenge to technology advancement including PIM and HIE. A respondent from one of the major hospitals in Kampala said, *'...even with two facilities (with different ownership) using an electronic health information system developed by the same vendor, it is not acceptable by both clients and the management teams (of both health facilities) have the two instances of that system be integrated in any way because they do not trust that their data will be safe or be kept private'.*

4 Discussion

This paper documents several mechanisms used to register patients, manage their identities and data; and key direct and indirect challenges facing PIM including, data storage, retrieval, client identity verification, client tracking, duplicate client records, among others, in Uganda's healthcare system. Relatively, there was no explicit identifier(s) used to link all person health information to an individual who may access care across health facilities identified. The study also revealed other related key challenges pertaining to data management including data entry, analysis and reporting which were of key concern to the respondents. Technical and organizational challenges which may influence PIM mechanisms were also revealed by this study.

Data storage, retrieval, analysis and reporting were reported as some of the key challenges because majority of health facilities selected to participate in the study were public health facilities that either use only paper-based forms or both paper-based forms and digital health tools to register patients and manage their identities and data. The same challenges relating to paper-based health information tools are common in low resourced countries like Uganda with recommendations to consider adopting digital tools (10). Furthermore, like many African countries, Uganda has recently developed a National eHealth Policy and Strategy to direct eHealth adoption with so much left to do in terms of understanding the current situation and creating awareness of what and how digital health interventions can alleviate some of the challenges faced in the healthcare system (7). Thus, the current situation characterized by low levels of proficiency on topics such as patient identification management and health information exchange among health workers, health system managers and policy makers may also have had an impact on the findings from this study. Organizational challenges, especially, the lack of active governance of data management mechanisms and absence of uniformity in data element definition are gaps that have an impact on the move towards the patient identity management and health information exchange. These are critical factors that that need immediate attention for successful implementation of the National Client Registry and Health Information Exchange (11). The main strength of this study is the Design Science Research (DSR) approach that allowed for a more rigorous process to achieve the major study objective beyond this paper. However, the study was limited by dominant participation of the public health facilities as compared to Private for Profit (PFP) and Private Not for Profit (PNFP) health facilities. It is possible that the latter could have demonstrated more post-eHIS gaps since majority have adopted digital health tools for patient registration and health data management (12).

In conclusion, the findings from this study reveal that several mechanisms are used to register and manage patient identities and their data. The study results also concretize the lack of a standard mechanism to manage patient identities within and across its health institutions in Uganda as a key challenge facing PIM in Uganda's healthcare system. Majority of health facilities use either paper-based or a combination of both paper-based and electronic information systems to register clients, manage their identities and data with data storage, retrieval, client identity verification, client tracking being common challenges across health facilities. Study findings disseminated in this paper focus on the problem and motivation identification; and study objective definition stages of the DSR process model. Processes within these two stages are what led to the documentation of mechanisms used for and challenges facing PIM in Uganda's healthcare system. NCR requirements elicitation and design of models based on the documented challenges will be done as the next steps under the third stage. Much as more needs to be done in terms of laying ground for the establishment of a national CR, we can recommend from this study that there is a clear need to embark on an all-inclusive journey to develop and implement NCR for PIM and HIE in Uganda. Most importantly, the government will need to examine and decide on whether Uganda will take up an existing identifier (NIN) to act as the individual identifier or a parallel health individual unique identifier for its health system. Therefore, our next steps are to establish possible CR requirements/services in order to harmonize patient identification management across Uganda's health facilities.

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Statement on conflicts of interest

The authors declare no conflict of interest.

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Networking and Securing Botswana's Public Health Care System (BPHS) to enable a secure digitalized patient-centered environment.

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Background and Purpose: The aim of the research was to investigate and develop an e-health mobile application with associated algorithms for use in managing patient information collection. The research explored the current role of Information Technologies (ICTs) in the Botswana Public Healthcare System (BPHS). Specifically, it dealt with elucidating, discussing and understanding the current status of BPHS and ICTs role in BPHS in relation to the utilisation of Electronic Health Records (EHRs). The author explored the current BPHS ways of gathering and processing patient information, categorization of the current BPHS and users' satisfaction levels with it and ascertained people's behaviours towards employment and utilisation of ICTs in health.
Methods: Triangulation of quantitative and qualitative methods was followed, with questionnaires, interviews and observation techniques employed to draw conclusions.
Results: There was strong evidence that many users showed dissatisfaction with BPHS, which is mostly paper oriented and manual, and indicated an embracement of mobile applications in health.
Conclusions: The study concluded that the current BPHS is mostly paper based and the satisfaction levels of users negate such systems in this modern era of utilisation of ICTs. In conclusion, the author designed and developed a working prototype for BPHS.

Keywords: e-health, Electronic Health Records, Mobile health Apps

1 Introduction

Many countries around the world have come up with different measures to manage patients' records through introductions and implementations of electronic patient health record systems, which have come to be known with various names such as Electronic Medical Records (EMRs), Electronic Patient Records (EPRs), Computer-based Patient Records (CPRs) amongst the so many names [1] [2] [3]. Thus, these systems have become successful in being able to deliver benefits to the health sector hence the development of an e-health application with associated algorithms for use in managing patient information collection in this research. There is clear evidence that patient records management in the Botswana's public healthcare system (BPHS) is no longer fit for purpose, despite government efforts to diversify it to embrace ICT [4] [5] [6], hence the undertaking of this research. The research explored the current role of ICT in the Botswana Public Health System (BPHS). Specifically, it dealt with elucidating, discussing and understanding the current status of BPHS and ICTs role in BPHS in relation to the utilisation of Electronic Health Records (EHRs), which has become a key component of health administration in various countries. Also explored in perspective, is how other countries have embraced use of EHRs and the associated consequences.

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2 Aim and Objectives

The aim of this research was to investigate and develop an e-health mobile application with associated algorithms for use in managing patient information collection. The objectives were:

- To analyse how patient information is gathered and processed on the current Botswana Public Healthcare System (BPHS) with emphasis on primary health care.
- To establish if the categorization of BPHS is paper and or electronic based system.
- To establish the satisfaction of users of the current BPHS.
- To ascertain people's behaviour towards employment and utilisation of ICTs (mobile applications) in health.
- To design and implement an e-health based system with relevant algorithms to process e-medical cards and utilisation of mobile communication.

3 Research Questions

The main research question was "What is the current role of ICT in the Botswana Public Health System (BPHS)?" And the sub-research questions were:

- How is patient information managed at BPHS?
- What is the makeup of the BPHS?
- Are users satisfied with the current system?
- Are users ready for a mobile health application?
- What functionalities and security mechanisms are best suited for an e-health mobile application?

4 Literature Review

4.1 Botswana Situation

Government funded health care services provided free or at subsidized costs to the general population are essential provisions of any civilized nation, and consequently so is the patient records management. There is clear evidence that patient records management in the BPHS is no longer fit for purpose as it has been plagued by many bureaucratic setbacks which could be advanced through usage of ICTs. ICTs are a wide field including "all various media employed in communicating information"[7], and this research focused on use of computer, mobile applications and network hardware in managing patient records known as e-health [1] [2] [3]. Botswana has partnered with various international institutions in the course of finding ways of utilizing ICTs in the health sector which is currently paper based [4] [6] [8] [9]. Researchers and developers alike, have embraced the importance of ICTs in the health sector [10] [11]. Botswana's adoption of use of ICTs in the health sector through its partner institutions have been constrained to use of mobile phones in communicating with patients diagnosed with long term illnesses such as AIDS, Diabetes, Cancer, TB and for appointments making [5] [12] [13] [14] [15] [16], neglecting the cornerstone of health care which includes patient registration, diagnosis and treatment which has remained paper based or manual. This has led to challenges in the patient record gathering, archiving, monitoring and maintenance of patient records [4] [6] [12] in BPHS primary health posts.

Contributing further to the BPHS are the socio-geographic elements which indirectly affects the healthcare system. Many of the dwellers of Botswana are rural occupants, poor or lack training on handling of medical documents or record management [12] [9] [17] [18]. In many circumstances, many rely on firewood, paraffin or gas devices for energy in their homes and lack of proper handling of such could lead to fires which could destroy their entire properties inclusive of medical documents thus leaving them with no concrete medical history for future reference. The general security and integrity of paper based records held by individuals and Health centres leaves these records vulnerable to loss and destruction [19] compounded by lack of records management and archiving skills by individuals [20] [19]. Moreover, escalating the issue is the inefficient and ineffective manual records management system run by the Ministry of Health facilities characterized with lack or limited use of ICTs and lack of relevant ICT skilled personnel [19] [20] [21]. The current "3-way process" has proven to be not efficient for BPHS, and it is summated as follows:

STEP 1: Patient registration: Patients visiting BPHS facilities are registered with their details captured including proof of identity, and are stored in a hardcopy notebook of the health facility and also on the patient card with the whole process involves only paper and pen.

STEP 2: Patient diagnosing and treatment: Succeeding registration is patient diagnosing and treatment which is done by a health attendant (nurse, doctor or specialist). Many patients do not bring their past illness history cards but only the new card given during registration, with the health attendant having to rely on the oral feedback from the patient whenever they pose the questions to know about their current status and past history. The process culminates with the health attendant prescribing relevant medication or treatment for the ailments and or making judgments to hospitalize or discharge the patient. This process also involves only pen and paper thus is also still manual oriented.

STEP 3: Dispensary: This is the last stage of the BPHS process involving a patient collecting their treatments or medications from the health attendant at the dispensary who relies on the writings on the patient card to give out either treatment or medication, and check to indicate the medication or treatment has been dispensed. There is no record to indicate what medication was given out and to whom. This process also involves manual form of paper and pen utilisation.

With this BPHS process, there is therefore, the potential for misunderstanding, misdiagnosis and mistreatment of patients, all of which affects the efficacy and efficiency of the service as substantiated by Kalogriopoulos et al [2] and the Botswana-Upenn partnership study [9]. Thus, there is a clear practical problem to be addressed in the collection and retentions of patient records in the BPHS, calling for introductions and implementations of electronic patient health record systems for better quality [22].

4.2 Existing relevant knowledge around the world and Sub-Saharan Africa

Many countries around the world have come up with different measures to manage patients' records through introductions and implementations of electronic patient health record systems, which have proved to be a positive outcome in many instances. Aminpour et al [1], Gray [23] and Stone [24] have indicated the importance of these healthcare systems in their studies. These systems have come to be known synonymously with varying names such as Electronic Medical Records (EMRs), Electronic Patient Records (EPRs) Computer-based Patient Records (CPRs), Personal Health Record (PHRs), Electronic Health Records (EHRs) or Computerized Medical Records (CMRs). Some countries who have implemented e-medical record systems include but not limited to USA, United Kingdom, Canada, Australia, New Zealand, Denmark, China and India, both which have made great strides in the electronic documentation of patients [23]. Having countries investing in information technology in health sector indicates how relevant and important this modern trend of utilisation of mobile and computer technology is, and how countries around the world are in need of such technologies to be employed in their health sectors [2]. In Sub-Saharan Africa, some countries have not been slow to take up and adopt EMRs as they have diversified their healthcare systems despite still facing various challenges. Highlighted here are the cases of South Africa, Kenya and Mozambique and the challenges faced by them and others.

South Africa: The South African government has embraced the use of ICTs in its health care as they are capable of bridging the digital divide between rural and urban areas [24] [25] [26]. South Africa is a vast country, and implementation of ICT health systems has been applauded as a great move though it has also come up with challenges due to the vastness of the country [27]. The country introduced the National Health Act (2003) in which it has taken strides to facilitate and co-ordinate the establishment, implementation and maintenance of information systems [28] [29] with the aim of achieving an integrated and enhanced National Health Information System in both the public and private health sector. Due to the vastness of the country, the systems are being run through District Health Management Information System (DHMIS) while efforts are being made to integrate all systems into an amalgamated national system [28]. A concern on the under utilisation of health systems due to paper persistence by some quarters [28] [30] has led to running of parallel systems with some reasons of under utilisation being lack of services, infrastructure and expertise [24].

Kenya: In Kenya, EMRs have been possible firstly due to the collaboration of Moi University School of Medicine (Kenya) and Indiana University School of Medicine (USA) in which an EMR Mosoriot Medical Record System (MMRS) was developed and later renamed to Academic Model for the Prevention and Treatment of HIV/AIDS AMRS [31] [32] [33]. The system provided the health attendants with functions of patient registration and transcribes visit data. Currently more work is still being done in

Kenya to fully engage the public health care to utilisation of ICT services in patient medical records, and just like many of the African countries, it has also engaged mobile phone usage in the various health elements such as TB, malaria [34] [35] [36]. In addition, in other parts of Kenya, similar systems have also been developed with the aim of replacing paper usage in favour of ICT as seen from Western Kenya through the utilisation of PDA/GPS-based system [37] [38].

Mozambique: In Mozambique, an HIV care system was developed with intentions of monitoring patients of HIV/AIDS. The system is known as Open Medical Record System (OpenMRS), and it provides all the necessary related technical assistance to the Ministry of Health of that country. The system is database oriented and it has only been limited to the use by patients of HIV/AIDS [39]. Many factors have been noted as the barrier to further rollout of the system to other areas of the country and inclusion of many ailments to it, and this has been advanced as lack of finances and better infrastructure amongst the reasons, similar to many challenges from other countries [40] [41].

4.3 Challenges

- Lack of ICT infrastructure and resources [27] [31] [42] [43] [44]: poor ICT infrastructure in developing African nations slows development and utilisation of electronic medical records.
- Poor Infrastructure: many African countries have poor infrastructure (roads, rail, networks and power) which contributes negatively in the set up of such systems [42] [46] [47].
- Finance: Many of the African governments and dwellers in developing countries are rural dwellers with limited and or no financial means to sustain the use of ICT technologies [27] [44] [46].
- Lack of integration of health systems [27]: many districts medical centres often have own systems to address certain problems, with many systems developed with response to certain pandemics like AIDS or malaria pandemic leaving the health systems as standalone [46].

5 Methodology

5.1 Methods

The study was carried out in the selected public health post, clinics and hospitals of Botswana (Scottish Livingstone Hospital, Broadhurst 1, 2 and 3 Clinics and Tlokweng Clinic), with the intention of understanding the current role of ICT in the Botswana Public Health System (BPHS). The author triangulated quantitative and qualitative methods, thus following a mixed methodology approach along the pragmatism paradigm lines. For primary data gathering, the triangulation of the quantitative and qualitative research methods was used, with the intentions of breath and depth understanding and corroboration of the problem domain [48] [49] [50] [51] [52], and the techniques of questionnaires, interviews and observation were employed. All the works undertaken for this research complied with the Open University policies and procedures, with research permits sought and given by Ministry of Health and on the concerned health facilities. Ethical research procedures were followed.

5.2 Population and Sample Size

The population has been drawn from an array of participants in Gaborone, Molepolole and Tlokweng and the related public health sectors of those areas (Scottish Livingstone Hospital, Broadhurst 1, 2 and 3 Clinics and Tlokweng Clinic). Babbie et al [53] explain that the population constitutes a large pool in which the sampling elements (group of elements with common sentiments) are drawn from and the findings from them generalized to give out the research findings. The author sampled a size of 200 participants with a confidence interval of ±4 and interval of 95%. 100 questionnaires were distributed in the Gaborone area, with the remaining 100 evenly split between Molepolole and Tlokweng areas. Ten people were interviewed from the health facilities of concern. The author also observed the proceedings at the selected health facilities. Interviews were done only for selected individuals, and the author approached a substantial number of people for interviews in the selected health facilities and their departments to ensure backup in instances where others didn't show up. Quantitative data was analysed through Statistical Package for the Social Sciences and qualitative was done through narrative analysis.

6 Results Findings And Analysis

The results were drawn from the field work using the methodologies, tools, procedures and participants alluded to and explained in the previously. The raw data collected comprised of literature notes, observation notes, interview notes and questionnaire questions. For the purpose of achieving the aim and the objectives of the study, a total of 200 questionnaires were distributed to the target population with the intention of getting at least 150 at confidence interval of ±4. The researcher provided a variety of ways for participants to return responses, and occasionally followed up on them to ensure a high response rate. Refer to table 1 for summarized feedback, 6.1 and 6.2 indicates summarised demographic and general findings.

Place of Questionnaire	**Sent**	**Target (Threshold)**	**Received**	**Percentage (%)**
Gaborone	100	68	96	96
Molepolole	50	41	48	96
Tlokweng	50	41	50	100
Total	200	150	194	97

Table 1. Questionnaire Summary

6.1 Demographic findings

Age Variable: Participants of the research were of diverse age backgrounds. Participants with age ranking between (a) 18-25years comprised of the majority of the respondents with 47.9%, followed by the (b) 26-33 age bracket at 25.8% and the (c) 34-41 age bracket with 19.6%. The age groups of (d) 42-49 and (e) 50 and above accounted for 5.7% and 1% responses respectively. Thus, if closely analysed, the age groups of (a), (b) and (c) if expanded and merged together represent 93.3% of the whole sample of the participants, suggesting that majority of the respondents are young to middle aged, with 6.7% showing adults respondents (participants), thus younger people are more likely to participate in questionnaires compared to adults, a view supported by Moore and Tarnai [54]. This aspect of age may have an influence in the understanding of the current role of ICT in the BPHS and how it may be enacted.

Gender Variable: Although the researcher did not put in place cognisant efforts to guarantee equivalent gender distribution of the questionnaire, it is noteworthy to analyse the gender distribution for the study. From 194 responses received, 26.8% represented male respondents with 73.2% indicating female respondents, a significant contrast between the two genders. Many females took part in the study, and this could be attributed to their willingness to actively engage in studies compared to males [54] [56].

Level of Education Variable: This demographic aspect was divided into 5 categories of (a) BGCSE and below representing lower levels of education, (b) Certificate representing tertiary at entry level, (c) Diploma indicating tertiary intermediate level (d) Degree and (e) Postgraduate showing advanced and more advanced levels. From the responses gathered and analysed, it indicates that 44.3% are degree holders, 38.1% diploma holders, with 16.5% indicating certificate holders, BGCSE and below and postgraduate accounting for 0.5%. Many of the respondents have formal education up to a certain level which could be critical in the deployment and utilisation of health ICT systems and or applications and sustains findings that educated people are more likely to participate in surveys [55] [56].

ICT Literacy Level variable: The ICT literacy level is another demographic aspect taken into consideration to understand from the participants their ICT skills. This was measured in three ways being the (a) Basic, (b) Intermediate and (c) Advanced. From the participants responses, it shows that majority of them at 69.6% are of intermediate level when it comes to ICT literacy level with 21.1% showing that they have basic ICT literacy level. Only 9.3% have shown that they are of advanced level. This shows that many participants have some form of ICT literacy level, thus this could play an important role in utilisation of health ICT systems and for basic operations of them.

Profession Area (Health Facility or Not) Variable: It was also important for the author to gather and analyse data related to the profession area of the participant, in which the researcher sought to understand their profession and where it is based. The responses for this variable indicated that 67.0% of the participants were not from the health area and those from the health area accounted for 33.0%. From the 33.0%, 51.4% of them were nurses, followed by 25.7% of Nurse Assistants and 22.9% being doctors. Therefore, this translates to affirming that the data gathered embraces all the users of health information systems, especially the general users who are patients to hospitals and indirect users of the systems.

6.2 General Knowledge Variable findings

The general knowledge variable constituted of the following questions.

1. *How is patient information gathered and recorded?*
2. *How are the patient's medical records kept?*
3. *Does your health facility have Internet Connection?*
4. *Your health facility is categorized as what?*
5. *If its paper based, is the patient medical history readily available?*
6. *Rate your satisfaction with your current system?*
7. *If your system is paper based how would you rate the priority for an electronic system.*
8. *The author intends to develop an e-health record based system. What system do you envision?*
9. *Do you have any views on the adoption of an all electronic system.*

Through these questions, the author explored the current BPHS ways of gathering and processing patient information, categorization of the current BPHS and users' satisfaction levels with it and ascertained people's behaviours towards employment and utilisation of ICTs in health. The primary data unearthed concluded the following key issues in relation to BPHS, its users and ICT usage in health. A summary is presented below:

BPHS is Paper Based: Data gathered indicates that 97.9% of the respondents' states that data is gathered and recorded through the means of paper, and 96.4% sustained that the patient records are kept on paper and 97.9% indicated that the BPHS system is paper driven. Therefore all the factors to gauge BPHS indicate that the system is paper oriented. These findings sustain Bussmann et al [15] findings that the Botswana public healthcare system is primarily paper based with minimal ICT electronic/technology driven systems.

BPHS Users not satisfied: Users are not satisfied with the current BPHS. The overall assessment showed that 65.5% participants were unsatisfied, followed by 17.0% who were very unsatisfied, 11.9% who are neither satisfied nor satisfied, 4.1% who are satisfied and 1.5% of those very satisfied. A combination of the very unsatisfied and unsatisfied categories takes the total numbers of generally unsatisfied users to 82.5%, generally satisfied users to 5.6% with the intermediate response rate remaining at 11.9%. This shows a huge disproportion between the satisfactory and unsatisfactory responses and corroborates same findings by other researchers [15] [17] [57].

People are eager to embrace the use of ICTs in health administration: Respondents indicated that they are eager to embrace the use of ICTs in the health administration. Participants overwhelmingly agree that there is need to have an electronic system with a priority of 80.3% and a convincing 84.0% of the participants responded that they want a mobile application. The mobile market in Botswana is growing faster than the Personal Computers (PC) market with an average growth of more than 150% compared to the 20% of PCs, and the government initiatives to promote internet usage play a vital role [36] [79]. Thus, more Batswana own mobile phones with the coverage from statistics indicating 90% coverage, thus mobile phones could play an important role in Botswana and its telemedicine sector [58] [59] [60].

7 Recommendations

- Government should consider investing in high quality health ICT systems and use of mobile devices.
- The government should consider networking all health centres in the country and furnish them with internet connection and mobile devices such as Tablet PCs for doctors and nurses for use in health.
- More security mechanisms and ways needs to be enforced in the Botswana networks.
- There should be provision of trainings to health professionals in relation to use of ICTs.

8 Conclusions

Patient movement is uncontrolled as they move from one health facility to another, and needed in place is a robust system to connect the gaps caused by patient migration. With the current status of BPHS which is paper oriented and plagued with bureaucracies, this can't be achieved. The displeasure of the users of BPHS, called for a system which is in line with the modern world. The research concludes that the problem of BPHS is far from unsolvable and this research achieved its mandate of understanding the current BPHS setup, satisfaction levels of users of the current BPHS, people's behaviors towards ICTs in health, similar systems from other countries and finally developing an e-health system for the environment of Botswana. The research itself was not without challenges and there remain issues to be solved technically and operationally to enhance on the current delivery.

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Information needs, access and coping strategies for cervical cancer clients at Mulago Uganda Cancer Institute.

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Background and Purpose: The advent of effective infection control and treatment measures has shifted the burden of disease from mainly infectious causes to chronic, non-communicable diseases. Diseases like diabetes and cancer are on the rise globally, mostly in low income world due to low levels of awareness among other factors. In recent past, information and communications technology are increasingly being considered important in helping people more aware of cancer. This study identified information needs priorities about cervical cancer (CaCx) and coping information access strategies for CaCx clients and the general public and develop an interactive information portal to help increase disease awareness.
Methods: Focus groups, key informant and in-depth interviews were audio-recorded, transcribed and analyzed using Atlas.ti to generate information themes.
Results: Cancer clients demonstrated need for extensive information concerning cancer, treatment, and prognosis. Causes and risk factors for CaCx, and where to access CaCx services were the most important information themes to the general public. Study revealed that at the gynae-clinic, information is being shared by word of mouth and this does not facilitate adequate information sharing.
Conclusion: These findings can be used by Oncology professionals to better address the information needs of CaCx clients and those of the general public in an effort to fill knowledge gaps in the fight against CaCx. Information needs vary between CaCx clients and those of the general public yet between CaCx clients and health professionals, they were comparable.

Keywords: Cervical cancer, information access, information needs, cancer awareness

1 Introduction

The advent of effective infection control and treatment measures has shifted the burden of disease from infectious causes to chronic; non-communicable diseases (NCDs) [1]. Diseases such as cardiovascular and cancer are on the rise globally with a rapidly growing crisis in low-income and middle-income countries (LMICs) [2][3]. In 2015 for example, cancer was responsible for 8.8 million deaths globally and approximately 70% of these deaths occurred in LMICs [4]. With lung, female breast, stomach and colorectal cancers combined with liver and cervical cancer (CaCx) explaining over half the incidence burden (54%) in LMICs [1][5].

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For CaCx, the pattern is striking since around 85% of women diagnosed and 87% of those who die from the disease live in LMICs [1]. The rise can be attributed to limited access to effective screening services hence late disease identification [4][6] or due to low levels of awareness [7][8] among other factors.

In Africa, CaCx is high in the sub-Saharan region with Uganda being ranked 10th on the continent with 44.4|100,000 women; Age-standardized incidence rate of CaCx cases [9]. Among the contributing factors for the high incidence of the disease in the country include; lack of screening tests and vaccines to prevent HPV [6][10], limited access to cervical screening programs [10] as well as lack of information [7] among others.

Until the 1980s, information about disease, treatment, and prognosis was assumed to increase patient emotional distress, physical complaints, and treatment refusal. Yet, these assumptions were not supported by evidence [11].

Literature on information-sharing in cancer clients revealed that clients indeed have unmet information needs especially those with advanced disease [12]. This study therefore investigated the information needs priorities about CaCx and coping information access strategies for CaCx clients and the general public.

2 Material and methods

The study was conducted at Uganda Cancer Institute (UCI) gynae-clinic and participants were women with CaCx (CaCx clients), women without CaCx (general public) and healthcare professionals in active care for CaCx (gynae oncologists, nurses, & clinical officers). All participants were first informed of the study and those willing to take part, were recruited between April and May, 2018.

For eligibility, participants had to be adults of above 18 years, able to speak the local language (Luganda) or English or both, confirmed evidence of CaCx or CaCx negative. Clients who were attending the clinic for the first time, and unaware of their diagnoses were excluded.

While recruiting CaCx clients, a list was generated and participants randomly selected. For healthcare professionals and women without CaCx, convenient sampling and simple random sampling were used.

Interviews were audio recorded and hand-written notes were done throughout the interview session. Data collection took place between 2nd week - 4th week of May 2018.

Focus Group Discussions (FGDs) comprised of participants with and without CaCx to explore what kind of information participants needed to know, how and when to access it. Key informant interviews (KIIs) comprised of nurses (n=2) clinical officers (n=2) and gynae-oncologists (n=2). The investigator explored what information health providers share with CaCx clients, and the general public. In-depth individual interviews (IDIs) comprised of women without CaCx (n=4) focusing on what kind of information they would prefer to know about CaCx, and how to access it. Interviews were transcribed then verbatim transcriptions were generated. Analysis of data was done using Atlas.ti version7 taking an exploratory approach (inductive content analysis) [13], and findings presented as themes.

Research and Ethics Committees of Makerere University, and Uganda Cancer Institute (UCI-REC) approved this study, and participants consented to take part. Each participant consented before taking part in the study.

3 Results

In total, two FGDs of 7-10 participants respectively were conducted. In addition, six KIIs (2 gynae-oncologists, 2 clinical officers and 2 nurses), and four IDIs with women without CaCx were conducted. Information needs of CaCx clients from both FGDs were generally comparable. All participants considered providing health information an important aspect of CaCx care not only to CaCx clients but also to their families and to care givers. It was evident that clients desire more extensive information concerning the disease, treatment, and prognosis and this needed to be prioritized.

However, the study also recognizes that clients vary in how much information they want and that this may change during their CaCx journey. Important information themes that emerged are highlighted in ***bold italics*** backed up by respective quotes in italics from interviews.

3.1 Information needs for CaCx clients.

CaCx Symptoms

CaCx clients expressed a strong need for information especially on the early symptoms of the disease. They noted that if such information was known to them and to the general public, there is/was a high likelihood for them to seek medical attention when the disease has not reached advanced stages. From an FGD conducted in English;

> *Information to do with warning signs and symptoms; if health professionals had told us about them, it could have been helpful. We wish health providers sensitize us about CaCx because some of us and many people in villages don't know what the cervix is and we are always in dark [English FGD].*

Screening

Participants needed to be armed with screening information in regard to where to find this service, how it is done and who to seek for it and when. By availing this information, will do away with fear associated with screening service and reduce knowledge gap hence increase its uptake. Also, it will help in early diagnosis; a point when medical intervention can still make a long-term difference.

> *Also, women are worried of CaCx screening process because they are scared of exposing themselves during the screening exercise. Therefore, screening process needs to be elaborated to women and again women be sensitized about it in order to help in early diagnosis. Some of our diagnoses were confirmed when we had started experiencing vaginal bleeding, others during screening experienced strange signs of CaCx disease while others had dizziness [Luganda FGD-after translation to English].*

Dos and Don'ts

Participants expressed great worry of not knowing what to avoid and what they should capitalize on in order to improve their health. Information concerning health-lifestyle which contributes to improved health was among what needed to be shared to CaCx clients as supported hereunder.

> *Now that we have the disease, we need to know what we should do and what we should avoid (Dos and Don'ts). This will make us further improve on our life without not necessarily visiting health care givers frequently [English FGD].*

Treatment Side Effects

CaCx clients want to know information concerning the side effects of the different kinds of treatment lines they receive along their care journey. They noted that along treatment, both short and long-term side effects occur; something they need to be cognizant of since some effects turn out to lead to a deteriorating health.

3.2 Information needs for women without CaCx (from in-depth interviews)

CaCx and its Causes

Many people seem not aware of this silent killer as it emerged that basic information relating to CaCx such as what it is, where it affects, who is at risk and the risk factors among others were not obviously known to them and needed to be shared to the public.

3.3 Information shared by health professionals (from key informant interviews)

From the perspective of health professionals, information being shared to people differs by their status as presented in table 3.1 below.

Information theme	Justification
To newly diagnosed with CaCx	
Informed about CaCx staging, in line with the treatment and side effects	There are many approaches. i.e one of surgery, chemo. All these have different side effects.
CaCx clients who have been on treatment for fairly a long time (Expert clients)	
Possible long-term side effects	These vary along treatment journey; some manifest early while others late.
The relevance of regular screening and symptoms of cancer	To identify the disease while still at young stage for treatment to have positive impact.
CaCx Survivors	
The relevance of Screening	There is a likelihood of having another cancer once you had one before.
To those simply worried of CaCx	
They are informed of what CaCx is, its causes, how it can be prevented, detected and later treated	A lot of information is shared to these people because they happen to have time to listen.
To the rest of the people out there	
It is general information like that shared to those worried of CaCx.	

Table 1. information being shared by healthcare professionals

3.4 Coping information access strategies

It evidently came out that health professionals share abroad range of information to kinds of people. The commonest mode of information sharing is by the word of mouth (face-face) and this does not facilitate adequate information sharing since the clinic is high volume with small numbers of care providers, also affected by language barrier.

> *It is a one-on-one talk. We don't have any other way yet we need programs of how we can talk to clients even when they are not here in a language they better understand. We need to use all available resources if we are to win; you can't keep it one channel [KI-2].*
>
> *This information is not anywhere instead it's in our heads; what I learnt is what I give out. We do one-on-one talk or group talks especially for those who have come for screening [KI-4].*

With this kind of information sharing, many participants believed they don't get adequate information as quoted below.

> *No, we don't access the right information we need; some medics are hesitant to tell us this information. The way we receive information from healthcare givers is not all good, its poor and we can give it only 5% score [English FGD].*
>
> *Not really, most things are simply hinted on; for example, in Nankabirwa ward, there comes a health professional who briefly gives educative talks to people every Monday but always the information is not adequate [Luganda FGD].*

4 Discussion

The study attempts to address CaCx awareness gaps by exploring the information needs of both the CaCx clients and those of the general public.

Participants reported that information on symptoms of CaCx needed to be shared as a way of increasing disease awareness because this could help people presenting themselves for care when the disease has not progressed to advanced stages.

This is consistent with [10] who stated that; lack of awareness of risk factors and symptoms for cancer may lead to late diagnosis and poor prognosis.

The need for information on CaCx symptoms can also be linked to the fact that most clients especially the expert ones are more worried of recurrence of the disease. Similarly, [14] found that 90% of cancer clients had a high degree of information needs regarding the prognosis of the disease, including issues related to the probability of recurrence and metastasis.

Prioritizing of screening information was based on the fact that its increased uptake will contribute to reduction in morbidity and mortality caused by the disease yet lack of knowledge about CaCx screening is among the most significant barrier to screening among women. Besides CaCx is treatable once detected early, and the need to know where to access screening service and what really happens in the process of screening, contributes to increased awareness of the disease hence increased uptake. Failure for women to be aware of where to access CaCx screening will deny them the likelihood of detecting the disease at early stages once they have it. Similar to this is [15] who stated that women who do not have access to CaCx screenings (i.e., routine Pap tests) have a significantly higher risk of developing CaCx. Making screening information available will further help address misconceptions about screening. This is comparable with findings by [6] where women who had not screened reported lack of awareness on CaCx as a barrier to screening.

The great desire to know the several causes and risk factors for CaCx can be attributed to the fact that most of these causes are avoidable and that the disease is treatable once detected early. It may seem obvious but knowledge about causes of CaCx and associated risk factors is limited among people. This is supported by for example, the Union for International Cancer Control (UICC) reported that more than a quarter of Africans surveyed believed that cancer had no cure once diagnosed and only 36% referred to cancer as an important health issue. In the same way, early healthcare-seeking is possible if women become aware of the CaCx risk factors and are able to avoid them. This is comparable with [10] that; early healthcare-seeking may be promoted if women become more aware about CaCx risk factors. Most often cancer is fatal due to the late stage of clinical presentation, something in turn a consequence of inadequate information and awareness [16].

Cancer interventions have got both long- and short-term side effects. It is important for clients to know what they are likely to experience after being initiated on cancer treatment. Some treatments have got very traumatizing side effects just like the disease itself which may deter some clients not to continue with the treatment. To many victims of these treatment side effects, have come to believe that they might be suffering from other strange illnesses which are unknown to them yet this is not the case.

Sharing such information is linked to help in adherence and also to elimination of fears in clients as well as dealing away with the negative attitude clients may have towards treatment. Similarly, Lila, et al, revealed that; newly diagnosed clients in the treatment phase needed information on stages of the disease, treatment plans, and treatment-related side effects; yet, clients who completed treatment still expressed a need for information on side effects, rehabilitation, and self-care [17].

Use of Information Communications Technology (ICTs) has the potential to enable provision of information especially in control and prevention for cancers to a wide population as well as increasing disease awareness. However, majority study participants indicated that they would require face-to-face communication for counseling and rehabilitation support which will most likely create more bonding between clients and care giver and bring about adherence.

This study had methodological limitations that should be addressed; focus groups were only for CaCx clients sampled though with varying socio-demographic and clinical variables.

5 Conclusion

Information needs slightly differed between CaCx clients and those of the general public yet between CaCx clients and healthcare professionals, they were comparable. Majority CaCx clients prefer to receive extensive information at their first diagnosis. Information about treatment, procedures as well as side effects, and prognosis are of particular relevance. Findings demonstrated that information seeking continues from diagnosis to follow-up. Therefore, healthcare providers listening to the clients might be more effective way to prevent and fight CaCx. It is also imperative to make use of the increasing adoption of ICTs to develop a centralized information portal on CaCx where all awareness information can easily be accessed by whoever might need it. Then efforts be made by referring and encouraging clients to use this portal as an effective way to further increase CaCx awareness.

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Conflict of Interest: the authors declare that they have no competing interests.

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Standardizing Representation of Medication in LMICs: Case of Malawi and RxNORM

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Abstract. Background: Sharing medication data between different health systems is essential for continuity of care. To provide common and consistent representation of medication data across disparate health systems, the National Library of Medicine (NLM) developed RxNORM; a normalized naming system for generic and branded drugs that facilitates semantic interoperation between different drug terminologies. RxNORM has become the standard vocabulary for representing medicines in the United States.
Objective: To assess the extent to which RxNORM concepts can be used to accurately represent essential medicine from a setting outside the United States.
Methods: To assess the coverage of RxNORM for medicine outside the United States, we used the 2015 Malawi Essential Medicines (MEML-2015) list as a test case. Terms from the list were transcribed electronically for easy processing and matched to RxNORM concepts using exact and partial matching algorithms. Results from the electronic matching were manually verified for correctness. All terms that could not be matched using the algorithms were manually searched for in RxNORM to ensure accurate classification as a term without a corresponding RxNORM concept.
Results: Of the 603 unique MEML-2015 medicines, 63% could be accurately represented by active RxNORM concepts. Anti-infectives were the class of medicines with the most unmatched medicines. Four other classes of medicine had complete coverage by RxNORM concepts.
Conclusion: A significant number of essential medicines could not be accurately represented using RxNORM concepts. A framework for adding such medicine as RxNORM concepts while maintaining continuous integration with periodical RxNORM updates is needed.

Keywords: RxNORM, Semantic interoperability, low-resource settings.

1 Introduction

Since the early 2000's, there has been an unprecedented increase in the use of electronic medical record (EMR) systems. By 2014, 75% of American hospitals had adopted a basic EMR in comparison to only 15% in 2010 [1]. This increase in EMR adoption has among other things highlighted the difficulties in sharing medical information electronically between different systems due to various reasons such as different representations of information [2]. Different systems encode information in different ways leading to ambiguity in meaning and interpretation. This introduces a significant barrier to the exchange and aggregation of data from various systems for continuity of patient care, planning, quality improvement and research.

To reduce the ambiguity in the meaning and interpretation of medical information, lists of terms have been explicitly enumerated where each term has an unambiguous and non-redundant definition [3]. A list of terms that has been enumerated in this manner is called a controlled vocabulary. Often, vocabularies

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contain terms from a single domain. An example of this is the Logical Observation Identifiers Names and Codes (LOINC) vocabulary which contains names of various laboratory tests. Each laboratory test in LOINC has a unique identifier which when used consistently describes the same test, thereby ensuring the same interpretation and meaning.

When a vocabulary has been widely accepted and adopted for encoding information in a domain, it is called a standard vocabulary for that specific use case. For example, LOINC is a standard vocabulary for encoding laboratory test orders. The Systematized Nomenclature of Medicine, Clinical Terms (SNOMED CT) is another standard vocabulary that is widely used for encoding diseases, symptoms, signs, specimen types, procedures and other things. To provide common and consistent representation of medication data across disparate health systems in the United States, the National Library of Medicine (NLM) developed RxNORM; a normalized naming system for generic and branded drugs that facilitates semantic interoperation between different drug terminologies [4]. The ability to map drugs across various drug terminologies and the accompanying meaningful use regulations have made RxNORM a standard for drug knowledge representation in the United States [5].

Various studies have been conducted to assess the coverage of RxNORM for medicine used in the United States ambulatory setting. One such study showed that at least 97% of electronic prescriptions could be accurately represented by an RxNORM identifier [6]. A similar study by O'Neil and Bell found that RxNORM provides concepts covering almost all ambulatory e-prescriptions [7]. However, these studies were conducted in the United States health setting. Little is known about how well RxNORM covers drugs used outside this setting.

RxNORM was developed by the NLM primarily for use in the United States. Therefore, while RxNORM has a large collection of drug products, its focus on the United States market could limit its coverage of products that are either not approved for use in the United States or are infrequently used in the United States. In addition, prevalence rates of diseases vary from country to country affecting the level of demand for certain medicines. Due to varying levels of demand, some countries will have a wide variety of drugs to treat some conditions while others will have fewer options. This is a result of both the demand for those drugs and the number of pharmaceutical companies operating in those countries or regions. Therefore, it is reasonable to expect that some drugs will not be present in RxNORM.

Furthermore, a drug can be produced by one or more manufacturers usually with different brand names and packaging. Since not all pharmaceutical companies operate at a global scale, it is highly likely that drug names used in various regions of the world will be different and that common and well-known brand names in one part of the world would be unavailable and unknown in other parts. Therefore, differences in drug formulary are to be expected across various regions and countries.

Lastly, before any drug can be used in the United States, the Food and Drug administration (FDA) must first approve it [8]. The same is true in most countries and being approved in one country does not guarantee that the same will happen in other countries. The ramifications of this is that different countries may have different list of medicines approved for use. With these factors in mind, any use of RxNORM in health settings outside of the United States must first assess the extent to which RxNORM meets their use case and consider how best they can handle any potential deficiencies.

This research measures the extent to which RxNORM covers drug formulary used in a health setting outside the United States namely, Malawi and proposes a framework for closing the gap where some drug formulary cannot be coded with the standard RxNORM vocabulary.

2 Methods

2.1 Materials

Drugs that are used to treat the most common and prevalent health conditions in an area are called essential medicine [9]. Essential medicines are often the most frequently used and address most of the health needs in an area. The World Health Organization (WHO) encourages countries to have a fixed, periodically reviewed list of these drugs and to ensure that there is a steady supply of drugs on this list. As such, an essential medicines list is a perfect yardstick for measuring coverage of a drug vocabulary for a given setting or use case. We therefore chose the Malawi Essential Medicines List (MEML) as our test case for assessing the coverage of RxNORM for a low-resource health setting outside the United States.

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We used the 2015 release of the MEML, henceforth referred to as MEML-2015, to conduct the initial coverage assessment of RxNORM [10]. The MEML-2015 has 696 drugs classified into 31 categories based on the ailments that they are used to treat. Some drugs are used to treat multiple ailments and are repeated between and within ailment categories. We removed these duplicate MEML-2015 drug entries to ensure accuracy in measuring the coverage of RxNORM. All drugs were listed using their generic names which prescribers from both public and private hospitals are encouraged to use [10].

The initial coverage assessment was conducted using the October 2017 release of RxNORM. We used the full release version of RxNORM to ensure that we did not miss any RxNORM concepts that had been deprecated due to discontinued use in the United States health setting.

2.2 Data pre-processing

All the drugs from the publicly available MEML-2015 PDF document were transcribed into an easily manipulatable form. During this process, fractional dose strengths were simplified to their lowest forms. For example, Promethazine HCL 5mg/5ml elixir and Azithromycin 200mg/5ml suspension were simplified to Promethazine HCL 1mg/ml elixir and Azithromycin 40mg/ml suspension respectively. We did not however change the dose strength unit for each of the drugs.

Furthermore, we matched the dose forms for the MEML-2015 drugs to those specified in the RxNORM documentation [11]. For example, implant was changed to drug implant and eye ointment to ophthalmic ointment. This was done to comply with pre-defined RxNORM dose forms. All syrups and elixirs were also changed to oral solution as stipulated in the RxNORM documentation [12].

2.3 Granularity of Terms Matching

To calculate the coverage of the MEML-2015 list by RxNORM, we matched terms from the MEML-2015 to concepts in RxNORM. RxNORM lists drugs at various levels of granularity. A fully specified drug has the active ingredients, dose strength and dose form which includes the route of administration [13]. For example, 50 milligrams of Ibuprofen in its fully specified form is listed as a concept with the name “Ibuprofen 50 MG Oral Tablet”. Specific brand names can also be added to RxNORM concepts if they exist. This introduces variation in the way the drug is represented such that the same 50 milligrams of Ibuprofen drug can be linked to more than one concept name as follows: “Advil 50 MG Oral Tablet”, “Ibuprofen 50 MG Oral Tablet”, “Ibuprofen 50 MG Oral Tablet [Advil]”. This poses a problem for matching using names as it is not always the case that all these different names are listed in RxNORM.

In this study, we considered a MEML-2015 drug to have matched an RxNORM concept if they had the same active ingredient, dose strength and dose form. For example, if both RxNORM and MEML-2015 had an entry for Acyclovir 200mg tablet, it was counted as a match. However, if MEML-2015 had Acyclovir 200mg tablet and RxNORM had Acyclovir 200mg capsule, it was counted as a mismatch because of the different dose form. The same criteria also applied to dose strength such that “Ibuprofen 50 MG Tablet” was not considered equivalent to “Ibuprofen 25 MG Tablet” even though 2 tablets of 25 MG Ibuprofen theoretically are equivalent to 50 MG Ibuprofen. This was done to ensure that individual products can be accurately represented.

Our matching criteria was not stringent on the route of administration because the MEML-2015 did not always explicitly specify the route of administration especially for oral products. We therefore made exceptions for dose forms such as tablets, capsules, suspensions and solutions that were not listed with an explicit route of administration by considering oral products with similar active ingredients, dose strengths and dose forms as matches. However, in the cases where the MEML-2015 made explicit mention of the route of administration, the same constraint was placed on the matching such that “Hydrocortisone 1% topical ointment” in MEML-2015 and “Hydrocortisone 1% ointment” in RxNORM were treated as a mismatch. Furthermore, for suspensions and solutions that were clearly labelled as injections, we did not consider oral products with similar active ingredients, dose strengths and dose forms as matches.

All MEML-2015 terms were first matched electronically and then verified manually. The manual verification process ensured that all terms were correctly matched. All false matches between MEML-2015 terms and RxNORM concepts were corrected. Furthermore, MEML-2015 terms that were unmatched were manually searched in RxNORM to ensure that they had no corresponding RxNORM concept that could accurately represent the term. Once the matching and verification was complete, we calculated the coverage of RxNORM for the MEML-2015 by getting the proportion of MEML-2015 terms that were matched with RxNORM.

3 Results

The MEML-2015 has 603 unique drug entries. Out of these, 380 drugs were matched to current concepts in RxNORM representing a coverage percentage of 63%. A further 29 drugs matched with RxNORM concepts that have been retired and are no longer recommended for use. The remaining 194 drugs could not be matched to pre-existing concepts in RxNORM. The drugs that could not be matched to RxNORM concepts came from 27 MEML-2015 categories. Of these categories with unmatched terms, Anti-infective medicines (43) had the highest count of unmatched drugs followed by dermatological medicines (24). Four MEML-2015 categories namely: Anti-migraine medicines, diuretics, peritoneal dialysis solutions, and medicines for arthritis had all their drugs matched with a concept in RxNORM. The complete breakdown of the counts of matched and unmatched drugs per MEML-2015 categories is provided in Table 1.

Table 1. A summary of the categories of the Malawi Essential Medicines List and the RxNORM concepts that matched to drugs in each category. Some drugs are repeated between and within categories.

Category	Matched	Obsolete	Unmatched	Total
Anaesthetics	26	1	15	42
Medicines for Pain and Palliative Care	29	3	4	36
Antiallergics and medicines used in Anaphylaxis	7	0	3	10
Antidotes and other medicines used in poisonings	8	0	2	10
Anticonvulsants/Antiepileptics	8	0	2	10
An-ti-infective medicines	87	6	43	136
Anti--migraine medicines	6	0	0	6
Antineoplastic and immunosuppressant medicines	28	1	6	35
Antiparkinsonism medicines	2	1	2	5
Medicines affecting the blood	9	1	4	14
Blood products and plasma substitutes	6	0	6	12
Cardiovascular medicines	37	0	10	47
Dermatological medicines (Topical)	16	1	24	41
Diagnostic agents	9	0	15	24
Disinfectants and Antiseptics	1	0	3	4
Diuretics	6	0	0	6
Gastrointestinal medicines	15	2	7	24

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Hormones, other endocrine medicines and Contraceptives	20	3	8	31
Immunologicals	1	1	15	17
Muscle relaxants (peripherally acting) and cholinesterase inhibitors	4	0	1	5
Ophthalmological preparations	33	2	9	44
Obstetric medicines	12	0	4	16
Peritoneal dialysis solutions	0	2	0	2
Medicines for mental and behavioural disorders	28	1	4	33
Medicines acting on the Respiratory Tract	3	0	7	10
Solutions correcting water electrolytes and acid--based disturbances	8	0	5	13
Vitamins and minerals	10	3	2	15
Ear, Nose and throat medicines in Children	14	0	5	19
Specific Medicines for Neonatal Care	1	1	1	3
Medicines for Arthritis	2	0	0	2
Medicines used to treat Nutritional Disorders	11	4	9	24
Total	447	33	216	696

4 Discussion

The initial coverage assessment of Malawi essential medicines by RxNORM raised several interesting points. To begin with, the category with the most missing drugs was Anti-infective medicines. This was not so surprising as this was the largest category of medicines in the MEML-2015. While most of the drugs have common active ingredients, we found that MEML-2015 items often differed with RxNORM concepts in dose strength. We were not able to identify why this was the case.

We also found that several concepts that could be used to describe entries in the MEML-2015 have over time been retired in RxNORM. These retired concepts accounted for 6.9% of all the concepts to which MEML concepts were mapped to. This proportion is comparable to 8.1% replacement rate that O'Neil & Bell found in their study [7]. However, unlike that study, we were not able to find replacements for those concepts. This suggests that overtime the coverage of RxNORM for any given drug list can either increase or decrease. It is therefore necessary that coverage assessments be performed regularly to ensure that RxNORM still covers most drugs used in a given setting.

Furthermore, our assessment also identified some inconsistencies in dose form specifications in RxNORM. The technical documentation for RxNORM specifies a predetermined list of permissible dose forms. However, when conducting the matching we encountered dose forms that are not part of the dose form specification such as gas and pessaries. This was mostly a result of bringing together information from various drug terminologies and maintaining the concept names and dose forms from the original terminologies.

We also observed that the MEML-2015 lacked specificity with regards to routes of administration as alluded to in our methods section. This led us to make assumptions that while sensible may not always be true. This was a limitation of our study design.

5 Future Work and Conclusions

Our initial assessment of the coverage of RxNORM for Malawi Essential medicine showed that not all drugs used in Malawi are available as concepts in RxNORM. The 63% coverage found is significantly smaller in comparison to similar studies conducted in United States health setting. To this end, we propose to improve the coverage by adding all drugs approved for use in Malawi to RxNORM. In Malawi, all drugs must be approved for use by the Pharmacy, Medicines and Poisons Board (PMPB) before they are made available to consumers [14]. By adding all PMPB approved medicine to RxNORM, we hypothesise that the coverage of medicine used in this setting will improve.

To the best of our knowledge, the only external tool that facilitates updating RxNORM by other people outside of RxNORM maintenance team was developed by the OHDSI collaborative [15]. This tool consists of several scripts that add new concepts to RxNORM. However, this tool may not be ideal for several reasons. To begin with, the output from this set of scripts is a new data model that is different from the original RxNORM schema. The change in data schemas makes it difficult to incorporate the monthly updates from RxNORM which are important for transactional EHR systems. Second, scripts do not provide an intuitive workflow for users that may not be familiar with the command line interface. An interactive graphical user interface is better suited for this work and would cater to the needs of people from various backgrounds. We therefore propose to build an application that will allow batch searching of RxNORM and facilitate addition of new concepts to RxNORM using a graphical user interface.

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Examining Challenges Affecting Management of Health Workers' Information in Uganda

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Background: To effectively plan for human resources for health, health managers need to keep track of the size and composition of their human resources and to anticipate their future needs. Effective strategic planning is however informed by quality and reliable workforce information. However, in Uganda, existence and access to adequate information on human resources for health still remains a challenge. This limits the capacity of health managers to effectively monitor and make policies. To this end, this study set out to examine the challenges that affect the management of health human resources information in Uganda; with an aim to recommend a single authoritative source of health workforce information that can provide an accurate count of all health work-force in Uganda's health system.
Methods: We used qualitative methods to examine the challenges that are affecting the management of health workers information in Uganda. Key informant interviews were conducted with purposively selected health-related organizations with a stake in human resources for health information management.
Results: The study reports various systems used for health workforce information management, the common one being the integrated Human Resources Information System (iHRIS). The study also provides various challenges affecting these systems including fragmentation and uncoordinated human-resource systems, which results to duplication of health workers records, incomplete or missing data elements, and inaccurate health workforce accountability.
Conclusion: Given the nature of the challenges, the study denotes the need for a single authoritative source of health workforce information that can provide an accurate count of all health workforces in Uganda's health system commonly known as a National Health Worker Registry. The registry can be used to aggregate the key attributes for all health workers in the country. Thus, our future study will focus on defining country-specific features and requirements that NHWR should poses.

Keywords: Human Resource Information System, Healthcare Workers, Integrated Healthcare Systems

1 Introduction

Health systems depend critically on the size, skill mix and distribution of the health workforce for improving the health outcomes of population (1). Therefore for Uganda to progress towards universal health coverage it will need a health workforce that is aligned with the population and community health needs and which is capable of adjusting to the health sector reforms set out in the national and health sector plans (2). In order for health managers to effectively plan for human resources for health, they need to keep track of the size and composition of their human resources for health and to anticipate their future

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needs(3). This should be informed by good quality and reliable workforce data; without these data, decision-makers are unable to plan strategically or anticipate future needs(4). However in many countries including Uganda, relevant information on human resources for health (HRH) remain far from adequate; limiting the capacity of health managers to monitor policies on their human resources(5). The insufficient health worker information has led to chronic health workforce shortages, skill-mix imbalances, mal-distribution, barriers to inter-professional collaboration, inefficient use of resources, poor working conditions, a skewed gender distribution and an ageing workforce further complicating the picture in many cases (2). Furthermore, reviewing past efforts in implementing national, regional and global strategies and frameworks on human resources for health, the key challenge is how to provide concrete evidence to mobilize the political will and financial resources to improve the status of health workers in the country(6).

A timely, reliable and relevant health worker information system is essential to support the formulation, and monitoring and evaluation of health workforce plans, strategies and policies at the sub-national, national and international levels (7). Unfortunately, for most countries, there remains a significant lag between the demand for data and the availability and usefulness of the information required to support decision-making (8) . In a survey by WHO conducted in 2012, 81% of the countries in Africa had Human Resources for Health Information Systems (HRHIS) in place in respective Ministries of Health and 19% did not have (9). Furthermore, only five of the 16 countries investigated, had their HRHIS linked to the Health Management Information Systems (HMIS), while for 11 countries the systems were not linked; in other words the systems are currently stand-alone (9). Unlinked systems may also cause some duplication in human resources information seated in various databases in different departments, e.g. cadre-specific data seating in different programs, yet this data if not linked, the overall picture is not clear (10). Precisely, defining and classifying the health workforce remains an important challenge in comparing information across sources which makes it difficult to use the data for decision making and developing evidence-based policy options (4). WHA Resolution WHA69.19 in 2016 urges Member States to implement policy options towards: consolidating a core set of human worker data with annual reporting to the Global Health Observatory, as well as progressive implementation of national health workforce accounts (11). Furthermore, during Dublin Declaration on HRH in 2017 included the establishment of health workforce information systems for progressive implementation of National Health Workforce Accounts to support evidence-based policies and planning for labour market transformation and employment for health (5). However, having functional HRH information systems to obtain reliable information for evidence-based HRH planning, development and management remains a major challenge in low-income countries. To this end the study set out to examine the challenges affecting management of health worker information in Uganda with an aim to devise a single authoritative source of information for all health worker information.

2 Research approach

The study employed qualitative approaches to inquiry. This method was chosen due to its ability to provide complex textual descriptions of how people experience a given research issue (12). We purposively selected the study respondents on the basis of their knowledge, relationship to the subject matter and expertise; in this case health worker registry and health information exchange. Additionally, the snowball strategy was used where interviewed respondents would refer their acquaintances to participate in the study. A total of 28 key informant interviews were conducted. The informants were selected at all levels of Uganda's health system, i.e. national level, sub national level and health facility level. At national level subject matter respondents were selected from the Ministry of Health (human resources division, information technology unit, division of health information, clinical services department), two respondents from the professional councils, all the five medical bureaus, two from the academic institutions, and one respondent from a health professional association. At subnational level, respondents were selected from the four major regions of the country (Eastern, Northern, Central and Western region), and at health facility level, the respondents included health workers from regional referrals, private for-profit health facilities and lower level health centers. Key carders such as Medical doctors, nurses, midwives, lab technicians among others were selected purposively to make sure a representation of cadres in the service delivery is ensured. In all interviews, written or verbal consent was

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sought before the interview. Data collection was completed over a period of 6 months and ended upon saturation, that is, when no further themes or new information emerged to add to the understanding of the phenomenon. Manual content analysis was used to analyze the data analysis; related codes identified from the data were grouped together to form categories and later merged into themes as discussed in the results section.

3 Results

Respondents' distribution by organization – the selection of respondents is described in the preceding section and visualized in Figure 1.

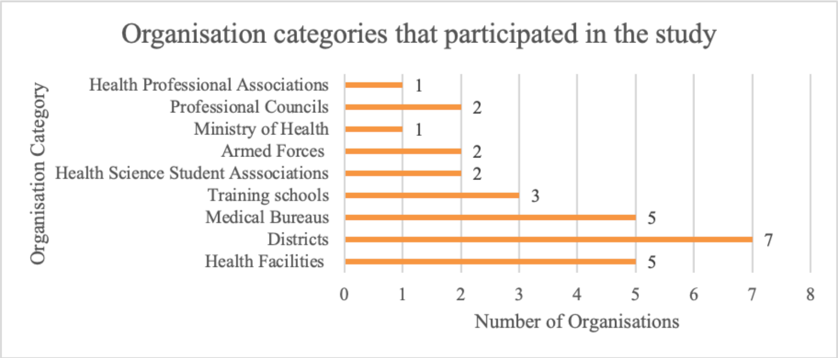

Figure 1. Respondents' distribution by organization

3.1 Systems used for Health Human Resources Information Management in Uganda's Health System

In Uganda, various systems are being used to manage data on the health workforce (see figure 2), the common system being iHRIS (63%). The iHRIS is a suite of applications used by different institutions at national through sub national to health facility levels. Also health facilities use a paper based system (17%), which is largely paper-based. Another system commonly used is the Ms Excel application (10%) that stores health workers' information in institutions such as academic institutions, health facilities and some districts; and finally a web portal system (7%), where health workers register their information is used by health professional councils and associations.

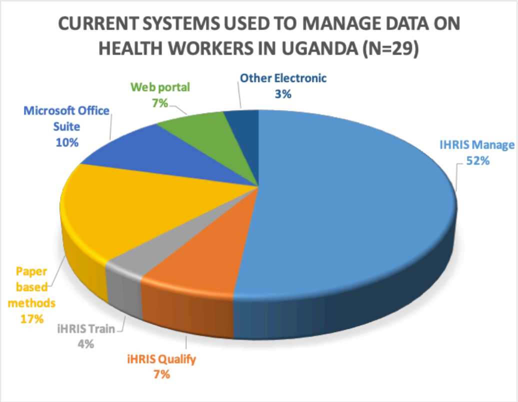

Figure 2. Current systems for HRH information management

3.2 Characteristics of the HRH Information Management systems

Integrated Human Resources Information System (iHRIS) – the iHRIS has four modules including iHRIS Manage, iHRIS Qualify, iHRIS Plan and iHRIS Train. iHRIS Manage is used for tracking detailed information about health workers throughout their employment i.e. where they are deployed, salary history, promotions and transfers, qualifications, in-service training courses, and reasons for attrition; tracking open positions and applicants. It is used mainly at Ministry of Health, Districts, Medical Bureaus and large health facilities (regional and national referral hospitals). iHRIS Qualify is used professional councils to register and license all health roffesionals. iHRIS Train is used to track and manage health worker training activities, including preservice education and in-service continuing education; and mainly used at health-related educational institutions. iHRIS Plan is a module that is used to model long-term health workforce needs and is useful for forecasting.

HRH paper-based system – involves keeping records of HRH in paper files in file folders and stored on shelves. The system is used to register health workers in training institutions, health facilities and some districts.

Microsoft Office suite (MS Excel) – this involves use of Microsoft office suite applications like Excel to manage data for in-service or pre-service health workers. Particularly data on the general and payroll for students and health workers in health training institutions, some sub-national institutions and health facilities is captured.

Web Portal– this is a web page linked to a database used to register health workers as part of being members of an association; it is mainly used by health professional associations to register health workers for membership.

In-house HRH information systems – lastly, there are small in-house developed HRH data management systems used in specific institutions that have health workers such as the Armed forces.

3.3 Challenges affecting HRH Information Management

Several challenges were reported to affect effective HRH data management systems in Uganda. These challenges are categorized as organizational, technology and data use challenges.

Organizational challenges – Fragmented systems are used to manage data on human resources for health in Uganda, that is, each of these instances is stand-alone system. Each regional referral hospital can manage their staff using the instance that they have at the facility. No agreed upon means of uniquely identifying health workers in the entire health system in Uganda (different systems use different IDs), for example the iHRIS has health worker unique identification numbers known as health worker numbers. However on resignation or leaving of any health worker from the ministry, this number will be assigned to the new staff that replaces the previous health worker. Ministry of Health cannot be able to update iHRIS instances at health facility level even when they commission transfers of health workers. Resource constraints in terms of logistics and time to collect the paper based forms from lower level health facilities to update the electronic system at the district. Human resources managers being in the back seat (IT managing the system) hinders full use of the system.

Technology and data related challenges -Unstable internet, hardware issues, standalone nature of the applications, software limitations were among the major technology challenges. The national HRH information system is challenged with several data quality issues since many instances are not up to date (missing and incomplete information). The study found out that the process of updating the system is very cumbersome. For the national iHRIS instance, the system managers have to collect the data from the health facilities and districts. The same process is also constrained by staff attrition; this affects data updates to be made in the system (data may take long to be updated) especially in health facilities, which manage their own system instances. The current national sytem also lacks the numbers of the health workforce in the private sector.

Data use challenges – there are several data use challenges affecting HRH data management systems. For instance, a comprehensive report on all health workers in the country takes long to be generated since data has to be collated from various sources. There is also a knowledge gap on the side of system managers to carry out analysis of the data. Inability to generate performance reports such as patient-clinician ratios other than just attendance due to lack of health information exchange with other systems like the medical records systems. Data needed to plan health worker inflows and outflows is missing in the systems. For instance, the web portal at the professional councils does not capture numbers of health workers who have been trained, as such it is difficult to easily calculate the proportion of health workers who have been licensed out of all graduates in the country. No reminders for expiry of licenses or transfers of health workers. There is delayed data synchronization in the system (iHRIS) once a change on a local site like a health facility is made. This leads to generation of wrong reports in case the system has not been updated with the most recent information. Incompatible data formats in the various systems. Naming of health workers cadres (positions) varies from system to system.

4 Discussion

Study findings indicate that different organizations run silo systems for managing data on health workers. In addition, some of the installations are fully functional while others are not. This makes it very hard to get a snap shot of all the health workers nationwide very quickly. A paper on monitoring and evaluation of human resources for health also noted that the two major challenges for HRH data compilation at the international level are to identify appropriate sources of HRH data at country level for timely analysis (13). It goes further to note that in many countries, information on the health workforce is fragmented, and the statistics generated by these various sources have received limited public dissemination and generally been underused (14).

This is common in many countries as data on health workers is collected partly due to lack of understanding of the full spectrum of the health worker force information which stems from training to inflows and outflows into the labor market. This is also because there are different bodies which manage sections of such data, that is, Ministry of Education managing health worker training information, Ministry of Health managing employment. This makes it hard to get data in one place. The study findings are consistent with previous reports and literature (15).

The Ministry of Health report (16) mentions a varied functionality of the iHRIS due to lack of updates. A recent study notes that even in countries where updated data are available, it may be difficult to establish the size and composition of the health workforce because data is not standardized to compare the data across systems and across countries (17).

5 Conclusion

This study examined multiple systems and challenges facing management of information on human resources for health in Uganda. Based on the study findings, the current HRH information management systems need to be strengthened if Uganda is to implement the Global strategy on human resources for health workforce 2030 in a bid to strengthen the health workforce to move the country towards achieving universal health coverage. Thus far, the study identifies the need for a single authoritative source of health workforce information that can provide an accurate count of all healthcare personnel that either have worked or are currently working at national or sub-national levels, including in the private sector. The single authoritative source is what we refer to as the National Health Worker Registry (NHWR). Consequently, further studies are needed on examining country-specific features and requirements/services for a National Health Worker Registry.

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A Fraud Detection System for Health Insurance in Nigeria

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Background and Purpose: This research developed a Fraud Detection System for National Health Insurance Scheme (NHIS) in Nigeria. This was with a view to addressing the fraudulent activities of some stakeholders in NHIS; as many researches have proven that the lack of appropriate tools to do this has negatively affected service providers as well as the beneficiaries of this Scheme.
Methods: In order to achieve the aim of this research, an inspection of organizational documents, direct observation and collection of existing data from NHIS accredited health facilities and Health Maintenance Organizations in Nigeria were carried out. The system was designed using Unified Modelling Language (UML) tools. The implementation of the system was done using MongoDB as the big data storage mechanism for the input, Comma Separated Values (CSV) files as a storage facility for the intermediate results generated during processing and MySQL as the storage mechanism for the final output, Apache MapReduce as the big data processing platform, Association Rule Mining as the data analytics algorithm, and Java programming language as the implementation technology.
Results: The system modules of comprised of four modules: user management, enrollment processing, referral processing and claims processing. With this, it identified different types of frauds in NHIS such as double billing, billing for services not provided, ghost patients, identity theft, self-referral, collusion with providers and kickback schemes.
Conclusions: This paper developed a system for the detection of the fraudulent activities of the actors of NHIS. This system employed data from the Nigerian NHIS which was categorised into: enrollment, referral and claim data with different file formats: pdf, jpg, png, csv and excel.

Keywords: Fraud, Detection, Health, Insurance, Prevention, NHIS.

1 Introduction

Health insurance covers the entire or fragment of the risk of a patient incurring medical expenses, spreading the risk over a large number of persons [1]. By estimating the total risk of healthcare and other expenses in the healthcare system over the pool of risk, an insurer can develop a routine finance structure, such as a monthly premium or payroll tax, to provide the money to pay for the healthcare benefits specified in the insurance treaty. The benefit is administered by a central body such as a government agency, private business or charity organisations [2]. Healthcare insurance has attracted substantial interest in the past. It is a social security plan that promises the delivery of the needed healthcare services to a person on the contribution of a token to provide economic protection to the participants. It is also, a mechanism for protecting families against the unforeseen exorbitant costs of illness by sharing the risks of future costs among healthy and sick populations in the form of regular predictable payments [3].

The National Health Insurance Scheme (NHIS) is a scheme put in place by the Federal Government of Nigeria to provide full access to quality healthcare service in the Country [4]. The scheme covers civil

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servants, the armed forces, the police, the organized private sector, students in tertiary institutions, self-employed, vulnerable persons, and the unemployed among others [5]. Social security is a human right, as well as an economic and political necessity; it is an indispensable part of an efficient market economy. Social security programmes are usually established as a means of improving the well-being of the poor, reduce inequality within society and conciliate different social demands, thus avoiding the social and political conflicts [6]. Adequate social security policies could be an important factor in the process of socio-political development and economic growth of our dear Country, Nigeria.
Conceptually, NHIS is a welcomed innovation and development in the Nigeria health sector given its objective. Although at present, only public servants in Federal establishments benefit from this scheme since the Federal Government is the only public-sector that has implemented the programme. On reduction of dependence on government for funding health services, [5] acknowledged that the scheme has reduced the burden on the government and improved the funding of health service through its contributory strategy. The 15 percent deduction from basic salaries of workers, which is remitted to the NHIS and the co-payment system, has increased healthcare funding.

Currently, the implementation of NHIS has not been easy due to inadequate physical health facilities and personnel, administrative and logistics bottlenecks [7]. The nation does not have enough healthcare providing institutions with adequate medical facilities and personnel for effective implementation of the Scheme. Besides, the administration of the Scheme has not been easy given the delays in processing document of registered beneficiaries and remitted contributions to the NHIS, and Health Maintenance Organisations (HMOs) and Heath Provides (HPs). Furthermore, the informal sector is very difficult to organized for the Scheme. Even private hospital and clinic are becoming unwilling to embrace the scheme. This has made NHIS prone to different types of fraudulent activities.

According to [8], healthcare fraud is defined as "an intentional deception or misrepresentation made by a person or an entity, with the knowledge that the deception could result in some kinds of unauthorized benefits to that person or entity". The NHCAA projected conservatively that at least 3%, or more than 60 billion dollars, of the United State of America's yearly healthcare expenses was lost to fraud in 2010. This loss which was also estimated by other government and law enforcement agencies was as high as 10%. Besides the monetary loss, fraud has severely hampered the healthcare system from providing quality care to authentic beneficiaries. Hence, the need for an effective fraud detection is imperative for providing easy access to healthcare services, improving the quality and reducing the cost of healthcare services. In any discussion concerning fraud, it is important to state clearly the distinction between fraud prevention and fraud detection. Fraud prevention define procedures to stop fraud from taking place. Fraud detection on the other hand, encompasses recognizing fraud as quickly as possible once it has been committed. Several fraud detection cases involve huge datasets that are continuously changing. In the nutshell, fraud detection surfaces once there is failure in fraud prevention [9].

Instead of prioritising quality healthcare delivery, fraudulent activities are prevalent among professionals in NHIS. These fraudulent activities include unrealistic bills from hospitals, cooking up cases in order to extort the Scheme by the hospitals, collusion of patient with providers or providers with HMOs, **ghost patients,** managed care fraud, reverse false claim cases, lying about eligibility, scheduling extra visits for patients, billing for services rendered by unqualified personnel, ganging, using the wrong diagnosis, false negotiation cases, providing unnecessary care and maximizing care, billing for services not provided, submitting double bills *etc.* [1][6][10]. The absence of a robust and functional health information system and lack of adequate modern information technology infrastructure has hindered the detection of fraud, sharing of information, prompt and timely data processing, creation of a database between various stakeholders in the scheme [6][7].

This paper developed a system for the detection of fraudulent activities in the health insurance scheme in Nigeria, NHIS. The system employed Association Rule Mining algorithm, MapReduce Framework, MongoDB, MySQL and Java Programming Language.

1.1 Health Insurance Fraud

The substantial increase in medical expenditures required to satisfy the quest for high quality and high-technology services has given birth to a greater demand for health insurance schemes. Most people now bank on health insurance systems, which are either funded by the government or managed by the private sector, to share the high cost of healthcare. With this intensive need for health insurance, fraudulent behaviours become a serious problem. For instance, [11] reported that 10% of United States annual spending on healthcare is loss to fraud. The health insurance programmes of other countries are also faced with similar challenges [12]. The other healthcare crimes (*i.e.,* medical and drug) which involve surgeries, invasive testing, certain drug therapies *etc.,* even place their patients at significant physical risk and affect patients' health.

Fraud in the healthcare insurance involve three parties [12][13]: the healthcare service provider (*i.e.,* the physician, pharmacist, laboratory scientist, health centre, pharmacy, laboratory, and even ambulance companies) which render healthcare services; the healthcare service consumer or beneficiary or insurance subscriber (*i.e*., patient) which receive healthcare service from the provider; and the healthcare insurance carrier which collect steady premiums from subscribers and make the commitment to pay healthcare cost on their behalves. These parties exchange information amongst them in the course of care delivery. This is basically in the form of service requested by the subscriber (patient visit) to the provider, explanation of benefits which contain the detail services rendered by the provider to the subscriber, claim/bill which is sent to carrier for the services rendered to the subscriber by the provider, and the payment to the provider based on the claim submitted to the carrier [11]. As the number of beneficiaries (patients) of this scheme increases, high volume of data is generated by both the providers and the carriers; and consequently, some fraudulent activities (such as billing services that were never rendered, performing medically unnecessary services, misrepresenting non-covered treatments as medically necessary covered treatments, and misrepresenting applications for obtaining lower premium rate) are carried by these actors (beneficiary, provider and insurer) which give rise to the need to investigate such acts in an attempt to identify perpetrators, and this requires a proper analysis tool for the purpose [13][14].

The reasons why health insurance fraud has become a prevalent practice is that majority of those involved find it beneficial in diverse ways. Several surgeons see it as necessary to provide quality care for their patients [15]. Most patients, although disapproving of the idea of fraud, are occasionally more eager to admit it when it affects their own medical care. Programme Administrators are often compassionate on the issue relating to healthcare insurance fraud as they seem to take full advantage of the services of their providers [14]. A summary of healthcare frauds is highlighted below.

Kickback schemes: One of the widespread and discussed form of healthcare fraud is kickbacks [11]. These occur in many forms. For instance, pharmacists can fill a prescription with a specific brand of drugs instead of the other that yields a bonus from the pharmaceutical company. Aside, financial implications, these drugs might also be harmful to the patient's health. Physicians themselves can fraudulently write prescriptions for money, essentially a kickback from the downstream illegal sale of these drugs.

Self-referral: This refers to the transfer of a patient to a facility with which the referring healthcare personnel has a financial relationship [12]. This might involve a kickback scheme if the facility where the patient is referred to, pays a certain amount of money back to the physician, but other financial relationships are conceivable [16].

Identity fraud: This kind of fraud occurs when an uninsured individual assumes the identity of an insured person so as to benefit from the services packaged in the scheme or to hide a particular illness. The healthcare services eventually provided to the person 'lending' their identity could be negatively affected, since this will be at par with their actual health records. This kind of fraud can also be perpetrated without the consent of the actual owner [14] [16].

Double bills: Many care providers submit the same claim multiple times, in order to get paid different times for performing the same action (*i.e.,* submitting a particular claim multiple time for the same service) [10] [17]. This is known as double billing and it is also a fraud.

Billing for services not provided: Here, claims are generated and submitted to insurance companies for healthcare services that are not provided or for drugs that have not been delivered to the patient. This is known as phantom billing [9] [13].

Ghost Patients: The submission of a claim for healthcare services provided to a patient who either does not exist or who never received the service or item billed in the claim or patients that are dead or have changed their provider [13].

Collusion with providers: Both provider and the member collude to submit false claims where the physician receives the benefits from the false claims [18].

Among these frauds, the ones committed often by health service providers accounts for the greatest proportion of the total healthcare fraud. The reason for this is that the historically prevailing attitude in the medical profession is one of “fidelity to patients”. Although the vast majority of service providers are honest and ethical, the few dishonest ones may have various possible ways to commit fraud on a very broad scale, thus posing great damage to the healthcare system. Some service providers’ fraud, such as that involving medical transportation, surgeries, invasive testing, and certain drug therapies, even places patients at a high physical risk.

1.2 Investigation of Healthcare Insurance Fraud

[19] developed a fraud detection system using data mining techniques. In all the categories of insurance including health insurance, fraud is a major issue. According to the researchers, fraud in health insurance is perpetrated via the intentional deception or misrepresentation of facts for gaining some shady benefit in the form of healthcare expenses. Data mining tools and techniques are used to identify fraudulent activities in large insurance claim datasets. Based on some identified cases of fraud from a sample dataset, the anomaly detection technique calculates the likelihood or probability of each record to be fraudulent by analysing the past insurance claims. The analysts can then have a closer investigation for the cases that have been marked by data mining software.

[10] developed a data mining approach for the investigation of fraud in health insurance scheme using knee-point k-means algorithm. NHIS was considered as the case study for the work. The research focuses on the use of some computer-based methods that could help to properly target investment in the healthcare sector and also drastically reduce fraud in health insurance by healthcare providers. To this effect, they applied the knee-point k-means clustering method, which was capable of detecting fraudulent claims by health service providers. Cluster-based outliers were examined. Health providers’ claims submitted to HMO were grouped into clusters. Claims with similar characteristics were grouped together. The claims were grouped into two clusters: fraudulent and non-fraudulent.

In a survey of hybrid methods for the uncovering fraud in healthcare insurance by [20], acts carried out with the aim of obtaining a fraudulent outcome from health insurance processes were carefully examined. According to the researchers, when providers tries to enjoys some benefits or advantages to which they are not entitled then that attempt is considered as insurance fraud and it has become a major concern for health insurance companies. They proposed a hybrid framework that applied some data mining techniques to detect frauds. This framework considered the analysis of the characteristics of healthcare insurance data, some preliminary knowledge of healthcare system and the fraudulent behaviours. The framework harnessed the advantages of both the supervised, semi-supervised and unsupervised learning methods to identify fraudulent claims.

[21] investigated the benefits of applying big data techniques in the detection of fraud in public health insurance system in Romania. They outlined the benefits of using big data technology in combating crime in the healthcare industry and came up with the following conclusions:

i. that big data technology and its distributed processing power has taken fraud detection in healthcare insurance to a higher level. Few years ago, insurance fraud detection was not considered cost-effective as it takes time and was also too expensive, and hence, so many organisations prefer to pay claims without proper investigation.

ii. that using big data analytics approaches can culminate into speedy identification of fraudulent claims, and also generates a new set of tests to automatically reduce the section that was potentially fraudulent or detect new patterns of fraud, previously not known.

iii. that the processing of complex data using sophisticated tools reveals its huge potential, and also shows that orthodox tools for data analysis cannot handle them. The analytics tools applied in the field of healthcare insurance were briefly described, each of them being effective for a particular type of fraud or a particular stage of the fraud detection process. All these culminate into the deduction that the best solution for detecting fraud in the health insurance system is, at present, a hybrid solution, both in terms of technologies and in terms of models of analysis.

iv. that in healthcare insurance frauds are country-specific, usually based on gaps or weaknesses in the country’s rules and regulations. Models are continuously changing fraud as dubious individuals are always seeking for new ways to evade the law.

Accordingly, approaches for detecting and preventing fraud must always be adjusted and ready to rediscover the fraudulent actions [22][23][24]. To add to the lapses in the country's constitution, each country has unique economic, political, social, and institutional opportunities for and barriers which makes fraud examination different amongst countries. A crucial and peculiar issue in the NHIS is the high level of corruption in the sector, lack of accountability and clear sense of irresponsibility [5][22].

[25] proposed a model using big data in investigating real time crime in the health insurance in the cloud. This approach utilizes fraud management solution to detect potential frauds in the cloud. The solution was based on massive amount of historical data, predictive statistical models and social network analytics. The model renders its services via client components like apps and web-services. Just like [21] and [20][25][26] did not implement any working system for their research. Also, as opined by [21], healthcare crimes are country specific and Nigeria has not adopted the cloud services and there are no healthcare laws relating to data on the cloud, and therefore, this model cannot be used to investigate crime in our healthcare system.

[27] developed a data analytics framework for Health Insurance data using Association Rule Mining. This was in a bid to identify fraudulent claims as deliberate cheating by concealing and omitting facts while claiming from health insurance providers has become in the health insurance domain which has led to significant amount of monetary loss to the providers. In view of the above, careful scanning of the submitted claim documents need to be conducted by the insurance companies in order to spot any discrepancy that indicates fraud. For this purpose, manual detection was neither easy nor practical as the claim documents received keep increasing and for diverse medical treatments. The researcher was able to detect fraudulent health insurance claims by identifying correlation or association between some of the attributes on the claim documents. With the application of a data mining techniques of evolving clustering method, association rule mining and support machine, this study was able to successfully determined correlated attributes to address the discrepancies of data in fraudulent claims and thus reduce fraud in health insurance. However, the study was used for structured data which made it unfit to be applied in big data which is highly unstructured. With the numerous data mining techniques implemented traditionally, it would consume more resources when applied to big data.

2 Materials and Methods

2.1 Data Collection

The data was collected from NHIS. Data collection was one of the most difficult task in this work as most of the data was collected manually in paper form by NHIS through HMOs and stored in file cabinets. This was done via document examination and observation which in either case, the data was collected from journals and NHIS databases. This data was classified into four (4) categories: enrollment, update, referral and claims. The formats of the data were: CSV, PDF, text, excel and images. The features of the data include: Enrollment: Name, Address, Date of birth, Sex, Next of Kin, Email address, Mobile, Telephone no. fixed, National ID no, Employer NHIS no., Date of NHIS registration, Nationality, Location of Posting, Photograph, Blood group, Genotype, Allergies, Relationship (Principal, Spouse, Child, Extra-dependant), Expiry date, Primary provider. Claim**:** Name, NHIS No. of patient, Name and NHIS No. of patient's primary provider, Name and NHIS No. of Secondary Provider, drug prescription sheet, Diagnosis/disease code, Treatment given, Date of treatment, Amount billed, Co-payment received (when applicable).

2.2 Design of the System

The design was done using Unified Modelling Language (UML). This was used to specified the developed model into a representative model to aid software system development. Two (2) different types of diagrams in UML were used to model the system: use case and sequence diagrams.

2.2.1 Use Case Diagram

The use case diagram for the system is shown in Figure 1. It has four (4) actors (*i.e.,* finance manager, data manager, contributory manager and the admin officer), and eight (8) use case (login /logout, upload data, analyse claims, analyse enrollment, analyse referral, analyse update, preprocess data and report). These are discussed as follows.

Login/Logout: The model is designed to be implemented in a web-based environment and hence, security is important. With this mindset, all users must possess valid user credentials before accessing the system. Before accessing the system, the user must provide these credentials and the system must acknowledge that these credentials are valid.

Upload Data: Uploading data needed for the system come in two folds. First, the existing data are digitized and uploaded to the system, and this is done by the data manager. The second method, the data is uploaded via the automated systems.

Analyse Claims: This is the processing of claims submitted for reimbursement. This produced two results: fraudulent and non-fraudulent.

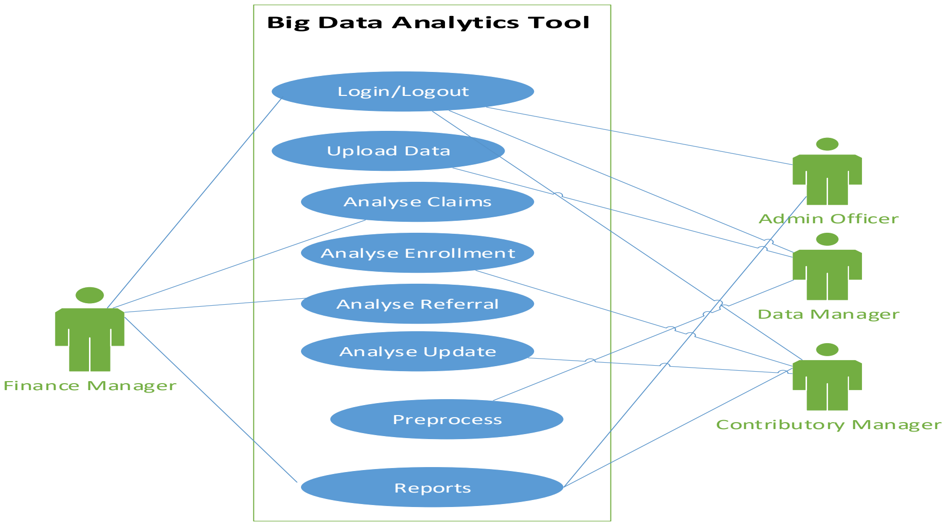


Figure 1: Use Diagram for the System

Analyse Enrollment: This is the processing of enrollment data submitted for new registration. This produced two results: fraudulent and non-fraudulent.

Analyse Update: This is the processing of update data submitted for addition of a dependant, change of primary facility or HMO *etc*. This produced two results: fraudulent and non-fraudulent.

Analyse Referral: This is the processing of referral requests made for referral of patients to higher facilities. This produced two results: fraudulent and non-fraudulent.

Preprocess Data: The cleansing of the data submitted for the processing.

Reports: These are insights generated after the processing of data.

2.2.2 Sequence Diagram

Sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario. Sequence diagrams are typically associated with use case realizations in the logical view of the system under development. Sequence diagrams are sometimes called event diagrams or event scenarios. Figure 2 shows the sequence diagram depicting the static features of the proposed basic flow of the model. This shows the different interactions by components of the model, the analytics and the results to be generated and their associated relationships. In the Figure 2, the data in the real world is captured and loaded into the big data warehouse (MongoDB) using the loadData() function. The data is extracted using the extractData() function and it is pre- processed and the attributes of interest are defined and captured using the dataPreprocessing() function. Also, if the data is structured, it is retrieved from the big data warehouse and preprocess directly with the aid of the dataPreprocessing() function. After preprocessing, the data is loaded into the map phase of the MapReduce where the different attributes are collated together using the collateAttributes() and rules are generated from the collated attributes using the generateRules() function. The generated rules are then pruned so as to drop the weak ones and pick the strong ones using the values of their confidence and support as computed by the pruneRules() function. These rules are used to generate insights using the generateReport() function. These insights are applied by the stakeholders using the apply() function, and are also stored in the relational database (MySQL) for future reference using the storeOutput() function. To make reference to these insights, a request is sent the stakeholders using the request() function and the response to the request is sent back to the stakeholders from the database using the response() function.

3 Results

The implementation of the system was developed using Java Enterprise Edition technology. It is web-based and can be used in a distributed setting. The front-end is built using Java Server Pages, the business logic is implemented using Enterprise Java Beans. and the back-end is implemented in two folds: input storage was implemented using mongoDB and the output storage was implemented using Structured Query Language (SQL-MySQL). The input storage (MongoDB) accepts data in different formats (*e.g.,* pdf, jpeg, png, gif, csv and excel) as inputs and process them to produce report for the stakeholders which is stored in MySQL. The large input in the different formats is first divided into smaller units using the Association Rule Mining Algorithm, which is implemented in the MapReduce Framework to ease the processing of this data. The system extracts the data stored in these formats via an OCR component built in it.

This implement the parallel distributed processing model of the MapReduce using the Apriori algorithm of the association rules mining. This classes contains constants, variables and methods that are used in fraud analytics. The business logic module has a sub module known as the fraud analytics module which implement the MapReduce framework and the Apriori Association Rule Mining algorithm. Whenever a task is forwarded to this sub module, details about the task is sent to the JobTracker which coordinate, allocates and control all the activities within the analytics sub module. When these details get to the JobTracker, it assigns the TaskTrackers the job which in turns load the task unto the mapper classes. The TaskTracker also feed the JobTracker with every detail of what happens with the task, both in the mapper and the reducer classes. The relationship between the JobTracker and the TaskTracker is a master-slave one, the JobTracker is the master while the TaskTracker is the slave. The mapper and reducer classes are the kernel of the analytics process. While the mapper carryout the dirty task of the analysis, the reducer summarises whatever is produced as the outcome from the mapper. This output is sent to the relational database, MySQL, through the entity bean. It is through this same entity bean that request for retrieval of that from the database and responses to the JSPs follows.

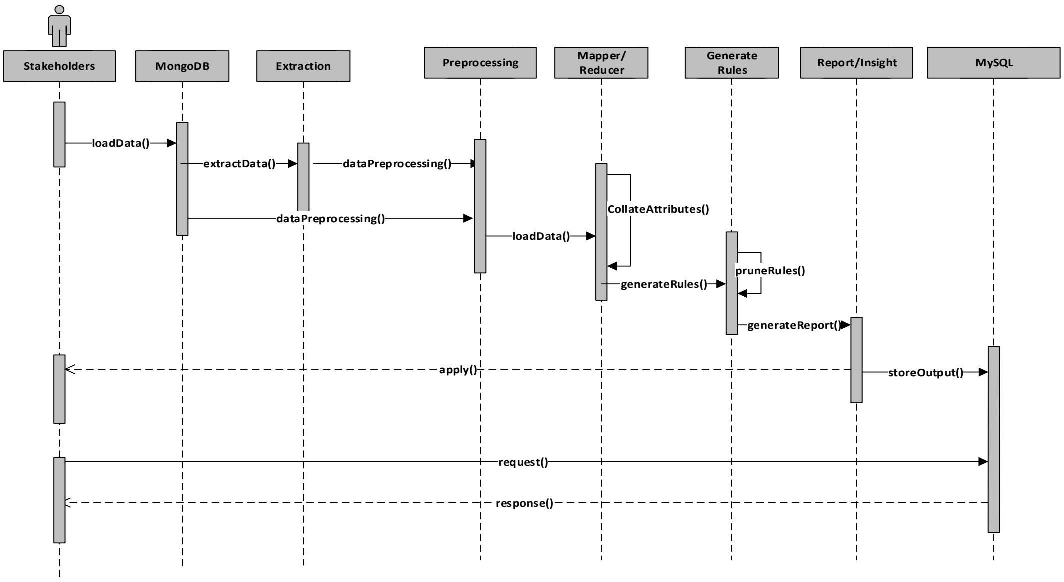


Figure 2: Sequence Diagram for the System

The backend is designed using two different databases: MongoDB and MySQL, and temporary csv files. MySQL is a relational database management system, and it is used for storing the output of the analytics. The logic about the MySQL component of the back-end is housed in the entity bean. This component stores only processed data. The MongoDB is a NoSQL database which is used for storing big data as it is captured from the various health facilities. This is where data captured by other applications too is channelled to.

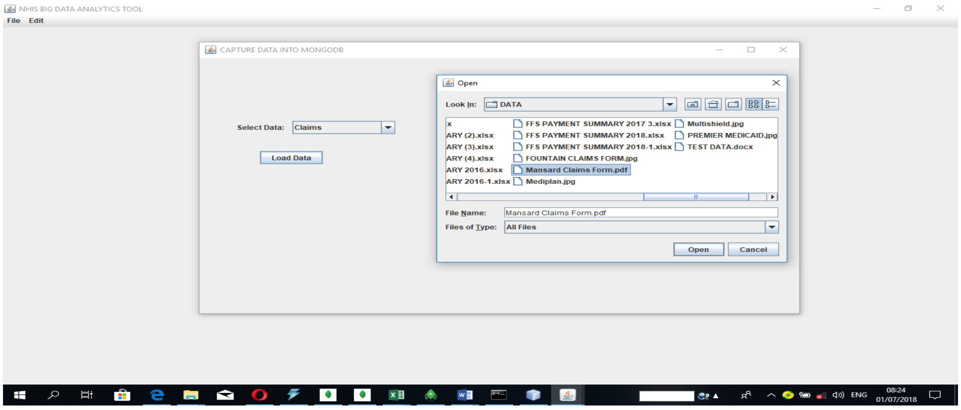
Figure 3 shows the capturing of the data into the system. Figure 4 and Figure 5 show the detection of fraud from claims and enrollment data.

4 Discussions

The modules of the application are discussed in the sections that follow below and it comprised of four modules: user management, enrollment processing, referral processing and claims processing.

User Management: This system uses single-sign-on which implies that all users must login through a single interface and are authenticated before authorizing them to access the system resources. The module is responsible for adding new staff and assigning login credentials (username and password) to them.

Claim Processing: This module handles the processing of all the claims submitted by providers for fee-for-service payment. The module verifies every item on the claim by comparing it with NHIS existing rate and anyone that fall short is either recalculated or at worse rejected. In the course of processing, all unprocessed claims in the repository are picked and process. This is to ensure that no claim spend up to fourteen days before been processed. The system was able to detect double billing, upcoding, billing for services not provided and identity theft.



Select Data: Claims

Look In: DATA

x
ARY (2).xlsx
ARY (3).xlsx
ARY (4).xlsx
ARY 2016.xlsx
ARY 2016-1.xlsx
FFS PAYMENT SUMMARY 2017 3.xlsx
FFS PAYMENT SUMMARY 2018.xlsx
FFS PAYMENT SUMMARY 2018-1.xlsx
FOUNTAIN CLAIMS FORM.jpg
Mansard Claims Form.pdf
Mediplan.jpg
Multishield.jpg
PREMIER MEDICAID.jpg
TEST DATA.docx

File Name: Mansard Claims Form.pdf

Files of Type: All Files

Figure 3: Data Capturing

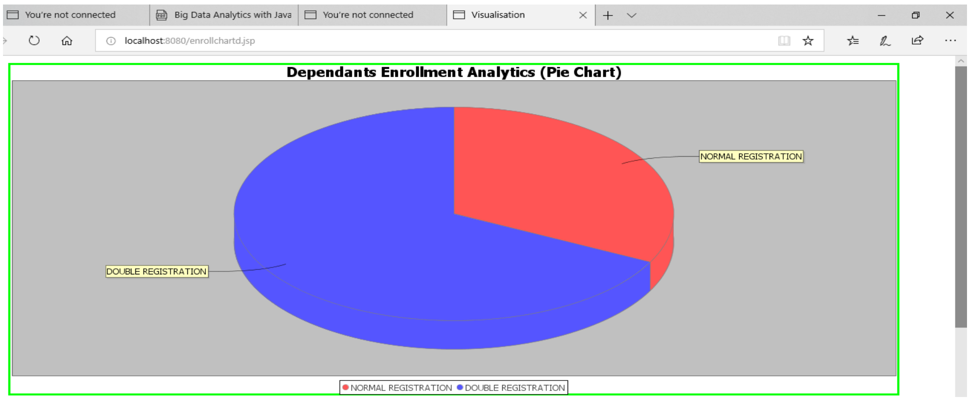


Figure. 4: Summary View of Processed Principals' Enrollment Data

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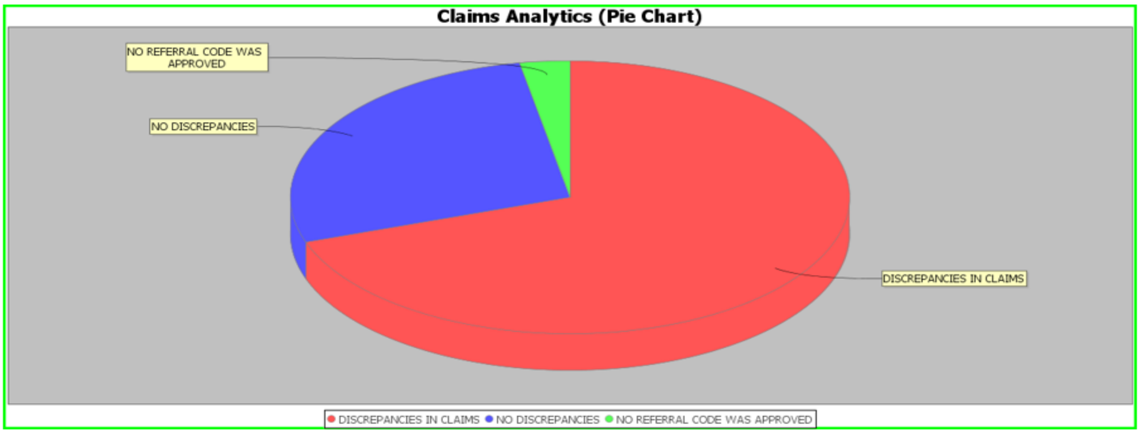

Figure. 5 Summary View of Processed Claims Data

Enrollment Processing: This module is responsible for adding or updating enrollees' information. These include personal information, next of kin information, educational information, employment information, primary providers *etc*. During enrollment, enrollees are checked to ensure that no enrollee registers twice, the number of biological children for an enrollee is not more than four. Also, that a child that is more than eighteen years is either de-register or not allowed to register. The enrollee is only allowed to register one spouse at a time. Also, there is provision to add one extra dependant which can only be allowed when the enrollee accept to be paying five thousand naira annually in addition to the normal monthly contribution. Again, enrollees who are not staying together with their dependants are allowed to have different primary facilities, otherwise, the system only allowed them to have one facility in accordance with NHIS guideline. The module was able to detect double registration of enrollees, registration more than four biological children, registration of children that are more than eighteen years and ghost enrollees.

Referral Processing: The module is responsible for the handling cases of referrals. A beneficiary is referred to another NHIS accredited hospital when the medical condition of the beneficiary is more than what the primary provider can handled. The principle of referral is that a beneficiary should be referred to the next closest NHIS accredited facility for a more specialized care. When referrals are made, the system evaluates the diagnoses in the referral request and compares it with what allowed by NHIS to be handled by the next level of healthcare. It also checks the distance between the facility they are referring the patient to and other facilities around the same location with the primary facility that is making the referral on behalf of the enrollee. In an event where the distance is more than the other facilities, such referrals are queried. Also, if the medical condition of the enrollee is not more than what should be handled at primary facility, they are also queried. Again, if the diagnoses do not tally with what the next hospital is registered to carry out, it is also queried. Otherwise, the NHIS guideline stipulates that referrals should not last for more than forty-eight hours with the HMOs. The module was able to detect self-referral, and collusion with providers.

5 Conclusion

In conclusion, this paper developed a system for the detection of the fraudulent activities of the actors of NHIS. This system employed data from the Nigerian NHIS which was categorised into: enrollment, referral and claim data with different file formats: pdf, jpg, png, csv and excel. The system was designed using UML and implemented using Association Rule Mining, MapReduce Framework, MongoDB, MySQL and Java Programming Language. The system was able to detect several fraudulent activities of providers, insurers and beneficiaries. These ranges from self-referral, collusion with providers, double registration of enrollees, registration more than four biological children, registration of children that are more than eighteen years, ghost enrollees, double billing, upcoding, billing for services not provided to identity theft. This system when adopted by NHIS, it will sanitise the entire Scheme.

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Digital Empowerment for Health Workers and Implications on EMRs Utilisation

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Background and Purpose: Utilization of Electronic Medical Records (EMRs) bring many benefits to patient record handling. Previous research has shown that medical doctors in hospitals in Africa had poor IT skills, partly disabling their use of EMRs. Working in health centres, we wanted to know how to improve the digital skills of their personnel.
Methods: Qualitative methods including interviews, informal discussions and observation were used for data collection. The study was conducted in three health facilities in Malawi, selected purposively as these were the ones implementing the EMR under study. The study targeted all staff that were capturing data at point of care using the app between January and June 2019.
Results: Personnel in the health centres were computer illiterate, even if they used phones, and some smart phones. After computer training, they were still not comfortable using EMRs because their typing speed was delaying the process. Improving the typing speed allowed the users to comfortably use the EMRs. Three levels of EMR empowerment were identified; being able to 1) use EMR where typing speed is less relevant, 2) use EMR at point of care, 3) guide colleagues on their EMR use and find new ways of exploiting the technology. For reaching level 2, 50-100 hours of typing practice would be necessary.
Conclusions: Health workers who lack computer skills tend to shy aware from using EMRs. Even if falling prices of equipment will enable more EMRs in rural areas, the digital empowerment process will still require significant resources.

Keywords: Electronic Medical Record, Digital Empowerment, Computer Literacy, Keyboard Typing.

1 Introduction

In health care, the patient record is at the center of everything [1]. Over the years, different information systems have been developed to improve the way of handling the patient records. One of the ways is the introduction of Electronic Medical Records (EMRs). “The electronic medical record has been pursued as an ideal by so many, for so long, that some suggest that it has become the Holy Grail of Medical Informatics” [2]. Further, some believe that handling the increased complexity of health care processes is almost impossible without the use of electronic records. Literature has shown that utilization of EMRs bring many benefits which include quality enhancement; efficiency of care; easing labour shortages; medical error reduction; providing accurate, up-to-date, and complete information about patients at the point of care; enabling quick access to patient records for more coordinated, efficient care; securely sharing electronic information with patients and other clinicians; improving patient and service provider interaction and communication; and reducing costs through decreased paperwork [3, 4]. Much as there are so many benefits associated with the use of electronic records; these benefits are realized once the requisites are in place. *Just like a car owner cannot drive his car without having driving skills; and may not enjoy driving if he has minimal driving skills;* In the same vain, a health worker who is not digital

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literate or has minimal digital skills may not be able to achieve the full benefits of an electronic system even if it were made available to them. They have to be digital empowered first.

Digital empowerment, is developing digital mastery in your particular field. In this paper we focus on health workers using EMRs. We argue that the health workers should have the digital literacy and skills to be able to competently use the EMRs. Kuek and Hakkennes [5] confirm that staff with low digital literacy adversely affects the safety and quality of patient care where EMRs are in use and they strongly recommend training of such staff prior to implementation of an EMR. Digital experience of the health worker matters in this case. In this study, we use health workers in Malawi as a case.

1.1 EMR Utilisation Gap in Malawi

Utilisation of EMRs in Malawi dates back to 2001. However, a study conducted by Msiska et al. [6] reveal that in the two main referral hospitals, some health workers still prefer to use paper-based records to EMRs. One of the factors hindering progress of EMR utilization is low digital skills amongst health workers. A global study revealed that the root cause of many issues is due to the fact that employees are not digital literate enough [5, 7, 8]. This is where this paper zeros in, critically analyzing the impact of digital experiences for health worker on EMRs utilization and discussing some processes and practices that can help in digital empowerment of health workers. A number of pilots have demonstrated that use of EMRs is possible and that they can expand to manage hundreds of thousands of patients. One important thing that needs to be taken into consideration is the time it takes to capture these records against the number of patients waiting to be served.

2 Literature Review

2.1 EMR Utilisation

Globally, EMR utilization is on the increase and have been widely adopted [9]. An EMR is an individual's health-related record, generated and managed using computer software, and used by authorized healthcare workers. Many researchers have testified that EMRs offers numerous benefits to the healthcare sector where it comes to patient record management; others are of the contrary view and to them, EMRs are "*a known source of frustration, stress and burnout for physicians*" [10]. Kunzmann [10] argument is based on a number of surveys: 1) where John Prunskis, MD, asked his staff of 75 health care providers a simple question: Which was better—their new EMR system, or the record-keeping system it replaced and not a single member of his staff could throw their support behind the EMR. 2) Another assessment conducted in July 2017 of 1752 practicing family physicians found that 44.6% (782) believed they spend an excessive or moderately high amount of time working on EMRs at home. 3) A cohort study of 27 ophthalmologists from November 2017 reported that a mean of 27% of an ophthalmologist's time with a patient is spent on EMR use —equating to nearly four hours per day. 4) When the question: "*are EMRs a boon or a bane your spine practice?*" was posed to Spine doctors and all of them felt it was bane to a larger extent; emphasizing that the EMRs can only become boon if fully implemented. Although most Medical Doctors view EMRs as being bane, EMR implementation has several benefits. Expected benefits must be weighed against the cost of software, hardware, and training as well as the ongoing costs of updating all three [11]. The benefits include: minimizing missing information and error reduction [12]. Castelnuovo et al. [12] allude to the fact that the improvements came about given the long implementation which allowed the clinic staff to gain knowledge and experience, as well as data quality awareness

2.2 EMR Implementation Cost

As EMR utilization is being widely adopted in developed countries, the same is true in developing countries. However, there is one notable difference between EMR development and implementation in the developed and developing countries. In developing countries EMR implementation is externally funded and failure of such implementations has far reaching implications both to the implementer and the funder. Ironically, the cost of implementing an EMR can be very high. Fraser et al. [6] estimate the cost of implementing an EMR in rural Haiti at $45,000; Humpage [11] discuss a major EMR initiative that will allow doctors from any institution access their patient's complete EMR in Mexico called the NECE (nuevo expediente clínico electrónico) with two components - software and hardware infrastructure to receive and provide information from diverse EMR systems, and a legal framework to regulate EMRs and guarantee their interoperability. This system is estimated at US$450 million over five years.

2.3 EMR Challenges

Amidst the many benefits of EMRs, there are also some challenges, if not properly handled, these may lead to failure. In developing countries, the problem of limited resources begs several questions whether this use of technology is practical beyond a few well-funded pilot sites and whether it has a beneficial impact on patient care or the management? [13, 14]. Further, in developing countries, there is a long history of healthcare information systems being used for generating aggregate statistics for higher levels [15]. EMRs are also believed to require comprehensive personnel training - personnel have to be trained on opportunities related to computer utilization [16]. Castelnuovo, Kiragga [12] found that usage of mandatory fields in an EMR has the danger of information being "invented or faked" to be able to continue with data entry. Further, EMRs are believed to have high adoption costs [16]. Further, a study conducted by Mohammed, Andargie [17] in Ethiopia recommend that the association between computer knowledge/skill and health care delivery competence should be studied. Another challenge is when the EMRs are provided from different vendors since every vendor has its own expertise [18]. Achieving high standards is also considered to be a particular challenge in sites with limited computer literacy and experience and it erodes the data quality [13, 14]. It is also believed that EMRs which are complex to use, the problem arises due to not properly thought through designs.

2.4 Digital Empowerment

The concept Empowerment has been used to express ideals related to changes, both for outcomes and the process itself, the latter often expressed as Empowering. In a literature review of Empowerment as outcomes in change processes in ICT for development, Pandey and Zheng [19] identified six categories:

- Community – mobilization to go beyond traditional limitations
- Psychological – self-esteem, self-perception, self-efficacy, participation, perceived control
- Gender – equal rights, voice, freedom of expression, independence
- Cultural – freedom of expression of cultural identities, rituals, tradition, language narratives
- Economic – basic goods, freedom from misery and dependence
- Political/structural – civil society mobilization

The operationalisation indicated in each category points to new capabilities being achieved. These six categories do neither address use of EMRs in any specific ways nor identify levels of empowerment.

With a case of health management information system, a taxonomy with two levels of digital competence were identified; Skills as the basis level, while the Advanced level included the abilities of Problem Solving, Learning, Helping others and Technical communication [20]. These covered the three areas Technology, Health Information and Use of functionality for work tasks.

A recent taxonomy introduced the six domains Technology, Health information, Digital identity and safety and security, Creation and Innovation, Teaching and learning, and Communication and collaboration [7]. Each domain had four levels, thus this is a much more fine-grained taxonomy. Considering Empowerment, we will say that for each domain, each level represents a level of empowerment from none up to the expert level. The expert level, which corresponds to the Advanced level in [20] has the characteristics of IT users called super-users [21, 22], power-users [23] and peer-coaches [24].

For empowerment in this study, the levels of basic technical skills to carry out the work (Level 1 in the technological domain in both models) and super-user (Advanced or Expert) will suffice as the basis for this study.

2.5 Digital Experience and EMR Implementation

Most studies find that the digital experience (computer knowledge and utilization) for most staff/users in the health facilities in developing countries is low [18] [17, 25]. Training instils confidence in the usage of the EMRs among users as it increases the knowledge and utilization of computers and facilitates the rate of diffusion of the technology to the health sector.

3 Methodology

3.1 Approach

An interpretive approach was used to analyse the data collected in this study. Other than assuming that meaning is socially constructed; interpretive research approach is concerned with understanding what is specific, interesting and unique about the social phenomena. The phenomena in this case is the implications on EMRs when health workers are or are not digital empowered. The empirical data from Malawi. The broad mHealth4Afrika project deployed co-design approach. Co-design is a well-established approach with its roots in the participatory design techniques, used as an umbrella term for participatory, co-creation and open design processes.

3.2 Methods

Qualitative methods were used to collect the data as they place great emphasis on the data collection methods. The methods included interviews, informal discussions and observation. Interviews were chosen as they allow for investigation of issues in an in-depth way and also allowed the researcher to probe why the health workers were or were not utilizing the EMR and probe the opinions they hold towards its implementation. Observation on the other hand provided the researcher liberty to use their senses to examine the behaviour and utilization patterns, and the interactions they were having with the EMR in the health facilities. It gave the researcher an opportunity to verify whether what they said, corresponded with the way they interacted with the system and gave information that goes beyond mere sayings.

3.3 Study Site

The study was conducted in two districts in the southern part of Malawi – Machinga and Zomba districts through an mHealth4Africa Project [26]. A total of three health facilities were studied – one in Machinga called Gawanani and two called Bimbi and Magomero in Zomba districts. The three healthy facilities were selected purposively as these were the ones implementing the mHealth4Afrika App, the EMR under study.

3.4 Data Collection

The study targeted all staff that were capturing data at point of care using the mHealth4Afrika EMR. Data was collected between January and June 2019. Interviews formed the main data collection tool in this study. Participants were interviewed during both the system implementation period, before the project ended, and after the project life. The interviews were conducted with the health workers eligible to be utilizing the system during implementation and the same number of health workers were also interviewed after implementation. The idea was to find out from the participants their opinion about the EMR, and if the way the EMR implementing project processes had a positive, neutral or negative effect towards the project's success. In total, 25 interviews were conducted, 15 during project implementation and 10 after projects life. In addition, observations were done on a daily basis by one of the authors. The data collected from interviews and observation was complemented with the number of transactions captured by a single health worker per day over a period of time.

3.5 Data Analysis

Data analysis was "based on the experiences and processes revealed by the text data" [27] collected. The analysis was based on the following: Usage vs number of patient records captured; number of patients captured vs digital experience at a particular point in time; opinions on EMR utilization etc.

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3.6 Ethics

Ethical approval for the mHealth4Afrika project was obtained from the National Health Sciences Research Committee of Malawi.

4 The Case

The study used an application developed through the mHealth4Afrika project through a consortium funded by the EU Horizon 2020. mHealth4Afrika Application is a HL7 FHIR-compliant comprehensive, scalable, and adaptable patient-centric health platform that interacts with a data model set up in DHIS2 via a WebAPI [26]. DHIS2 is a generic toolkit that supports Ministries of Health to configure a data structure that can be used to store aggregate monthly program indicator related data for analysis [28]. In Malawi, DHIS2 is used as the Health Management Information System. mHealth4Afrika application was co-designed and validated with Ministries of Health, District Health Officers, Clinic Managers and Health Workers in four countries (Ethiopia, Kenya, Malawi and South Africa). It integrates electronic medical record (EMR) functionality with the use of medical sensors, and analytical, visualisation and decision support tools to facilitate monitoring and interpretation of patient results. The aim of the mHealth4Afrika Application is to support the efficiency and effectiveness of both management and healthcare professionals in primary healthcare facilities.

The development process started with one programme, but due to the co-design nature, the health workers asked for a holistic Application, with all programmes [29, 30]. Currently, the mHealth4Afrika Application has the following programmes: Medical History, Maternal Health (Antenatal Care, Delivery, Postnatal Care), Family Planning, Child Under 5, Tuberculosis, ART, and Outpatient Department. Essentially, the development process was iterative, started with alpha version, got feedback and re-designed the UIs, developed beta version. During the pre-beta validation in June 2017 the health centres asked for a more comprehensive health information system that allows a patient to be registered once and then enrolled in multiple programs depending on their health conditions over a period of time, to facilitate holistic monitoring of a patient's well-being. The health centres needed a platform that supported a range of interdependent services to facilitate holistic monitoring of a patient. Feedback from the beta version led to the development of the second iteration of the beta platform, Beta v2. This version has a number of repeatable stages around the core areas of Growth & Nutrition, Immunisation and Childhood Illnesses. A third iteration of the beta platform followed. It included a new user interface and refined workflow; updated Clinic related functionality, updated Patient list, Clinic appointment list, Program specific Access rights for healthcare workers; and updated Patient related functionality. Most importantly, it included program reporting for individual patients. Final refinements were done in Beta v4. In the requirements solicitation phase, it was found that health workers in the facilities spend an average of 5 to 7 person days each month per clinic to manually count relevant data sets across multiple manual paper-based registries; a necessary exercise to prepare the aggregated statistics that are provided to the district health office each month. However, this data was found to be extremely inaccurate. The functionality to automate this count based on electronic patient records and provide access to this anonymised aggregate data on a monthly basis across programs will save the health workers a considerable amount of time (60 to 84 working days per clinic – the equivalent of three or four months) across a calendar year.

During the implementation of the mHealth4Afrika project, a number of implementation and adoption challenges were identified, experienced and addressed in different ways. The challenges related to infrastructure, digital literacy skills, technologies, and access to reliable power among others. For the purpose of this paper, we will focus on the challenges of digital literacy skills and technologies. This learning curve helped the researchers identify processes and procedures to solve these challenges, in the process, learning and building on to the good practices.

5 Findings

Much as we were set out with the mind that automation of the patient records will save the health workers a considerable amount of time, this was not the case in the first instance. It was discovered that there were several other critical factors; digital skills being one of them.

5.1 Characteristics of Study Participants

A total of 15 health workers participated in the study, 9 female and 6 males. Three clinical officers (one from each health facility); 6 nurses; and 6 community health workers. Most health workers have worked with a particular program they were responsible for capturing data for more than 2 years. Out of the total, none of the health workers had a computer for their work and over 80% were not digital literate at the inception of the mHealth4Afrika project. All of the participants (100%) had mobile phones; however, only 27% had smart phones. None of the health workers had proficient typing skills.

5.2 Challenges Encountered During Implementation

After training the health workers how to use the EMR, it was found that despite their being enthusiastic about electronic system, some of the health workers were shying away from using the EMR. Upon probing, it was established that they were not comfortable using the EMR on their own; and whenever they tried, they found that they were too slow, hence delaying the patient queue.

The slowness was yet another factor that led to health workers stop using the EMR. There were cases where the health workers knew all the procedures and how to navigate through the system; however, they were very slow in typing. Due to the original qualitative study design, measurements of typing speed were not taken, it was only observed to be slow. The slow speed meant that the patient queue would grow and the patient would have a long wait on the queue. In cases where the health workers persisted and continued using the system; the long waits on the queue would discourage some of the patients and they would start complaining; some talking against the system.

Another group of health workers would stop using the EMR and postpone the electronic data capturing to later time. However, considering the workloads, the health workers already would knock off late, making it difficult to find time later for data capturing.

5.3 Feedback through Co-design

Co-design being an open design process, provides a lot of room for interactions between the researchers and participants. These interactions provided the health workers a good platform to provide feedback which is the issues highlighted in section 5.3. The health workers were honest enough to explain that they were digital illiterate. This was explained after the initial situation analysis. After they underwent a digital literacy training, they gave more feedback that their pace of typing is causing delays and leading to patients complaining of long waits.

6 Discussion

Implementing an EMR, is one thing, having the EMR fully implemented and fully utilized is another. As mentioned by Braa and Hedberg [15], healthcare information systems in developing countries have been driven mostly by the need to report aggregate statistics for ministry or funding agencies; in this case, EMRs bring a new paradigm where each patient record has to be captured in the system. The capturing of the data requires both digital skills and typing proficiency – be it trained or acquired through experience.

6.1 Role of Co-Design in Digital Empowerment

In this study, we used co-design to design and develop the mHealth4Afrika Application. Research has shown that there is a paradox of technology where electronic systems are introduced as a solution and later the very solution brings more challenges [31]. In this study, the co-design allowed for two-way interaction between the implementers/researchers and the facility staff, discussing the possible solutions to the challenges encountered there and then. A combination of adopting co-design and agile development was beneficial in facilitating responsiveness to inputs based on active stakeholder engagement and proved to be very valuable. For any innovation to take shape, prerequisites should be set [31]. In the absence of the co-design that provides for interaction, the health workers would end up shying away completely from using electronic system and relying mainly on paper-based registers and forms to collect and report routine data. This emphasize what Nguyen, LeFevre [32] found.

6.2 Problematizing Digital Skills Gap amongst Health Workers

In most cases, electronic systems are deployed in health facilities with a requisite of few days training on how to use the system. The findings indicate that none of the health workers had a computer; over 80% were not digital literate; only 27% had smart phones and none had proficient typing skills. This is a clear indication that most health workers would struggle to competently use electronic system despite having a few days training.

The progression while learning a skill normally follows a hyperbolic curve reaching a plateau. The findings suggest that we have to consider two aspects of the computer skill learning separately. First, the health personnel learned the sequence of operations and where to locate these quite quickly, corresponding to the shape of the blue curve in Figure 1. This curve is an illustration and is not based on quantitative observations. Second, getting up to speed of typing follows a more gradual learning curve, reaching the required speed to carry out the typing at point of care after a much longer period of practice. A study of the learning speed of keyboard typing showed that after 20 hours of practice, the speed was around 7 words per minute (WPM), and thereafter a linear increase to around 35 WPM minute after 80 hours [33], illustrated by the red curve. The learning speed is thus 1 additional WPM after 2 hours of practice. Training will speed up the learning somewhat, but practicing for 40-80 hours may be needed to achieve typing skills which are useful at point of care. The lack of digital experience hinders the health workers using the electronic systems. This can lead to the health workers abandoning a system that is functioning properly.

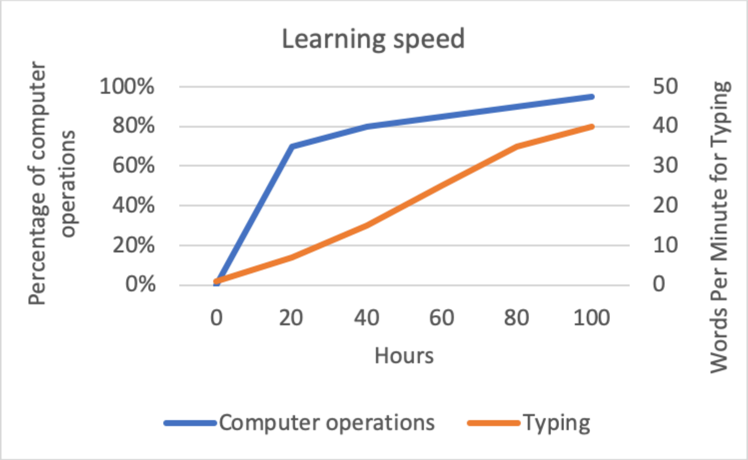

Figure 1. Learning curves for learning computer operations and typing

The observed difference in speeds of learning also points to inadequacies in the first level of digital competence in both of the taxonomies referred to [7, 20]. Their first levels should include typing and also which speed of typing that is required for the tasks to be carried out.

6.3 Implication of Digital Empowerment on EMRs

The findings showed that health workers were shying away from using EMRs as they were trying to balance between using an EMR and attending to the high patient volume. Of interest in this paper is the revelation that digital empowerment plays a critical role in the success of EMRs. According to the findings, all what the health workers knew was that the EMR was going to ease their work, learning from the benefits cited in literature, only to find out later that without typing skills, it is very hard to use an EMR. This is emphasizing Norman's [34] sentiments that much as technology is supposed to simplify our lives, what it provides can also complicate the same lives it is supposed to simplify.

The range of domains where the concept Empowerment has been used was summarised in section 2.4, and none of these captured the specifics of learning EMRs. Based on our findings, we would rather suggest the three levels of empowerment for health workers' EMR practice in Table 1. At point of care, the health worker has to type and operate the computer with a speed corresponding to that of writing in paper registers, not to delay the flow of patients. In an administrative setting, where no clients are waiting, speed has less relevance, such that slow speed during the first months of using a computer system can be tolerated. For health personnel, we will thus identify two levels of ICT competence, for administrative and care tasks respectively. The distinction between levels 1 and 2 concerns the higher speed of operation needed for point of care.

Table 1. Empowerment levels for health personnel concerning electronic medical records

1	Being able to use the EMR in an administrative setting.
2	Being able to use the EMR at point of care.
3	Being able to guide colleagues on their EMR use

Bringing the same ideas over to the social life, a person at level 1 could use the computer for browsing, since little typing is needed. For the task of writing an application, this would require some typing speed or take very long time. Social media, where quick responses may be expected, might require a typing speed corresponding to that of point of care. Level 3 correspond to people being able to help their family and friends using with computers and suggest using ICT where appropriate.

In Section 2.4, digital empowerment was defined at two levels; basic technical skills to carry out the work and super-users who help others. Typing speed is a general digital skill and can hence be distinguished from specific competencies required for one application. Adequate speed of operating computers could therefore constitute a basic level of digital empowerment, since this general skill empowers people to use IT for other purposes, while inadequate speed would mean a disempowered computer user. We will therefore refine the empowerment definitions into the two levels in Table 2.

Table 2. General empowerment levels for computer use.

1	Technical skills at adequate speed empowering the person to productively use computer applications.
2	Super-user helping others learn computer use, suggesting new ways of using the technology, and adapting the ICT.

The second general level, corresponding to EMR empowerment level 3, might only be reached by some people who experience ICT as particularly interesting and relevant.

7 Conclusion

EMRs may have the potential to offer so many benefits to health workers, however, if the prerequisites such as necessary skills are not in place, this remains a mere dream.

We extended the list of domains for empowerment from [19] to include digital empowerment, meaning adequate capacity to use computers, and at a more advanced level, to help others use computers.

In their recent literature review on adoption of EHR in Africa, Odekunle et al. [8] report that medical doctors had poor IT skills, including low typing proficiency referring to publications up to 2013. This study addressed health centre workers, all of whom were below the medical doctor level of education. Unsurprisingly, seven years later, the digital literacy amongst lower level health worker cadres in rural area is inadequate. Also, there was little transfer of skills from smart phones to computers, partly due to the much higher need for typing on computers and also the experienced complexity of computers versus phones. Kuek and Hakkennes [5] also found that one third of hospital personnel in Australia were not so confident in using the information systems in the hospitals. This seems to indicate that this problem is not only for health personnel in rural Africa.

Prices of computer hardware and solar power are falling, the internet is extended by mobile phone operators, and the smart phone is penetrating into rural areas. Computer literacy levels are to a minor degree influenced by these developments, however. Significant resources are therefore needed to empower health workers to become efficient and effective computer users, and even to help others, suggesting new ways of using the computer and adapting the systems on their own.

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Cost Analysis of an Electronic Medical Record System at an Urban Clinic in Kampala, Uganda

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Background and Purpose: While the benefits of electronic medical record systems (EMRS) are well known, the costs associated with their implementation in resource-constrained settings are not well documented. Establishing such costs is crucial for sound decision-making regarding allocation of scarce resources. This study aimed at conducting a comprehensive cost analysis for developing, implementing and maintaining an EMRS in a resource-constrained setting.
Methods: The study was conducted at an urban HIV/AIDS clinic in Kampala, Uganda using an organizational perspective. A cost inventory was used to collect costs from original receipts and invoices, and vendor market prices used where receipts could not be accessed for the 8 years under study. All costs were converted to the equivalent US dollar value and those with a lifetime more than one year annuitized. A paper-based and an open-source record system were the comparators.
Results: The total direct cost of the system was USD 1,066,965 while an open-source instance would cost just over USD 800,000. The paper-based system cost was half the cost of the EMRS (USD 544,159). Salaries and wages contributed 70% (USD 757,332) and 81% (USD 438,842) of costs in the EMRS and paper-based system, respectively. The other major cost driver was software and licensing (20%, USD 258,341).
Conclusions: EMRS have higher costs as compared to paper-based medical record systems. However, expenditure on the system reduces with time. Salaries and wages are the largest contributors to the cost burden. Open-source systems have a potential to lower costs.

Keywords: Cost Analysis, Electronic Medical Record System, Developing Country

1 Introduction

Electronic Medical Record Systems (EMRs) are increasingly being utilized in developing countries to support care.[1] This is evident from the fact that countries like Kenya, Uganda, Mozambique and Nigeria are rolling out EMRs systems nationally within the public health sector to support care such as for HIV patients.[1] EMRs promise to improve efficiency, quality and safety of medical care delivery.[2] Furthermore, these systems have the potential to strengthen the health system, by improving use of data for decision making, and for reporting to the national level.

Implementation of these systems however comes at a cost. High EMRs costs have been shown to impact adoption of systems and subsequent success of EMRS implementations.[3] In low- and middle-income countries (LMICs) where resources are already constrained, strong justification is needed to allocate resources towards EMRs implementations, as opposed to using these resources for other proven health interventions. Cost evaluations of EMRs aid in the justification for implementing these systems, and provides relevant information to help decision-makers in allocating the limited resources.

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To date, there is a dearth of rigorously conducted evaluations and publications on the costs of EMRs systems that are currently being deployed in LMIC-settings. While there has been strong focus on evaluating the benefits of EMRs on patient outcomes, data quality, reporting and other aspects, little has been done to assess the related costs. In this paper, we present a systematic evaluation of the cost of implementing an EMR system to support HIV care in Kampala, Uganda using an organizational perspective. We further compare these costs against a widely used open source system and also against the cost of a paper-based record system.

2 Materials and methods

2.1 Study Setting

This study was conducted at the Infectious Diseases Institute (IDI) in Kampala, Uganda. IDI is a not-for-profit organization with a strong emphasis on infectious diseases and provides care to People Living with HIV and other infectious diseases. Since December 2017, IDI has served over 50,000 adult patients. Prior to implementation of the EMR system, the institution used a paper based medical record system. In addition, the institution had a Microsoft Access based electronic aggregation system where summaries were entered by data entrants. From 2009 the clinic embarked on development and implementation of a home grown EMRS systems which was fully deployed.

2.2 Study design

This was a retrospective quantitative study of the direct costs of EMRS implementation. The costs were compared with the calculated costs of a paper-based system at the same facility, and of an open-source system, OpenMRS,[5] that is widely adopted for HIV care within Ugandan public health facilities. Research is a core component of the IDI work and therefore an estimate of how much would have been spent into data abstraction and retrieval from the paper-based system was compiled with input from a key people from the research department.

2.3 Study approach

We use well-accepted metrics for evaluating the cost of the three systems for comparison, namely IDI EMRS system, paper-based system, and the OpenMRS system. Input metrics for costing were derived from those outlined in the systematic review on economic evaluation of health information systems conducted by Bassi et al.[6] Key cost input metrics included one-time implementation costs and the ongoing costs after initial implementation. One-time implementation costs were determined for: hardware and peripherals, network and telecommunication supplies, application development and deployment, configuration management, packaged and customized software, project planning, contract negotiations, procurement, initial IT support costs, costs of converting retrospective data, initial user training, end-user project management, facility upgrades, office accommodations, site assessment costs, transition costs, and quality assurance costs. Ongoing costs included software maintenance, upgrades and subscriptions, system maintenance, hardware and equipment replacement, salaries of IT and end-user staff, ongoing training, facilities rental and utilities, EMRS consultant costs, other personnel costs, reviews and audits and ongoing operating costs.

2.4 Data Collection

Where available, cost data were retrieved from financial records from the accounts department of the institution. Where original receipts or invoices were not available, prevailing market rates from local suppliers were used, averaging quotations from three suppliers. If the item did not exist in the local market, online vending sites like Amazon and eBay were considered to provide information on the cost of the item.

To determine time personnel costs related to the system under evaluation, a modified Delphi technique with key informants to determine the percentage of time staff spent towards system development,

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deployment and maintenance.[7] Government documents from the ministry of Public Service of Uganda were also reviewed to provide salary and wage rates and employee benefits as well as job descriptions. All costs were recorded on cost inventories that was as designed by the research team and the study was approved by the Moi University Institutional Review and Ethics Committee and permission to conduct the study was sought from the top management from IDI, and from within each relevant department in IDI through its head of department.

2.5 Data Analysis:

The study looked at costs and savings from the organizational (implementer's perspective) and only looked at the direct financial effects without considering value placed on non-financial outcomes as these were beyond the scope of this evaluation. The detailed items of costs were determined based on differential costing, which is mainly used for decision making in managerial accounting, after comparison of workflows between the paper-chart system and the EMR system. For reporting, all costs were converted into US dollar using the mid-year rate for each of the individual years. Costs with a lifetime of greater than one year were annuitized using a well-accepted annuitization formula by Drummond et al., and using an annuity factor of 0.823 and interest of 4% per Drummond et. al's recommendation. Depreciation rates, were calculated using a reducing balance depreciation rate of 40% was used as per recommendation by the Uganda

3 Results

3.1 IDI EMRS Costs

Costs are provided for the evaluation period between 2009 and 2016. Total actual direct costs for development, deployment and maintenance of the home-grown EMRS at IDI during this period came to USD 1,066,965 (**Error! Reference source not found.**). When annuitization and depreciation is applied, this cost comes to 1,084,498.18. 71% of the overall costs went to staff salaries, and 24% to software licensing. Salary costs were largely associated with recruitment with two international consultants, two local developers, two IT support staff and data managers. Additional costs included the wages of health providers including a nurse and doctor who participated in the design and championing of the system. Hardware bought included personal computers (USD 24,500), switches (USD 600) and cables (USD 1000), a power backup generator (USD 2500), one 16 core processor, 64 gigabyte random access memory (RAM), 10 terabyte server, and 3 Uninterruptible power supply (UPS) (USD 300). Several licenses were required for the EMR and these included; Kaspersky (USD 458), Visio studio ultimate (USD 15,698), ReSharper (USD 1,168), SQL 2005 license (USD 199,992). Utility costs primarily included electricity costs.

Table 1. Costs of IDI EMRS development, implementation and maintenance (2009-2016)

Category	**Item**	**Year**								
		2009	2010	2011	2012	2013	2014	2015	2016	Total Cost
System development	Salaries	244,258	222,486	-	-	-	-	-	-	466,746
	Software	12,769	4,547	-	-	-	-	-	-	217,316
	Hardware	8,102	4,300	-	-	-	-	-	-	12,402
	Utilities	68	57	-	-	-	-	-	-	125
Deployment and maintenance	Salaries	-	-	65,114	57,846	45,804	43,362	39,445	39,013	290,587
	Software	-	-	15,370	5,520	5,520	5,520	5,520	5,520	41,025
	Hardware	-	-	29,212	612	612	612	612	612	32,272
	Utilities	-	-	573	785	760	711	650	676	4,157

Total		**465,198**	**231,390**	**110,660**	**64,763**	**52,697**	**50,205**	**46,227**	**45,823**	**1,066,965**

The overall cost of the inputs for the IDI home-grown system showed a downward trend with costs being highest in the earliest years and levelling out in the subsequent years (**Error! Reference source not found.**).

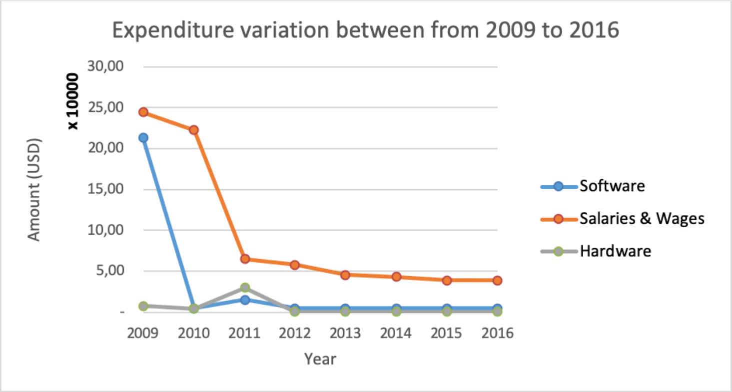

Figure 1. Variation of individual cost items for IDI EMRS from 2009 to 2016

3.2 OpenMRS and paper-based system costs

The calculated costs of running the open-source OpenMRS in the same facility over the same period was almost 20% ($806,290) lower than that required to develop and maintain the proprietary software at IDI even when using similar salary estimates for both systems (**Error! Reference source not found.**). This is because of the significantly lower costs related to system development and software for the open source system.

Table 2. Estimated cost of running an Open source EMRS in the same setting.

cost	**Item**	**Year**								
		2,009	2,010	2,011	2,012	2,013	2,014	2,015	2,016	Total
Development	salaries and wages	244,258	222,486	-	-	-	-	-	-	466,745
	Hardware	8,102	4,300	-	-	-	-	-	-	12,402
Deployment and maintenance	Software licensing	-	-	-	-	-	-	-	-	-
	Salaries	-	-	65,114	57,846	45,804	43,362	39,445	39,013	290,587
	Hardware	-	-	29,212	612	612	612	612	612	32,272
	Utilities	67	56	573	785	760	711	650	676	4,282
Total		**252,429**	**226,843**	**94,900**	**59,243**	**47,176**	**44,685**	**40,707**	**40,302**	**806,289**

The direct costs of running a paper-based system including stationery costs and data entry costs into an MS Access database came to USD 544,160 with over 85% of the costs going towards salaries and wages (**Error! Reference source not found.**).

Table 3. Direct costs of running a paper medical record system (2009 - 2016)

Item	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Stationery	16,138	15,048	12988	12383	11233	9323	7057	6681	90,855
Personnel ($)	71566	62493	56738	56084	57202	51430	42173	41152	438,843
Computers	4200	-	-	-	-	-	-	-	4,200

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Data Extraction	9,300								9,300
Utilities	135	113	98	134	130	121	111	116	962
Total	**92,040**	**77,655**	**69,825**	**68,604**	**68,566**	**60,877**	**49,341**	**57,251**	**544,160**

4 Discussion

In this paper, we present the direct cost evaluation of implementing a home-grown EMRS in an LMIC to support HIV care. Even for a small implementation, these costs come to over a million dollars over a seven-year period. The main drivers of cost were salaries and wages which accounted for over 70% of the direct cost followed by software licensing with over 20%. Contrary to what would be expected, hardware accounted for the smallest portion of the cost burden. These findings are similar to those of a study that also reported that human resource costs accounted for the highest portion of the costs.[9]

From our study, it is evident that direct cost reductions could be achieved using an open source EMRS. However, open source does not mean ‘free’, as human resource costs still contributed to a large component of the costs. This observation highlights one of the key factors that could be leading to many of the implemented systems not being sustained beyond the pilot stage, as implementers might think that all they need to do is to put hardware in place, and that the other factors will automatically workout, only to realize that there are significant continued costs for maintaining these systems.[9]

We observed an interesting but expected trend in costs with time. The costs of the system were higher at the onset but there was a general downward trend of these costs with time with the total cost in 2016 being just 16% of the costs incurred at the start in 2009. This is attributable to the fact that at onset, both hardware and software must be procured, and the full-time equivalent contribution of the staff was high with staff contributing between 50 to 100% of their time to the EMR and this went on reducing over time to around 20-50% time contribution. This is similar to findings from other studies although most of these were conducted in the developed world.[10]

In comparison to the cost of running a paper based medical record system, maintaining a paper based medical record system between 2009 and 2016 cost less than 50% of amount required to develop, implement and maintain the electronic medical record system. This is similar to findings from other studies that also reported increments in expenditure due after implementing EMRS. [9,11] These added costs are due to need for more specialist personnel to manage the system hence creating new job openings and more expenditure on salaries and wages. The EMRS also came with need for procurement of new hardware and software, increments in electricity consumption as highlighted under the results section. However, simple direct cost comparison between paper and EMRS miss the indirect costs of the various systems, with paper-based indirect costs potentially being higher. Further, the benefits of the EMRS systems are also not considered in direct cost calculations, and this might affect the equation as to whether to implement the EMRS instead of a paper-based system.

Our study is limited by the fact that it looked only at direct costs within one facility and for one system. Future work would look at comprehensive cost calculations and with the performance of a cost-benefit analysis. Other costing perspectives, such as a societal perspective could also be considered, especially for systems in use within the public sector.

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Statement on conflicts of interest

The authors and funder had no competing interests regarding this work.

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From Evidence to Practice: The implementation of digital health interventions in Africa for achievement of Universal Health Coverage

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