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Editorial to JHIA Vol. 5 (2018) Issue 1

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The Journal of Health Informatics in Africa is the official journal of the Pan African Health Informatics Association (HELINA). Whilst JHIA publishes the proceedings of the HELINA conferences, this issue consists of three papers that were submitted directly to the journal and is thus an open-call issue. The next issue that will be published before the end of 2018 will consist of the papers that were accepted for the HELINA 2018 conference that was held in Kenia at the beginning of December 2018. All papers in both open-call, as well as conference issues, are double blind peer reviewed before being accepted for publication.

Although JHIA also publishes papers written in French, all three papers in this issue were written in English. A framework for the management of diabetes in the Mauritian context is proposed and the effectiveness of ICT interventions for diabetes are also investigated. The causes for Sub-Saharan Africa's lag in Electronic Health Record (EHR) adoption is also explored, and possible strategies to increase (EHR) adoption in this region proposed.

Thank you to the editorial team, authors, and peer reviewers that made this issue possible.

Nicky Mostert, 04.12.2018

Journal of Health Informatics in Africa

Effectiveness of ICT interventions for Diabetes: A Systematic Overview (protocol)

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Background and Purpose: The use of Information and Communication Technologies (ICT) in fighting diabetes is particularly booming in recent years. Previous studies showed to varying degrees the impact that these technologies can have in the prevention and management of diabetes.
The main objective of this overview of systematic reviews is to systematically summarize the best evidence on ICT interventions that can significantly improve one or more indicators of diabetes
Methods: We will include all type of reviews that aim to evaluate the effect of ICTs on diabetes indicators. We will consider all types of ICT applications, including: mobile health, teleconsultations, tele-expertise, electronic health records, decision support systems, elearning etc. Key comparisons will be: ICT intervention for the management of diabetes versus no intervention; ICT intervention compared to the usual management of diabetes; ICT for the management of diabetes compared to other non-ICT interventions; ICT intervention versus another ICT intervention for the management of diabetes. We will include systematic reviews published in English and French during the past 25 years, i.e. between January 1991 and March 2015. Reviews will be limited to those on human subject only. Two reviewers will screen independently the title and abstract of the papers in order to assess their eligibility, and extract relevant information based on a predetermined grid.
Any disagreements will be resolved first by discussion and consensus between the two reviewers, or will imply a third author as arbitrator.
Results: Outcomes of interest will be clinical indicators of diabetes that could be influenced by ICT interventions. These will be the main non-exhaustive and objectively measurable indicators related to the monitoring and the management of diabetes and which are generally accepted by diabetes experts
Conclusion: Based on concrete interventions that have demonstrated scientific evidence, this overview could help identify the most effective ICT interventions for improving diabetes indicators.

Keywords: Diabetes, ICT, E-health interventions, diabetes indicators

1 Introduction

Despite the availability of wide range of therapeutic and preventive means, the prevalence of diabetes in the world continues to increase year after year. According to the World Health Organization, in 2014 the prevalence of diabetes was estimated to 9% for people aged 18 years and older [1]. Furthermore diabetes was the direct cause of 1.5 million deaths worldwide in 2012, 80% of which were in low-income countries [2]. The WHO predicts that diabetes will be the 7th leading cause of death worldwide by 2030 [3]. Its complications are many, causing increased morbidity and mortality. This results in increased social, human and financial burden related to this disease.

In this context, the use of Information and Communication Technologies (ICT) in fighting diabetes is particularly booming in recent years. Multiple tools have been used such as mobile technology, remote training, teleconsultation/ telemonitoring, and electronic patient records. Previous studies showed to varying degrees the impact of these technologies on the prevention and management diabetes [4,5,6,7,8].

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It becomes important to summarize this evidence to help guide practitioners and patients to the most effective ehealth interventions in solving problems related to diabetes, and ultimately improving care and the use of scarce resources.

1.1 Objectives

Given the existence of numerous studies showing the effects of ICT interventions on diabetes, it is necessary to have a global overview based on a review of systematic reviews in order to achieve the following objectives: 1) To explore and summarize specific ehealth interventions and their characteristics that have demonstrated an impact on the management of diabetes; 2) To highlight in a systematic way the indicators for the monitoring and the management of diabetes on which ICT interventions can have influence.

1.2 Why it is important to do this overview

There exists a wide and rich range of studies about ICT interventions for the management of diabetes. A preliminary Pubmed search on diabetes and ehealth in human subjects published in the last 25 years retrieved more than 400 reviews, including systematic reviews.

Moreover, it is known that systematic reviews about the same topic can vary depending on several factors: the methodology, the quality, the number of publications, the publication medium etc [9].

Similar to systematic review, an overview of systematic reviews is a systematic technique to synthesize evidence to inform not only practitioners but also political authorities, hopefully for better decision making. [10]

Moreover given the considerable development of ICT interventions in general [11] and in the field of diabetes, in particular, with some studies directly targeting specific indicators [12,13,14,15,16,17] and other more general [18,19,20,21], it becomes imperative to highlight the real impact of these interventions on indicators used in monitoring this particular disease. This comparative analysis of different ICTinterventions would certainly help accurately answer the questions: Which intervention? For what impact? On what indicator of diabetes management?

2 Methods

2.1 Criteria for considering reviews for inclusion

Types of reviews.
Will be included in this overview all the systematic reviews that meet the following main criteria:
Those assessing and describing the effects of ICT on the indicators of management of diabetes, regardless of the type of diabetes and type of interventions

Those published in English or French during the last 25 years (1991 -2015)

Those clearly describing the method used to select studies

Those that used systematic search strategies to identify selected studies

Those that have a systematic presentation and provide a summary of the results and main characteristics of the included studies [22]

Types of participants.
All individuals suffering of type 1 or type 2 diabetes, gestational diabetes or with risk factors of having diabetes.

Types of interventions.
All types of interventions using Information and Communication Technologies (ICT) that have an effect on one or more indicators for the management of diabetes will be considered, regardless of the technologies used.

Possible interventions might be teleconsultation, remote monitoring, mHealth, electronic patient record, etc.

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The classification done by Mair et al. will be used. This classification suggests a division of ehealth interventions in four areas [23]:

- Management systems: in this case it might be computerized medical record. For example an electronic medical record for a better monitoring of a diabetic patient.
- Communication systems: synchronous or asynchronous telemedicine activities such as teleconsultation, telemonitoring, tele-expertise.
- Computerized decision support systems. This area includes all computerized or automated systems based on patients' data and/or rules that serve to support health professionals in the decision-making process. Interventions in this category will be part of our study only if they have had a direct impact on the diabetic patient.
- Information systems: This area includes all Internet resources or ehealth portal users can access.

In any case, any intervention that will not have a direct effect on at least one indicator for the management of diabetes will be excluded. It could be intervention in the management or administration of human resources for which direct impact is difficult to measure in the management of diabetes.

Types of comparison.

Key comparisons will be: Using ICT for the management of diabetes versus no intervention; ICT intervention for the management of diabetes compared to usual management of diabetes; ICT intervention for the management of diabetes compared to other non-ICT interventions; ICT intervention in diabetes versus other ICT intervention for the management of diabetes.

2.2 Main expected outcomes measures

Three broad types of effects will be outlined: effects on behavior, effects on physiological indicators; and effects on knowledge and ability of the diabetic patients to take care of themselves [24].

Our analysis will focus on clinical indicators of diabetes that could be influenced by ehealth interventions. These will be the main non-exhaustive and objectively measurable indicators related to the monitoring and the management of diabetes and which are generally accepted by diabetes experts including:

- HbA1C or glycated hemoglobin
- Lipids: Total Cholesterol -HDL-LDL Triglycerides
- Albumin / creatinine
- Micro-albuminuria
- Pallesthesia of lower limbs
- Retinal screenings and microangiopathic complications
- Clinical android obesity factors (BMI, waist circumference, waist-height ratio)
- Fundus oculi
- ECG
- Screening of the foot
- Education about risk factors (BMI, possible complications, Hypertension)
- Adherence to treatment
- Neurological, ophthalmologic and skin complications

2.3 Search methods for identification of reviews

We will conduct standardized Literature searches using the following databases

- EMBASE,
- PubMed,
- CINAHL,
- Web of Science (Web of Knowledge)

Sources of information specialized in systematic reviews and other synthetic materials will be searched too. This includes: Cochrane Database of Systematic Reviews, Database of Abstracts and Reviews (DARE), the Health Technology Assessment (HTA) database and Epistemonikos. Will be included systematic reviews in English and French published during the past 25 years, i.e. between January 1991 and March 2015. Reviews will be limited to those on human subject only.

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Search strategies using controlled vocabularies will be developed and used to retrieve relevant publications. For example, MeSH descriptors will used with Pubmed while EMTREE will be used for EMBASE. The equivalents of these descriptors will be found in the vocabulary used by each database.

In addition to searches with controlled vocabulary, free keywords searching will be performed in the title and abstract fields.

A sample search strategy with Pubmed for our study is presented in Appendix 1.

We will conduct manual searches in the following journals specialized in medical informatics, telemedicine and diabetes: *BMC Medical Informatics and Decisions Making; International Journal of Medical Informatics; Studies in Health Technology and Informatics; Journal of Telemedicine and* Telecare; *Journal of Medical Internet Research; Journal of American Medical Informatics Associations, Telemedicine Journal and e-health; Journal of Diabetes and Its Complications.*

3 Results: Data collection and analysis

3.1 Selection of reviews

First of all, duplicates will be removed. Two independent reviewers will review the titles and abstracts of all articles to assess their eligibility according to the inclusion criteria. The full text copies of the papers meeting the predetermined inclusion criteria will be acquired.

Reviewers will compare their results and discuss any differences. A third reviewer will assess all cases on which the reviewers had different opinions.

Based on Smith's study [25], for each systematic review the following information will be retrieved: author name, year of publication, objectives of the review, research methodology, number of included studies, number of participants and method of analysis.

3.2 Data extraction and management

Two reviewers will independently synthesize all reviews that meet the inclusion criteria following the method proposed by the "Cochrane Handbook of Systematics Reviews of Interventions"[26] in the table "characteristics of the included journals".

The following information will be extracted: Description of the ehealth intervention (context, process, synchronous / asynchronous application), type of intervention (mHealth, telemonitoring, teleconsultation), comparison, description of the results (information on diabetes indicators that the intervention had an effect on) and any limits on the reviews.

The data or results will be summarized in tables and charts for readability. All contradictions and differences of opinions will be discussed in order to find a consensus between the two reviewers. In the case the two reviewers do not agree the opinion of a third reviewer will be required.

When there is missing or incomplete information the authors of the review will be contacted. In the case it is impossible to have this information the following footnote will be explicitly stated at the bottom of the review: "included without data" or "incomplete data".

3.3 Quality assessment

The quality of the methodologies used in the reviews included will be evaluated by two independent reviewers based on AMSTAR tool [27, 28]. This method provides a checklist of 11 items that allow reviewers to give one point for each item met in a review. All reviews with a score of more than 3 points will be included [29]. However, an exclusion of any review will be amply justified by clear and precise explanations.

3.4 Data Synthesis

A meta-analysis will be conducted for the synthesis and consolidation of data. If necessary a statistical analysis based on the types of variables will be performed [30]. For dichotomous data the risk ratios, their 95% confidence intervals and corresponding P values will be reported, and standardized mean differences will be presented for continuous data.

3.5 Sensitivity analysis

For all primary outcomes a qualitative synthesis of the evidence will be done. To do this end, the GRADE approach will be applied [31, 32].

3.6 Sub-group analysis

The reviews will be classified in different sub groups according to the types of intervention and their main goal (which must prove an impact of ICT on one or more indicators of the management of diabetes); the study population (type I diabetes, type II; people with risk factors) and positive effects on indicators of diabetes management, as mentioned in the inclusion criteria.

4 Discussion

The results of this overview could help to accurately establish the effectiveness of various ICT interventions on specific diabetes indicators. Based on concrete interventions that have demonstrated scientific evidence, the practitioner and the diabetic patient will be able to choose between interventions depending on the problem to solve. This will avoid exposing blindly the patient to many interventions some of which are often unnecessary and costly.

An overview of the contribution of ICT for diabetic care is a necessity to ensure the quality and safety of the healthcare system [11, 33]. In this sense, we believe that this study will guide health services to the interventions that have shown a proven efficacy on targeted indicators related to diabetic care. Furthermore, we also know that diabetic patients often are reluctant to accept the situation of chronic disease and thus to adhere to interventions [34], hence there is a need to target useful and effective interventions.

Finally, we think that a better understanding of the effects of ehealth interventions on indicators for monitoring diabetes through a synthesis of scientific evidence will facilitate the establishment of the most appropriate deployment strategies for better care. Indeed, these interventions can easily influence the doctor / patient relationship [35]. Therefore, a better understanding of these interventions and their effects is an important prerequisite to maintain this relationship [36].

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Statement on conflicts of interest

The authors declare that they have no competing interests.

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Journal of Health Informatics in Africa

Why Sub-Saharan Africa Lags in Electronic Health Record (EHR) Adoption and Possible Strategies to Increase EHR Adoption in this Region

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Abstract. Poor health information system has been identified as a major challenge in healthcare in many developing countries including sub-Saharan African countries. EHR has been shown as an important tool to improve access to patient information with attendance improved quality of care. However, EHR has not been widely implemented/adopted in sub-Saharan Africa. Therefore, this study seeks to identify factors that affect the adoption of an EHR in sub-Saharan Africa and strategies to improve its adoption in this region. A literature review was conducted using one of the second generation approaches, mixed synthesis. A comprehensive literature search was conducted on two electronic databases: PubMed and Medline. The available evidence indicates that there are many factors that hinder widespread adoption of an EHR in sub-Saharan Africa. These include high costs of procurement and maintenance of the EHR system, lack of financial incentives and priorities, poor electricity supply and internet connectivity, and primary user's limited computer skills. However, strategies such as implementation planning, financial supports, appropriate EHR system selection, training of primary users and the adoption of the phased implementation process have been identified to facilitate the use of an EHR. Wide adoption of an EHR in sub-Saharan Africa region requires a lot more effort than we think because of the current poor level of technological development, lack of required computer skills, and limited resources.

Keywords: Electronic medical records, sub-Saharan Africa, Adoption, Africa, Implementation, Barriers

1 Introduction

Sub-Saharan Africa is a resource-constrained region that suffers a top-heavy share of the world's burden of disease. According to the World Health Organization (WHO), about 12% of the world's population live in sub-Saharan Africa, yet the region suffers 27% of the world's total burden of disease [1]. To make the matter worse, the same region with a high burden of disease still lags in health information technology (HIT) which is vital in ensuring improved patients care [2,3-7]. Timely as well as accurate patient information is essential to meet the health care needs of any patient in any population. Physicians and other care providers require high-quality information to make sound clinical decisions; however, their information needs are often not met [6,8]. This lack of high-quality information often leads to lesser-quality and inefficient patient care; reporting as well as clinical research is also affected adversely [9]. The critical need of good health information systems in sub-Saharan Africa has become the current focus of attention.

In recent years, there has been a growing interest in Electronic Medical Records (EMR) or Electronic Health Records (EHR) adoption in many countries this is due to an increasing recognition that a stronger HIT is crucial to achieving a higher quality care at lower costs [2, 4, 5, 7]. The International Organization for Standardization (ISO) defines EHR as a “Repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. It contains retrospective, concurrent, and prospective information and its primary purpose is to support continuing, efficient and quality integrated health care” [10].

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EHR has been identified to be an important integral part of an efficient healthcare information system that guarantees positive health outcomes [3, 5, 7, 11].

Many studies conducted in different health care settings have indicated that EHRs will assist health professionals to reduce medical errors, achieve better effective care coordination, improve safety and quality, and also, it can reduce health care costs [2, 4, 6, 7, 12, 13]. Healthcare systems, like all business entities, are information-intensive enterprises [14]. Healthcare workers require adequate data and information management tools to make accurate decisions, both while caring for patients and while managing and running the enterprise, to document and communicate plans and activities, and to meet the requirements of the regulatory and accrediting organization [14]. Currently, the use of an EHR includes clinical care application/functions, clinical research function, and administrative function. The Institute of Medicine (IOM) highlights that a more immediate access to computer-based clinical information, such as laboratory and radiology results, can reduce redundancy and improve quality [15]. Similarly, the availability of complete patient health information at the point of care delivery, together with clinical decision support systems such as those for medication order entry can prevent many medical errors and adverse events (injuries caused by medical management rather than by the underlying disease or condition of the patient) from occurring [15,16].

Additionally, through a secure EHR, patient health information can be shared amongst all authorized users in the health care settings. Computer-based reminder systems for patients and clinicians can improve compliance with preventive service protocols. A more advanced EHR is also crucial for various forms of biomedical and health systems research, as well as educating patients and citizens about health [15]. Furthermore, the study conducted by Hillestad et al. on the potential health benefits and cost savings benefit of EHR adoption revealed that broad implementation of EHR would reduce health care costs by more than $81 billion yearly in the United States [17]. Overall, the significance of EHR in improving patient safety and quality care, reducing medical errors and health care costs cannot be overstressed so also the benefits of its broad adoption in Sub-Saharan Africa.

Several industrialized nations such as Canada, United Kingdom, and the United States of America have either implemented or are in the process of implementing EHR system because of its possible benefits [6,7,11].

However, there is a limited adoption of EHR in sub-Saharan African countries, despite the huge benefits arising from its usage. The study conducted by Akanbi and colleagues on the use of EHR in Sub-Saharan Africa showed that the use of EHRs in sub-Saharan Africa is largely driven by HIV treatment international programs such as PEPFAR (President's Emergency Plan for AIDS Relief) HIV program [18]. Implementation is still, however very low [5,7,18]. Additionally, many of the most commonly available electronic functionalities with EHR in this region are more administrative, rather than clinical [18].

The factors that limit the implementation of EHR in different healthcare settings in this region have not been widely studied. Therefore, in order to bridge this gap, this paper reviews both the challenges that hinder its wider adoption in the region and the factors that facilitate its implementation in the few piloted projects or few sub-Saharan countries that have minimally adopted it. Identifying factors that affect EHR adoption in this part of the world is essential to inform all health stakeholders, policy makers, researchers, and academic health institutions that train medical doctors, pharmacist, nurses, laboratory scientists, just to mention a few. In order to answer the question of why low adoption of EHR in this region, it is imperative to identify and understand the factors that limit broad adoption of EHR. Besides, to accelerate wider implementation of EHR, there is a need to have a better understanding of the EHR adoption facilitating factors.

2 Methods

A literature review was conducted using one of the second generation approaches: narrative synthesis (a mixed method approach). This type of review is useful where the aggregation of data is difficult because diverse studies are being analyzed [19]. This is a type of review that allows the synthesis of both quantitative and qualitative information, as long as the evidence is of sufficient quality [19]. It involves telling a trustworthy story through summarizing the body of evidence synthesized in the review [19].

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2.1 Search Strategy

A comprehensive literature search was conducted on two electronic databases: PubMed and Medline. The Google scholar search engine was also utilized as well as organizations' websites such as those of the WHO and ISO. In order to facilitate the search, the following keywords sub-Saharan Africa, electronic health record, Africa, electronic medical record, developing countries, names of each country in the sub-Saharan African region, facilitating factors, barriers, EHR adoption, and implementation were adopted.

2.2 Inclusion and Exclusion criteria

Publications of interest were those published in English and with information on factors that limit the implementation/adoption of EHR as well as factors/strategies that will improve its adoption in sub-Saharan Africa. Exclusion criteria were studies that were not published in English as well as those that were not on developing countries.

2.3 Search Outcome and Synthesis

Forty-seven papers were retrieved. Duplicate papers in the databases were deleted. After screening of abstracts and application of the inclusion and exclusion criteria, twenty-one papers were included in the final review. Inclusion and exclusion criteria were based on matching types of evidence to research purposes on the basis of their relevance and quality of individual studies. In assessing the quality of the included studies, the criteria from Dixon-Woods et al.(2006) were adopted, so as to exclude the papers that are fatally flawed [20]. The appraisal prompts for informing judgments about quality of papers are as follows:

- Are the aims and objectives of the research clearly stated?
- Is the research design clearly specified and appropriate for the aims and objectives of the research?
- Do the researchers display enough information to support their interpretations and conclusions?
- Is the method of analysis appropriate and adequately explicated?

No papers were excluded in respect of quality. The twenty-one studies included were of three different study designs ranging from quantitative to qualitative to mixed designs

3 Results

3.1 Barriers to adoption of the EHR in sub-Saharan Africa

The main issues that emerged from the studies reviewed are grouped under four themes.

High Implementation and Maintenance Costs.
The cost of EHR implementation is one of the most frequently identified factors that limit EHR adoption. Studies have shown that low adoption of EHR in sub-Saharan Africa can be linked to high costs of implementation and maintenance due to hardware, software, training, and support costs [18,21]. Many hospitals and physicians in sub-Saharan African countries are mainly concerned about the large capital outlay [5-7,11,18,21] associated with hardware, software, and installation; broad-brand connection costs; the cost of accessories such as scanners, printers, paper, and ink; and recurring expenses for system maintenance. Furthermore, Akanbi and colleagues stated that lack of robust/poor infrastructure in developing nations also increases both the costs of setting up EHR and costs of maintenance [6, 11.18]. Awokola et al. pointed out that the software used in healthcare establishments is very expensive and that a basic EHR costs about $32,000 excluding technical support and ongoing maintenance [21]. As a result of high costs of EHR procurement, many hospitals, though beneficial in a number of other ways, did not see EHR implementation as a priority [21].

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Limited Computer Skills.

Low computer literacy level is another variable that clearly emerged from the articles reviewed as one of the potent factors that limits the wider adoption of EHR in sub-Saharan African countries. Physicians reported a series of skill-related factors that they believe would make it difficult to use an EHR. These included lack of typing proficiency, low/no understanding of how to use a computer, lack of understanding of how to use the EHR system, and inability to type while talking with patients [4, 22-24]. The study conducted on computer and internet use by doctors in one of the Sub-Saharan African countries showed that the overall proficiency of the respondents in computer-based competencies was below average. Only 32 (26.7%) were sufficiently familiar with computer tools to perform advanced tasks [22]. The researchers stated further that the Appalachian Regional Informatics Consortium Survey of 2005 in Ohio, United States showed that 91.4% of doctors could use an EHR. In the Canadian Medical Association physician resource survey of 2000, 84% of doctors showed computer use proficiency. Similarly, higher values were seen in a study of student doctors in Malaysia in 2002, where 94.4% of the subjects could use a computer well [22]. As a result, of low-level computer literacy in the sub-Saharan African countries, many physicians and other key end users are not eager/ willing to adopt an EHR and ultimately low EHR adoption in the region.

Poor Electricity Supply and Lack of Constant Internet Connectivity.

Lack of constant supply of electricity has also been identified by many researchers as a major barrier to a successful wider implementation and adoption of EHR in this region [7, 11, 16, 21]. For instance, Awokola and colleagues reported that for many months, they could not use the EHR consistently because of the constant power outage. In addition, Pantuvo et al. stated that many hospitals in this region do not have access to constant electricity supply [7]. In fact, many hospitals depend mainly on the alternative power supply commonly called "generator" for their operations. Due to the infrastructure problems throughout the country and lack of guarantee of always-on internet connection or even unsure uninterrupted electricity supply [2,7,11], a wider implementation of EHR in some sub-Saharan countries may not be possible. Furthermore, the study conducted on the use of health information and communication technologies by health workers in seven state hospitals and a private hospital in the North-Eastern Zone, Ogun State, Nigeria reported that only one of the hospitals examined was connected to the internet and none of them had a website [3]. Jimoh, Pate, and Lin noted that the internet penetration was very low. For instance, the internet penetration of less than 16% and average broadband download speed of 1.38 megabits per second (Mbps) (compared with 10.1Mbps the United States [25]. Overall, poor electricity supply and lack of constant internet connectivity have been reported as strong barriers to EHR adoption in this region.

Lack of Prioritization of EHR.

Studies have shown that most developing countries face many challenges ranging from disease epidemics to civil wars to disasters so EHR implementation may seem outside the priority agenda in this region [6, 11, 17]. Akanbi et al. revealed that most EHRs in this region are sustained by funding from foreign partnerships, thereby raising the question about the sustainability of these systems by the domestic institutions. Many countries in sub-Saharan Africa did not have a specific policy in place on EHR adoption and no financial incentives for adoption [6, 11, 17, 18].

3.2 Factors Facilitating EHR Implementation in sub-Saharan Africa

The following section presents the strategies that enabled the adoption of EHR in the few piloted projects or few sub-Saharan countries that have minimally adopted it.

Implementation Planning.

Comprehensive planning prior to implementation was frequently cited in the literature. Planning steps included setting realistic goals and expectations, involving EHR users early in the planning process, determining how current workflows will be redefined with EHRs, system selection, staged implementation processes, and learning from facilities that have implemented EHR systems [7, 11, 27].

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Training and Education.
Training of EHR users was also reported in studies to be an effective strategy for getting end users' acceptance. Training should be both initial and ongoing [2, 11, 27]. Physicians and other EHR end users will have to set time aside in order to study how the system is operated and how their workflow should be redesigned to allow for an efficient use of the system. Training, however, should commence with the most interested EHR users, the so-called local champions who will subsequently be used to motivate the others and developed to "super users" to handle most basic hardware and software problems locally [27]. Equally, incorporation of health informatics into the school curriculum by the academic health institutions that train medical doctors, pharmacist, nurses, laboratory scientists, and other health workers was frequently mentioned by researchers [7,13].

Financial Supports.
In addition, literature supports the notion that financial assistance from the government to cover implementation costs. This can be in the form of grants or one-time payments for infrastructure and hardware costs, reimbursement incentives. Many researchers pointed out that some form of government incentives would be required to in order to see substantial adoption and meaningful use of EHR in sub-Saharan African countries [7,12].

Appropriate EHR System Selection.
Studies have shown that while it is true that the cost of implementation of an EHR can be prohibitive for most developing countries, the use of low-cost technologies has been demonstrated to be sustainable in many such countries [5, 7, 12, 26, 28]. "The functionality of EHR systems varies across multiple settings. To be most useful, a functional model of an EHR system must reflect a balance between what is desirable and what can feasibly be implemented immediately or within a short time frame" [15].

Phased Implementation.
Another strategy that facilitates EHR adoption in sub-Saharan Africa is the embracing of phased implementation. According to Pantuvo et al., a phased implementation involves implementing one unit at a time. The author stated that "a phased implementation is preferred for resource-constrained areas where the resources to tackle all the issues that implementation will raise are not readily available. This gives room to manage changes in small units and transfer lessons learned to other units" [7].

4 Discussion

There are many reasons why hospitals/clinics in sub-Saharan African countries might not be adopting EHRs despite the immense benefits of improving patient safety and quality of care, reduce medical errors, decrease healthcare cost, greater efficiency, and enhanced care coordination. The most frequently reported major factors that limit EHR implementation in sub-Saharan African countries are as follows: high initial and ongoing maintenance costs, lack of financial incentives for adoption, lack of priorities, poor electricity supply, lack of internet connectivity, low computer literacy level, some of these identified factors are similar to findings in developed part of the world. For instance, the study conducted by Abramson et al. in the United States reported that major barriers to EHR adoption are the initial cost of IT, lack of fiscal incentives for EHR adoption, lack of interoperability with current systems, ongoing maintenance costs, and competing priorities [29].

However, it should be noted that some of the most important barriers to EHR adoption in sub-Saharan African countries identified are typical to this region, and other developing countries. For example, poor electricity supply, inadequate/ lack of internet connectivity, and lower computer literacy level issues that are identified in the reviewed research studies in this region, but these factors have not been identified as barriers to EHR adoption in many developed countries. Identifying factors that affect EHR adoption in this part of the world is essential to inform all health stakeholders, policy makers, researchers, and academic health institutions. The findings in this review have provided valuable information in this regard. This review is very useful, given that poor resource-constrained countries are traditionally described as lagging behind other developed countries in the health care sector so having a better understanding of the limiting

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factors of EHR adoption in the sub-Saharan Africa will serve as a platform for improvement to achieve the desired goals and objectives of wider EHR implementation in the region.

4.1 Limitations and Strengths of the Study

As with any study, this review has limitations. The available evidence does not represent all countries in sub-Saharan African region equally, thereby limiting generalization of the findings. Due to the heterogeneity of the study design of the reviewed articles, no statistical analysis was conducted. The major strength of this desk study is that it comprises studies which have used different study designs to triangulate the result to provide knowledge about factors affecting and promoting EHR adoption. This effort of triangulation results in deeper and better understanding of these factors.

4.2 Recommendations

Improved efforts such as the inclusion of the biomedical informatics program in medicine, pharmacy, nursing, and other potential users of EHR curricular and establishment of computer laboratories are required to increase the student's access to computers and the internet. Early involvement of stakeholders in order to build up the requirements of end users and reduce resistance to change is highly recommended. The perceived benefits of EHR should be identified and communicated to stakeholders as much as possible. The building of robust healthcare infrastructures should be taken more seriously in this region.

5 Conclusion

EHR has been shown to play significant roles in improving healthcare information system. The main drivers for the increasing interest in EHR include the need to improve efficiency in healthcare service delivery, improve patient safety, increase access to healthcare services, and more importantly, the need to reduce the costs of medical expenditures. However, there are many factors that limit broad adoption of EHR in sub-Saharan Africa. These include high initial costs of procurement of EHR system and ongoing maintenance costs, lack of financial incentives for adoption, lack of priorities, poor electricity supply, lack of internet connectivity, primary user's limited computer skills, and lack of robust healthcare infrastructure.

Therefore, any efforts that will be directed towards widespread adoption of EHR in this region by any stakeholders must be tackled at a much more fundamental level within the context of sub-Saharan African region and uniqueness of the region's present situation. The following strategies have been shown to promote EHR adoption: proper and adequate implementation planning, financial supports from the government, appropriate EHR selection, training of primary users, and adoption of the phased implementation process.

5.1 What is already know on this topic

- It is well documented in the literature that there is low adoption or implementation of electronic health record in sub-Saharan Africa.
- Factors that affect the adoption of electronic health records at country level are well known.

5.2 What this study adds

- It provides us with a bigger picture of the factors that limit electronic health record adoption in sub-Saharan Africa as a region and not as individual countries.
- It gives us collated information on factors that improve the adoption of the electronic health record in sub-Saharan Africa as a region and not as individual countries.

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Competing Interests

No conflict of interest associated with this work

Authors' Contributions

We declare that this work was done by Florence Odekunle, Shankar Srinivasan and Raphael Odekunle and all liabilities pertaining to claims relating to the content of this article will be borne by these authors. Florence Odekunle conceived and designed the study. All three authors were involved in the preparation of the manuscript and the approval of the manuscript for publication.

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A Proposed Framework for Hypertension in Mauritius

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Background and Purpose: Considered to be one the major contributors to cardiovascular diseases, hypertension has caused much ravage on a global scale. As a developing country, Mauritius is not immune to this condition. The country is ranked at the twelfth position among those having a high percentage of death caused by hypertension. Mobile applications are increasingly being used to manage and monitor hypertension. This paper analyses existing mobile applications and frameworks used for managing hypertension and proposes a new framework for Mauritius. According to the European Society of Hypertension (ESH), the use of electronic blood devices for blood pressure measurement such as ambulatory blood pressure monitors and smartphone applications have reinforced blood pressure monitoring and diagnosis. The framework therefore comprises of a smart mobile application which takes readings of systolic and diastolic blood pressure on a daily basis and makes use of intelligent techniques to conclude whether the patient is hypertensive or not. Components such as Stress Management and Dietary Approach to Stop Hypertension (DASH) Diet Recommender are integrated in the framework.
Methods: Studies describing approaches, mobile applications, frameworks and devices used for managing hypertension were identified from the PlosOne, PubMed, Science Direct, Google Scholar and the Google search engine. Studies that attempted to manage and predict hypertension were selected. The studies were categorized according to different characteristics such as hypertension management and monitoring applications, stress management applications for hypertension, frameworks for hypertension and devices for hypertension.
Results: Despite the emergence of many tools, platforms and frameworks, it was found that there is no framework that that integrates hypertension management and prediction, DASH diet and stress management in a single application. Additionally, many of the existing mobile applications do not fit the Mauritian context.
Conclusions: A framework that englobes hypertension management and prediction, DASH diet based on the Mauritian context and stress management is therefore proposed as these components are among the core components to improve the health of people suffering from hypertension.

Keywords: mhealth, Hypertension, Intelligent Techniques, Diagnosis, Framework

1 Introduction

Increasing death rate around the globe, hypertension is considered to be among those diseases that are life-threatening. It is also the main contributor to cardiovascular and cerebrovascular events and diseases [15]. Giles has defined hypertension as "*a progressive cardiovascular syndrome arising from complex and interrelated etiologies*" [14]. In other words, it is actually the persistent rise in systemic arterial pressure above a certain minimum value [14]. Based on international health guidelines and the Mauritius Clinical guidelines for the management of hypertension, high blood pressure has an average threshold value of 140 mm Hg for systolic blood pressure or 90 mm Hg for diastolic blood pressure, or both and it can be categorized into two types namely primary and secondary hypertension [38]. Primary or essential hypertension mostly arises while aging due to lifestyle and genetic factors while secondary hypertension occurs at a much younger age due to renal or endocrine disorders or iatrogenic triggers which occur due to the use of oral contraceptives [38].

Over 28% of the Mauritian population is suffering from high blood pressure, which is quite alarming for the country [40]. Some studies concerning developing countries have shown that blood pressure monitoring and control has become a great challenge due to limited health care facilities in addition to low funding and inexperience medical assistants in the field and Mauritius might as well face these difficulties [17].

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Therefore, there is a need for a system that allows early diagnosis of the condition. The paper proposes a framework to aid in the diagnosis of hypertension at an early stage. The framework makes use of mobile devices in order to make the diagnosis process more accessible to the public. According to the European Society of Hypertension (ESH), the use of electronic devices for blood pressure measurement such as ambulatory blood pressure monitors and smartphone applications have reinforced blood pressure monitoring and diagnosis [36]. This framework might prove to be beneficial to Mauritius as no such system or framework was implemented in the country.

The rest of the paper is structured as follows: Section 2 gives an overview of the status of hypertension in Mauritius. Section 3 presents an analysis of the different existing systems, frameworks and devices used for hypertension. Section 4 describes the gap analysis and recommendations as improvement of the existing systems. Section 5 proposes a framework for hypertension with relevant details. Section 6 finally concludes this paper.

2 Status of Hypertension in Mauritius

The section describes the culture of Mauritius, the population's eating habit and their way of living. It also gives an overview of the percentage of people suffering from hypertension in the country and shows how the Mauritian government is trying to tackle them.

2.1 Mauritian Culture

The Mauritian population are descendants of immigrants who arrived from India, China, Africa and France and half of them are Hindus [8]. Most of the Mauritian population follow the Indian culture and gastronomy [8]. The Indian gastronomy often comprises mostly of rice and curry which are high in fat and carbohydrates [8]. Added to this, most foodstuffs such as pickles, salted fish and octopus, and Bombay duck (commonly and locally known as *"Bombli"),* which are very popular among the Mauritian population are high in sodium, and salt has a very negative impact on hypertension [23]. Moreover, the increase in fast food companies in Mauritius has also led the population to adopt an unhealthy manner of food consumption, westernizing the eating habits of people [41]. People are refusing their safe meal prepared at home for unhealthy and unhygienic fast foods [39]. A constant consumption of these food stuff have led to an obese population. Approximately 45.5% of the Mauritian population is considered to be obese [40]. Obesity entails several health risks of which is high blood pressure, or hypertension [29].

2.2 Hypertension statistics

According to the Mauritius Non Communicable Disease (NCD) survey carried out in 2015 and as mentioned above, over 28% of the Mauritian population is suffering from hypertension and only 52% of them are going through medical treatments of their condition[40]. Thus, for every treated case there is at least one untreated case [40]. There is about 47-48% people who might be unaware of their condition or deprived from medical treatments [40]. Even the younger population is being affected by hypertension. According to the Indian Ocean Times, in 2013 more than 500 people between the ages of 20 to 44 were admitted to the hospital due to high blood pressure [38]. This is quite an alarming situation for the Mauritian population and should be taken into consideration due to the fact that Mauritius has an aging population and age is a great factor of rising blood pressure [38]. Nonetheless, Mauritius is trying to offer better facilities to treat hypertensive patients even though it is still a developing country. However, it is not proving to be quite effective as there has not been a significant level of improvement concerning the hypertension status of Mauritians.

2.3 Measures taken by the government

Physical inactivity in addition to an unhealthy diet have been the causes to many deaths by hypertension and other non-communicable diseases. According to the National Action Plan of 2011-2014, only 16.5% of the Mauritian population practice physical activities daily, for a considered period of 30 minutes [34]. To encourage people to practice more and more physical activities the government has built several health tracks and parks throughout the country allowing the population to benefit from them. These health parks are equipped with several gym equipment in addition to its lengthy jogging tracks. Physical education courses in educational institutions have been strengthened in order to inculcate an active sense of living in the younger generation.

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Furthermore, the government organizes talks and campaigns to sensitize people about the dangers of the various diseases prevailing in the country, including hypertension. It is believed that prevention is better than cure. Therefore, sensitizing people about the causes of certain diseases is better than curing them. However, hypertension can be inherited genetically through parents [38]. So, the government supports people suffering from this disease through medical care. Year by year, the government is working upon increasing the quality of health care in order to properly assist hypertensive patients. Mauritians can thus benefit from proper health care and medications.

3 Existing Systems, Frameworks and Devices for Hypertension

This section describes some existing systems, frameworks and devices currently being used for hypertension. Innovation in mobile phones has greatly contributed to the emergence of mobile applications for health care, termed as "mHealth apps" [16]. The main focus of these applications is to capture bio data and transmit it to healthcare system for processing. One example is heart-related healthcare system which captures heart rate signal for patient monitoring purposes. The usage of internet connection further provides opportunities to improve disease management, since clinicians can retrieve patient's symptoms information without the latter being present at the clinic [16]. The latest trends in mHealth applications also involve the use of non-intrusive sensors for real time monitoring. Examples of such sensors include ECG sensors for keeping track of heart rate and chip which allows "Point of Care" test that makes quick disease detection possible [36]. A search was carried out in different search engines to find out about hypertension mHealth applications as well as frameworks and devices related to hypertension management. Those research works are categorized as follows in the following sections.

3.1 Hypertension management and monitoring applications

Many mHealth applications are developed in order to keep track of patients' blood pressure level, enabling users to assess their progress. The two ways in which the applications can get the blood pressure of the patient is either by using sensors or perform sync process with the blood pressure monitor equipped with Bluetooth. Below are the examples of such type of system that help both hypertensive and non-hypertensive patients to monitor their BP level.

i. *Hypertension management using mobile and Home blood pressure monitoring [29]*

This application makes use of a cloud computing, automated self-management calls and a server which manages and retrieves information from the phone calls [29]. The patients have to take BP reading several times on a weekly basis and keep a written record of the readings. The readings are taken by the patients who have been taught how to use a blood pressure monitor. Automated calls are sent from the server in order to gather information about BP readings and to know whether medications are taken according to schedule and diet. Advice is given to the patient based on the information received from the telephone call. In case of dangerous BP readings, emails alert are automatically created and sent to medical staff. Patients also have the option to register someone of his/her choice to receive brief automated updates regarding the patient's health status via a telephone call [29].

ii. *A mobile rehabilitation for the remote monitoring of cardiac patients after a heart attack or coronary bypass surgery [9]*

This application makes use of smartphones and bio sensors in order to provide patients with instantaneous advice while they are performing exercises [9]. This type of monitoring when done outside the medical environment is called ambulatory monitoring. It provides the user with both options that is to input readings taken from blood pressure monitor or to make use of bio sensor which will take the readings. In case the patient suffers from a heart attack, the application will detect it based on the bio data and an audio message is played loudly so that any person who is around will hear steps to be followed to help the patient. The application runs locally on the mobile, that is, the data is processed on the mobile phone itself. While monitoring the heart rate, the application can also notify the user in case the heart rate is too high during exercises. Additionally, the application comprises of reminder to notify user to carry out physical activities.

iii. Monitoring System for management of hypertension in diabetic patients[18]

This application monitors diabetic patient's blood pressure level and its main components comprise of user interface, database, decision support system and the reporting and alert component [18]. In case, a patient's blood pressure level is beyond the acceptable range, the system will prompt the user to take another reading. If ever the average reading over a period of three days is still high, automatic message is sent to the physician to make him aware of the patient's condition. If the user does not comply with the schedule of taking BP readings or taking medication, an automated audio message is sent to the patient via his phone. The physician also has the option of changing the acceptable range for BP level in case required.

3.2 Stress management applications

There are different applications which aid and guide users to carry out different types of exercises to reduce or eliminate their stress level which will have a positive impact on their blood pressure level. Two stress management applications namely ***Mind the body*** and ***Oiva*** are described below.

i. Mind the Body[33]

Mind the Body is a stress management application to encourage individual reflection based on the history of stress states [33]. This application makes use of sensors such as heart rate, accelerometer and skin conductance sensor to identify the stress level of an individual based on arousal and adaptability. Arousal refers to the rise in heart rate, BP level and perspiration. It also shows the data fed in by the sensors and current state of the body compared to previous ones. The user can also see the data in real time while making breath exercises and checking the effect of the heart rhythm in real time.

ii. Oiva [2]

Oiva is an android application on Acceptance and Commitment based stress management [2]. The main plus point of Oiva is that it does not require internet connection for its different features such as its exercises and user written comments. It comprises of a series of aware mind exercises such as breathing exercises which are scheduled on a day to day basis. Each exercise is detailed in term of the reason and benefit, the amount of time required and steps on how to proceed to practice it. The explanation of steps is available both in text and audio format to ease practice. Additionally, the application enables checking of progress by changing colors of exercise already performed and allows some personalization such as adding exercises to favorite. After each practice, a reflection screen is shown outlining the skills acquired during the activities, writing and saving comments that will help the user for reflection purposes. In order to make the user more confident about using the application, a video introduces the application. The video comprises of an expert in Acceptance and Commitment based therapy [2].

3.3 Existing Frameworks

There are various patient centered frameworks that have been developed in the last decade that involve the use of mobile phones and ambulatory monitoring. Ambulatory monitoring refers to taking medical reading and monitoring outside the medical environment. The frameworks vary from web based services to real time and cloud computing services. [20] proposed a framework that involves the use of wireless non-intrusive sensors that capture vital medical readings such as blood pressure. These readings are transferred to the mobile phone which in turn transmit them to the server via Wireless Application Gateway (WAP) services [12] as shown in Figure 1. Its server is hosted on Apache and information is stored on mySql database. This application comprises of a management information system and an expert system that supports medical professional for decision making purposes.

[1] implemented a predictive model for the diagnosing hypertension among Nigerians using the decision tree algorithm. The author made use of two types of decision tree algorithms namely C4.5 and ID3. The model was simulated using the Waikato Environment for Knowledge Analysis (WEKA), making use of the 10-fold cross validation technique for the purpose of training and testing the model. It made use of four hypertension risk factors which are length of work, marital issues, gender and occupation of the patient and a good performance of the model was observed based on the results of the true positive (TP) rate, false positive (FP) rate, precision and area under the receiver operating characteristics (ROC) curve.

[24] proposed a framework which mainly focuses on producing alerts in case of critical conditions of patients. This framework consists of module on the mobile application for medical information gathering which is transferred to a remote server for processing. SocBes is another framework that makes use of cloud which is based on Service Oriented Architecture [3]. It includes the use of wearable sensors to measure the

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different information such as BP reading and performs the process on the cloud-based server. In case the patient is facing a problem, the location of the patient is tracked.

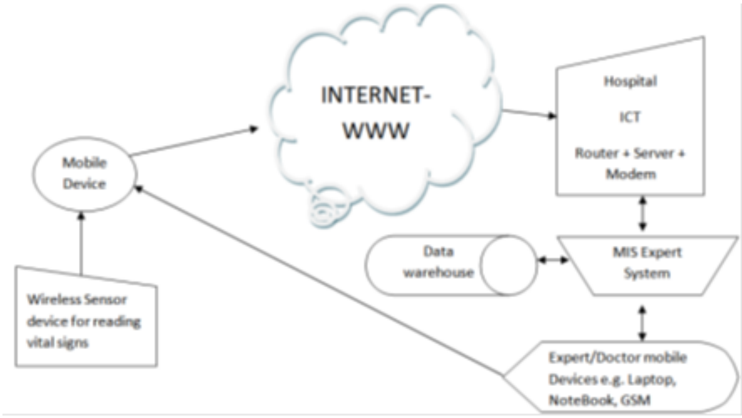

Figure 1. Wireless sensor framework for Hypertension [12]

Another recent aspect in the field of mHeath applications is the implementation of gamification features. Gamification is defined as "*the use of video game elements in non-gaming systems that aim to improve user experience and user engagement*" [28]. There are various gamification principles such as "badges, leaderboards, points and levels, challenges and quests, social engagement loop and onboarding" which have been used to increase motivation [7]. One example of the application of gamification is for stress management and the framework is based on the Octalysis framework [6]. The Octalysis framework involves the different factors that drive people motivation such as the meaning, empowerment, social influence, unpredictability, security, ownership and accomplishment [38]. Another mHealth application that makes use of gamification features is Avafeed. The latter makes use of avatar and gaming features such as social media to increase the adherence of children for healthier food consumption [10].

3.4 Existing Devices for Hypertension management

There are numerous techniques that can be used to measure blood pressure level ranging from automatic blood pressure monitor to wearable sensors. The increasing demand of self-monitoring of blood pressure has boost up different research and development in the field of ambulatory monitoring [24]. Cuffless blood monitor has been developed to make blood pressure measuring less invasive [30]. Moreover, there are also wearable sensors which can be placed on different parts of the body or embedded in clothing which is also known as "smart textile" [27]. These different sensors and devices will greatly help in the reduction of the "white coat" effect which refers to the increase in patient's blood pressure measurement in medical environment [13]. These devices are described as follows.

3.4.1 Blood pressure monitors

The main type and the commonly used blood pressure monitor in the medical field is the sphygmomanometer [22]. The sphygmomanometer is being replaced by electronic monitor which takes the reading by automatically controlling the inflation and deflation of the cuff [37]. This type of BP monitor makes use of an oscillometric technique whereby the cuff is placed at the upper arm of the patient. Wrist BP monitor has also been developed to make the measurement less intrusive compared to placing the cuff at the arm [24].

3.4.2 Wearable sensors

The main purpose of wearable sensors is to provide non-invasive measurement for physiological data such as heart rate and blood pressure level. One of the common BP sensors is the photoplethysmography (PPG) which also measure respiration and heart rate [39]. The main advantage with the PPG sensor is that it can be placed at different parts of the body such the wrist, fingers or ears [21]. It can also be integrated in a cloth or in a belt which makes it very useful for ambulatory monitoring. One example of the wrist BP monitoring is the use of 2 PPG sensors one placed at the wrist and the other at the finger as shown in Figure 2. The sensor at the wrist level is the leading sensor while the one at the finger is the lagging sensor. Smart watch has also been developed. It makes use of PPG sensor and ASIC chip which collect the data of the sensor, process and display the diastolic, systolic and heart rate on the watch display [31]. Another aspect

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of ambulatory monitoring involves the concept of "smart textile". One example of smart textile is the smart vest which takes BP reading, heart rate reading using ECG along with other medical data [25]. Another common sensor used is the Electrocardiogram (ECG) sensor which measures heart rate value [26].

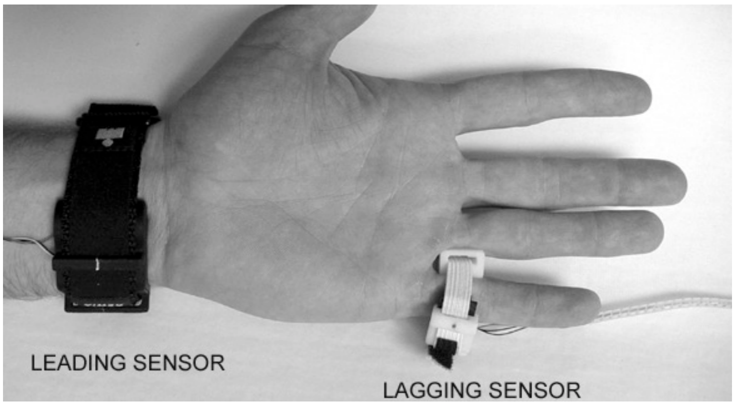

Figure 2. Wrist and Finger PPG Sensors [21]

4 Gap Analysis and Recommendations

This section involves the critical analysis of the existing systems, frameworks and hypertension devices. It additionally outlines their applicability with respect to the Mauritian population and according to medical standards and provides recommendations for an improved system.

Various applications have been described in Section 3.1 and 3.2 which comprise of mainly hypertension and stress management. The functions of the different applications namely [2],[9],[19],[29],[32] are compared in the Table 1 based on criteria such as hypertension management, use of sensors, DASH diet, stress management, real time alert, reminder and hypertension diagnosis.

The different criteria to evaluate the applications are based on the different reviews derived from the user acceptance of the above mentioned applications. Considering [29] which mainly consists of the hypertension management, DASH diet and reminder functionalities have been rated as excellent by 75.9 percent of the users. The usage of application [29] led to a consecutive reduction of 4.2 mmHg in the blood pressure for the 181 patients who used the application.

Stress is another main factor that leads to hypertension [3], [5]. Therefore, applications that address stress reduction and management have been analyzed. Oiva [2] consisting of stress management functionalities, has been used and reviewed by different users who have experienced a considerable reduction in their stress level as well as an improvement in life satisfaction. Reminder has also been used in most of the applications discussed in section 3 in order to increase user adherence in following the different hypertension management activities. The Diagnosis functionality has also been considered since most of the applications discussed in section 3 address people who are mostly suffering from hypertension while the objective of this study is also to cater for normal people to increase awareness of their hypertension status in order to provide appropriate recommendation based on the diagnosis. Therefore the existing applications are compared and contrasted based on the desired functionalities as illustrated in Table 1.

From comparative table 1, it can be deduced that the mentioned existing applications do not provide all the desired functionalities such as hypertension management, DASH diet and hypertension diagnosis in a single application. Due to the current trends in the use of sensors in mHealth, two of the mobile applications namely [8] and [32] make use of sensors for capturing important data such as heart rate while the others require user to input the data manually. The applications mainly focus on how to reduce or to control hypertension. Most of them may not be suitable in the context of the Mauritian population.

Considering [28], its automated calls to retrieve information from the conversation with the patient is based on Honduras and Mexico population language which is mostly Spanish. In Mauritius, the most spoken languages are Creole, French and English [8]. Furthermore, the application gathers the BP reading and medication details on the phone calls but those information have to be recorded manually by the patient every week. Moreover, the details are conveyed via the call, which makes it prone to data loss and errors. There are systems that notify the physicians whenever a critical condition is being faced by the patient, for example, alarming heart rate. Considering [19], the physicians must be enrolled in the system in order to receive patient medical data. The Mauritian physician may not be enrolled in this application, therefore considerably reducing its effectiveness.

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The frameworks discussed in section 3.3 as well do not integrate the hypertension management, DASH diet and stress management in a single framework. The described frameworks focus more on the transfer of medical data to medical professional or raising alarms. Most frameworks neglect the aspect of lifestyle management of the patient to maintain or reduce the blood pressure level such as exercises and DASH diet. According to the Seventh report of the Joint National committee, the lifestyle management plays a very important role in the preventing and reducing the hypertension level [4]. Exercises and DASH diet are examples of activities forming part of lifestyle management.

Table 1. Comparative table

Features	**Hypertension management using mobile and Home blood pressure monitoring [29]**	**A mobile rehabilitation for the remote monitoring of cardiac patients after a heart attack or coronary bypass surgery [9]**	**Monitoring System for management of hypertension in diabetic patients [19]**	**Mind the body [32]**	**Oiva [2]**
Hypertension management	Yes	Yes	Yes	Yes	No
Use of sensors	No	Yes	No	Yes	No
DASH diet	Yes	No	No	No	No
Stress management	No	No	No	Yes	Yes
Real time alert	No	Yes	No	Yes	No
Reminder	Yes	Yes	Yes	No	No
Diagnosis	No	No	No	No	No

Moreover, there are various devices that can be used to measure blood pressure reading but the main issue is about the accuracy of those devices. The sphygmomanometer is actually used as a “gold standard” to make comparison with the other types of BP monitoring devices as it is more accurate [22]. Wrist BP monitor has also been developed. However, if the arm is not placed properly during measurement, the reading will not be accurate [24]. The arm cuff blood pressure monitor yields blood pressure reading that is more accurate compared to the wrist worn BP monitor. According to the European society of Hypertension the arm cuff blood pressure monitor also has more accuracy than the BP monitors that are placed at the finger [22].

Additionally, none of the applications mentioned above provide diagnosis and prediction facilities. This particular functionality is of paramount importance to help people to actually know the status of their blood pressure so that they can control it. There are various models that have been created to predict hypertension. However, they are not included in a mobile application. A predictive model that provides timely and accurate information of hypertension status along with blood pressure management on their mobile phones will surely be beneficial to the people. For diagnosis of hypertension, the system should also take into consideration the different lifestyle factors for the basis of recommendation. Therefore, the diagnosis should not be biased only towards factors such as systolic, diastolic reading, family history but should also consider the different activities and consumption of the person which have not been considered by the above mentioned mobile applications and frameworks.

The ideal solution would have been to have a framework that integrates hypertension management, DASH diet and stress management. Taking into consideration the DASH diet, stress and blood pressure management component, the progress of the BP reading can be tracked to make the patient aware of the impact of adhering to the DASH diet and the stress exercises. In order to ease the assessment of blood pressure over time, graphical display such as graph and charts will be used to ensure concise and meaningful information is provided to the users for quick analysis. Along with the graphical display, color coded design can also be used to further enhance the comparison of different blood pressure values. One example is the use of red color in case of dangerous blood pressure level reached. For the stress management part, relaxing colors such as green can be used in order to increase its effectiveness [27]. For the lifestyle management such as DASH diet, recipes for the Mauritian gastronomy can be included to further increase the adherence

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and usefulness of the framework. Concerning the blood pressure reading, an arm cuff electronic BP monitor could be used to ensure maximum accuracy. Gamification aspects such as point, level and social media can be used to further enhance the user experience for the stress management components. The stress management components may consist of a series of exercises and different levels. After each exercise, the user receives a score. Reminder can further be used to ensure that the user adheres to the schedule of taking blood pressure reading for the diagnosis. In order to perform an accurate diagnosis, knowledge discovery and different intelligent techniques can be applied to find and use patterns in order to diagnose a user based on a set of parameters. Furthermore, emphasis should also be placed on how to predict the stress level and estimate consumption data to enhance hypertension prediction. The diagnosis component should differentiate hypertensive from non-hypertensive and also predict the type of hypertension experienced by the users.

5 Proposed Framework for Hypertension

Based on the gap analysis and recommendations, a framework is proposed for the Mauritian context. The proposed framework comprises of 3 major components namely the BP monitor that takes BP readings, a gateway and the server. The gateway is the mobile of the user which serves as a middleware between the server and the BP monitor. According to the European society of Hypertension, upper arm cuff BP monitor is more reliable than the other devices such as wrist worn and fingers [36]. In the proposed framework, an electronic upper arm cuff BP monitor equipped with bluetooth can be used to maximize accuracy. One of the most used mobile operating system is android which amounts to 61% of mobiles in Mauritius [11]. Figure 3 illustrates the basic components and interaction of the proposed framework.

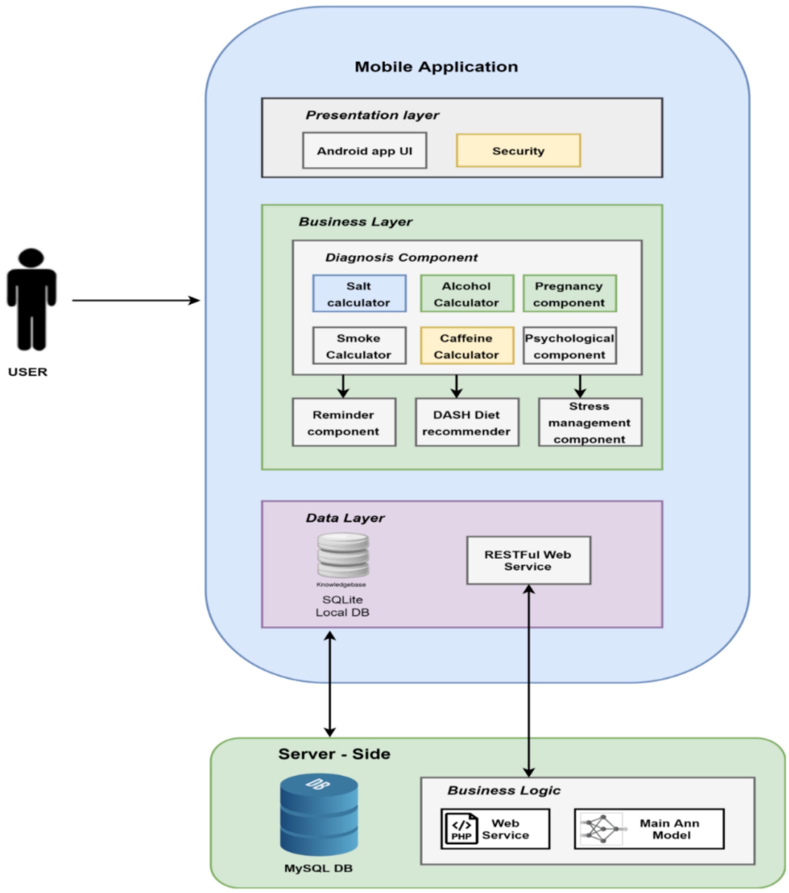

Figure 3. Proposed Framework for Hypertension

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A. Data storage

The proposed framework consists of two primary storages namely the local database and a web server database. The local database stores important details such as BP readings, the users profile details such that even if the user does not have internet connection, he/she will still be able to use the basic functionalities. The database residing in the web server, stores all the details of the different user profiles and hypertension datasets that will be used for diagnosis component. The database also stores data about the schedules of BP reading and medication. The web server database additionally stores the stress exercises details.

B. Mobile application

The main purpose of the mobile phone is to act as a gateway between the Bluetooth blood pressure monitor and the web server. The application stores the BP readings locally on the mobile and sends them to the web server as soon as internet connection is available. The mobile application is easier to access compared to a web site and it provides various advantages like using the mobile features for functionalities like making a phone call. The mobile application provides an interface which allows the user to navigate through the different components such as BP reading schedule and display of progress by using charts. The mobile application also pops up notifications for medication time.

C. Web server

The web server is used to carry out the processing when a request is received to the web service. The server makes the necessary computation and processing result which is sent to the mobile application through the web service. This architecture of a web server has been chosen so that the mobile application remains lightweight as the processing is being carried out by the server. The graph for the BP reading over a set period of time is produced on the web server and this diagram will be sent to the mobile application. The diagnosis process as well is carried out on the web server as it requires significant processing such as classification of the data based on the learning algorithm.

D. Diagnosis component

For predicting hypertension different models can be considered. The first model is the psychological model which takes different factors such as stressful event, anger, financial support, marital status, work overload and time pressure, high effort low gain, examination, exercise, project deadline and depressed to estimate the stress level. After the estimation of the stress level, the different factors such as salt intake, alcohol, smoke, caffeine are estimated. The salt intake is estimated by requesting the user to input the different types of food consumed and the quantity to determine the sodium level. The alcohol level is classified according to the type of alcohol, amount and time at which drink has been taken. Similarly the smoke level can be determined based on the number of cigarette smoked by the user, and time since the user has smoked the first cigarette. The caffeine level can be determined based on the type of caffeine drink taken, amount and the time.

The model can predict whether user has low bp, is normal, hypertensive or is facing hypertensive crisis. After the prediction of the first model, the system further checks whether the patient is female and is pregnant. If the user is pregnant and the prediction of the first model is hypertensive, the user is asked details specific to pregnancy. The pregnancy model takes the different attributes such as history of pre-eclampsia, proteinuria, predated pregnancy, number of weeks, visual disturbance, organ dysfunction and diabetes. The Hypertension diagnosis model can be implemented using the back propagation Artificial Neural Network (ANN) Multilayer Perceptron algorithm, the Pregnancy and Psychological models can be implemented using the Decision Tree J48 algorithm.

E. Stress management

The life style management component consists of mainly stress management. The stress management component comprises of various exercises which help to reduce the stress level. In order to increase adherence to the exercises program gamification features like points and levels are used to boost extrinsic motivation of user that will also enable quick view of progress made. These exercises also include physical activities such as jogging that not only impact on the stress level but also on obesity.

Audio features along with pictures can be used for stress exercises instruction to ensure user understands it the right way. Another purpose of this component is to assist the user in the exercise by providing a timer for each level of exercise. An additional feature for each exercise is to display the amount of calorie burned for a particular exercise based on the duration it has been practiced by the user. This might further enhance the user's adherence if the latter also wants to be in good shape.

Gamification aspect can further be used to enhance the adherence of the user to the stress exercises by making use of scores, levels and achievement. Moreover, the stress component can be strengthened by

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combining social networks and gamification whereby a community can be created to allow people with the same objective to communicate and help each other to attain the stress reduction goal.

F. DASH Diet

The main purpose of the DASH diet component is to recommend Mauritian recipes for hypertensive patients. The recommendation engine is based on an item-based collaborative filtering. According to the US National Heart, Lung and Blood institute, there are two main types of diet available for hypertensive patients namely the 2300mg sodium menu and 1500mg sodium menu [35]. In order to predict which diet plan will be suitable for the patient, a decision tree can be used. A dataset that consists of the patients' age, body and mass index, exercises and whether the patient is diabetic, hypertensive and suffers from kidney disease is be used to create the decision tree. The decision tree model can be implemented using the J48 algorithm in Weka and can be tested using the 10 fold cross validation. Once the model has been created and tested successfully, it can be used to predict which diet is suitable for the user based on his/her

$$sim(u,v) = \frac{\sum_{i \in Uuv} (r_{iu} - \bar{r}_u)(r_{iv} - \bar{r}_v)}{\sqrt{\sum_{i \in Uuv} (r_{iu} - \bar{r}_u)^2} \sqrt{\sum_{i \in Uuv} (r_{iv} - \bar{r}_v)^2}}$$

information. For the recommendation engine, a dataset that consists of the user ratings of the different Mauritian recipes can be used. In order to perform recommendation and predict the missing ratings of a user, an item to item similarity matrix is used. The similarity between the different items is calculated using the centered cosine also known as the pearson correlation illustrated below [42]:

Using the Pearson correlation formula the similarity value obtained will be in the range of -1 to 1. The r_u refers to the raw average of user u which is calculated by the sum of ratings divided by the number of ratings. It takes into account the positive and negative relationship between the items. After the item to item similarity matrix has been constructed, it is used to predict missing ratings of a particular user. These missing ratings are computed based of the similarity between the items rated by the user and the similarity of that particular item to be predicted with the user rated items. After all the missing ratings have been predicted, the top 5 recipes which match with the predicted DASH diet category provided by the decision tree are recommended to the user.

G. Data visualization

There are various and different data visualization techniques such as text, audio, picture and charts [21]. The charts can be in 2 dimensions or 3 dimensions. These graphical displays are a "value added feature" for keeping track of health data such as diabetes and hypertension [25]. Charts can be used to make it easier for the user to keep track of BP readings over a period of time specified by the user.

6 Conclusion

Maintaining a proper blood pressure is quite challenging. However, people nowadays are living quite a hectic life in this fast developing world, whereby proper and healthy diet are not followed and taking some time for exercising is quite difficult. That is why more and more people are suffering from hypertension. Nonetheless, the government of Mauritius has left no stone unturned in helping hypertensive people as well as people with other illnesses. However, one to one patient-doctor intervention approach is not always as effective as it seems, due to the fact of the white coat effect of hypertension. Fortunately, advances in the mobile health (mHealth) facilities have helped a lot in monitoring the health condition of patients. Therefore, implementing this framework shall aid in the diagnosis and monitoring of hypertension in people, bearing in mind the disturbing fact that half of the hypertensive patients in Mauritius are not aware of their condition. The framework caters for additional components such as stress management and DASH diet as these components are among the core components to improve the health of people suffering from hypertension.

Statement on conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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