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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.

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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.

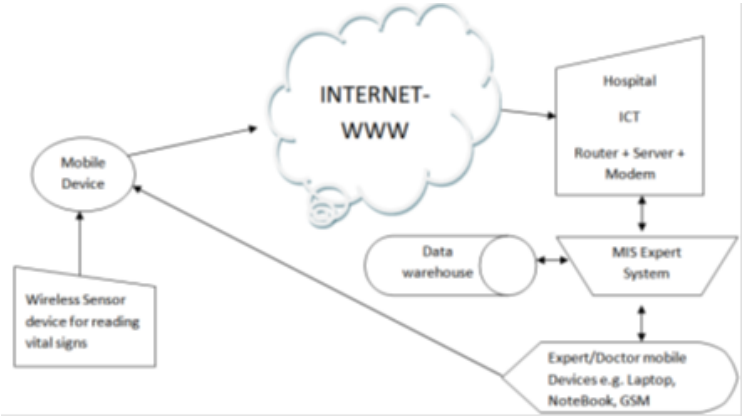

Figure 1. Wireless sensor framework for Hypertension [12]

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].

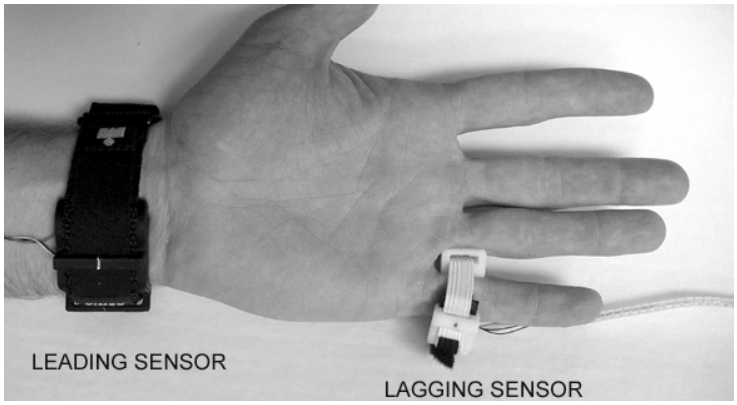

Figure 2. Wrist and Finger PPG Sensors [21]

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.

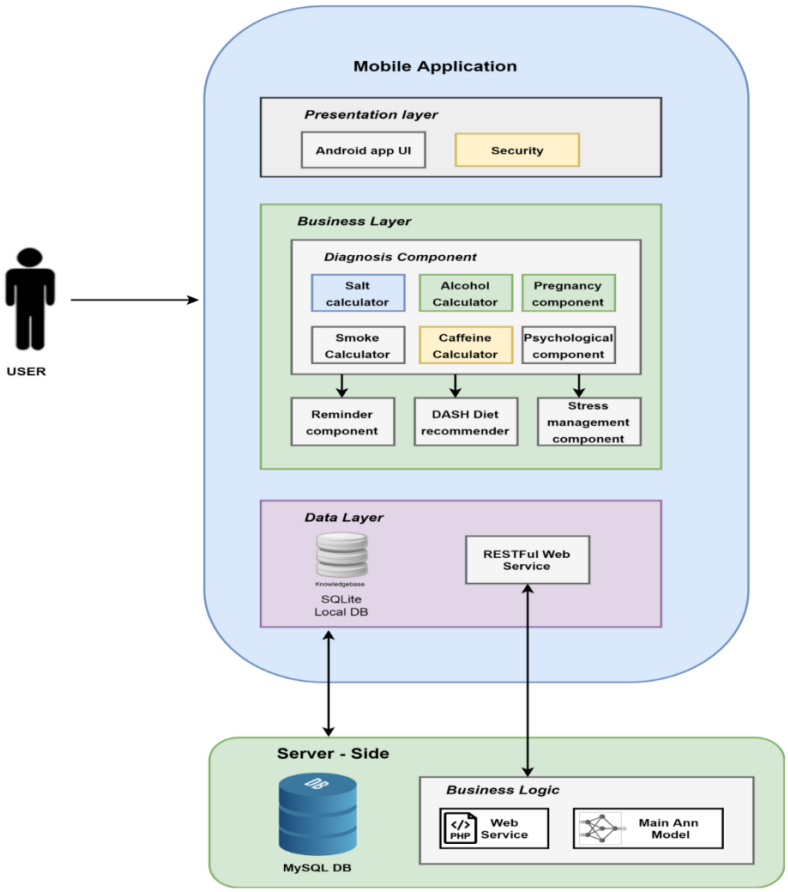

Figure 3. Proposed Framework for Hypertension

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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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