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# A Mobile-Phone Tele-Medicine System That Promotes Self-Management of Blood Pressure among Hypertensive Patients in Kirinyaga Sub County

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**ABSTRACT**
The current practice adopted by hypertensive patients in managing hypertension is making frequent visits to a health center as recommended by medical specialists. However, very few patients adhere to this practice as it is time consuming and tiresome especially if they have to travel for long distances to have their BP checked. This practice is also not practical for critically-ill patients. Consequently, most patients neglect BP check-ups and therefore focus on medication alone. This puts the patients' at risk as uncontrolled BP can lead to fatal complications. The overall objective of this research was to design, develop and pilot-test a mobile telemedicine system that helps patients' to self-manage their BP condition from the comfort of their homes. Participatory action research design was used in this study. Testing for performance, usability and utilityof the tele-medicine system was conducted.

**Keywords:** Hypertension, BP (Blood Pressure), Tele-medicine, Tele-medicine system, Usability, Utility

## I. INTRODUCTION

Hypertension, also known as high or raised BP, is a condition in which the blood vessels have persistently raised pressure. If left uncontrolled, hypertension can lead to a heart attack, an enlargement of the heart and eventually heart failure. Uncontrolled high BP is a major public health concern and leading cause of cardiovascular disease worldwide [1].

Tele-medicine is the use of telecommunications for medical diagnosis and patient care. It involves the use of telecommunications technology as a medium for the provision of medical services to sites that are at a distance from the provider [2].However, tele-medicine is still an unpopular and emerging technology in Kenya. Hospital visits is the most common practice. But with the dramatic expansion of mobile technology, delivery and quality of health care is bound to change. Better and improved control of chronic diseases like hypertension is likely to be achieved through proper utilization of mobile technology.

For hypertensive patients, they can collect and transmit their BP readings through their mobile phones to doctors, at the comfort of their premises. The doctor can then access and analyze patients' BP data on their mobile phones and provide feedback to the patients remotely.

## II. LITERATURE REVIEW

Hypertension is a terminal disease that requires to be regularly monitored and properly managed to keep the BP levels within normal [3]. Uncontrolled high BP is a major public health concern and leading cause of cardiovascular disease worldwide [1].

World Health Organization projects that in the next 10 years, the African continent will experience the highest death rates related to chronic diseases like hypertension. The high death rate is attributed to factors like lifestyle change, poverty, urbanization etc.[4]. The statistics also shows that at least 12.5 per cent of people in Sub Saharan Africa die from Cardiovascular Diseases compared to HIV/AIDS (12.3 per cent) or malaria at 7.3 per cent. In Kenya between 37 to 44 percent of the Kenyan adult population has hypertension. In order to reduce mortality rates, better ways of monitoring and managing hypertension need to be developed.

In an attempt to manage chronic diseases like hypertension, a research by [5]had proposed the introduction of remotely hosted medical records of patients to enable health service providers make references to a patient's medical history for an informed therapy plan. They argued that long term therapeutic management of these diseases requires availability of medical records to a provider when a patient presents him/herself at a medical facility. However, managing patients' records alone is not enough but rather actively engaging patients in the process of self-care. Through self-care patients are able to know their BP status early enough before the condition deteriorates.

One strategy, according to [6] to improve hypertension control in the community involves the use of specialized clinics. This approach partitions health care into undesirable silos and is neither cost effective nor practical for highly prevalent conditions such as hypertension and diabetes mellitus. As a consequence, new health care delivery models that promote patient self-management and incorporate advanced communication systems are being developed and tested. Recent surveys indicate that patients are willing to become more actively involved in managing their own care, and that self-monitoring at home is one way to increase their involvement.

Ideally the current practice involves patients making frequent visit to the hospital for BP checkups. This practice has proved to be time consuming, costly and not practical for critically-ill patients. With pervasive high speed wireless networks and powerful mobile devices, there is no doubt it is going to transform how health care is delivered. Consequently, this is likely to lower the cost of accessing professional health care and improve patients-physicians interaction. Most patients are currently willing to engage themselves in self-care. By engaging the patient in the process of self-monitoring it will increase the level of awareness of the disease, it causes and effects and how it can be managed. As a result the patient will become responsible in preserving the integrity of his/her health. This procedure will become a strong incentive to adopt a course of conduct like improving on eating habits, exercising regularly and regular intake of treatment to achieve normal BP values.

By realizing the devastating consequences of elevated BP levels, it is therefore important to emphasize on the prevention and systematic observation to fight against this disease. Through recording and quality management of BP by the patient will provide valuable information to the medical specialist. On the other hand the doctor can monitor the short-term and long-term course of the disease, develop a complete treatment plan and assess in detail the performance of a specific medication [7]. Without remote monitoring, problems can go unnoticed for a while. Homebound patients with chronic diseases often don't notice or report subtle changes in their conditions to doctors, and those changes aren't discovered until a doctor makes a scheduled visit, which could be days after a problem first develops. Therefore a remote monitoring system is useful as it alerts the doctor as soon as a medical problem crops up with a patient hence letting the doctor respond fast.

In this study a mobile telemedicine system that helps patient to monitor and self-manage their hypertension condition is described.

## III. METHODOLOGY

In this study Participatory Action Research Design was used, where patients and medical specialist were involved in the research and subsequent development and implementation activities.

Recruitment of participants was based on purposeful sampling. In order to collect reliable and valid information for usability and utility patients and medical specialist were actively engaged using the E-Delphi method.

### 3.1 Phase 1: Interview with Doctor and Patients

Semi-structured direct interview was conducted with one medical specialist to help identify hypertensive patients. As a result, 27 patients were recruited. The patients were also interviewed one-on-one. This was to get their consent in the participation of this research. Parameters that guided in system development were also identified

### 3.2 Phase 2: Pilot Testing of the System

The system was installed on doctor and patients' mobile devices. Special training was conducted for 7 days to help them use the system. Patients were also provided with Wrist BP monitors to help them take their BP readings. Patients were required to take at least 3 readings per day, that is, morning, mid-day and evening respectively, for a period of one month.

After measuring their BP readings, patients would manually feed them on the system and transmit the data to the doctor. The doctor would then receive an SMS notification of his mobile device. Using the system the doctor would examine the BP history of the patient and immediately respond/provide feedback in form of general health tips, change of medication recommendations or an appointment request. The evaluation metrics for this study were:-

- The performance of the tele-medicine system, to transmit and retrieve data to and from remote database. Metrics such as Uptime, Downtime, MTBF, Reliability, Response Time and Availability were evaluated.
- Patients' perceptions on the usability of the mobile tele-medicine system, assessed through a SUS questionnaire administered at the end of the study.
- Patients' perceptions on the utility/usefulness of the mobile tele-medicine system, assessed through a tailor-made questionnaire administered at the end of the study.

## IV. RESULTS

### 4.1 Phase One

Patients were very impressed about the idea of using the proposed system in self-managing their BP from their homes. However they stated that some training was required before they could start to usethe

system. In our discussion, most of the patients claimed that they did not have the BP monitors. Therefore Wrist BP monitors were to be provided to enable them take their BP readings.

On the hand, the medical specialist/doctor was also enthusiastic about using the system to monitor BP of patients who were not able to visit the clinic. However he was fearful about the aspect of the patients not visiting the clinic often as this meant he would lose some revenues generated from the consultation fees and patient diagnosis. Moreover the doctor felt that if patients were taking their own BP, it was likely that they would collect wrong readings which could be significantly misleading. Adequate training wasto be given to patients to ensure that they were proficient in using the Wrist BP monitors. In our discussion, the doctor highlighted three important parameters that were to be collected and transmitted by the patients namely:-Systolic, diastolic and pulse rate readings. These parameters formed the design principles of the proposed system.

**4.2 System Architecture**

The mobile tele-medicine system consists of three units, namely: - data collection unit, data storage unit and alerting and reporting unit.

The data collection unit consisted of Wrist BP monitor and an android mobile phone. Patients use the BP monitor to take their BP readings. The mobile phone then transmits the vital data to a remote centralized MYSQL database. The patient can access his/her BP history whenever need arises.The system also consists of a web server known as WAMP server. This web server is the central part of the entire system. The data collected from patients via the mobile application is sent to the web server. The Web server will then process the collected data and store it to the MySQL database server.The alerting and reporting unit sends an SMS notification for every reading sent by the patient. Doctor has the option of retrieving the patient data from the remote web server. Data is then displayed on the mobile device in tabular and list formats. The doctor can then review the BP history of a patient and provide appropriate feedback.

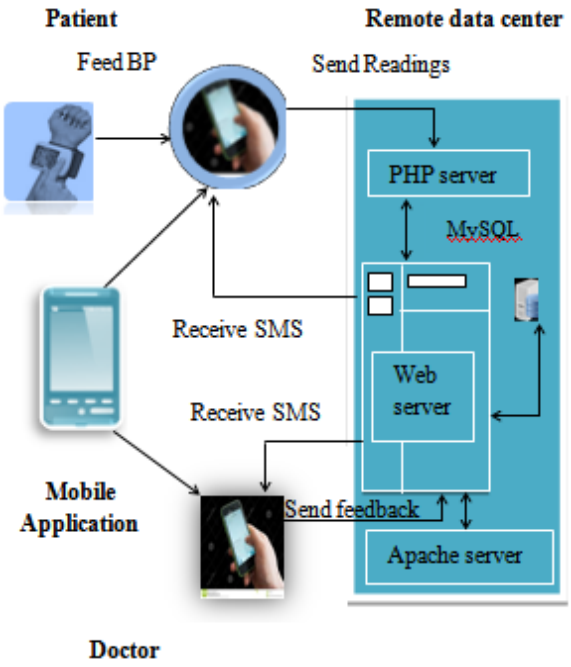


Figure 1: Mobile tele-medicine system architecture

**4.2 Phase Two**

This phase involved the actual design and development and performance testing of the mobile tele-medicine system. Sample result of system design and development is shown:-

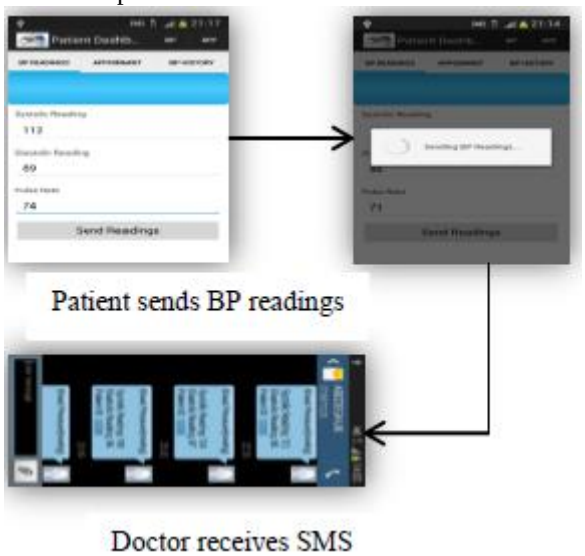


Figure 2: Patient data transmission process

**4.2.1 Performance Results**

Performance metrics such as Uptime, Downtime, MTBF, Reliability, Response Time, and Availability were evaluated. The results are as shown below:-

Table 1: A table showing performance testing results

| | **Day 1** | **Day 2** | **Day 3** | **Day 4** | **Day 5** | **Total** |
|---|---|---|---|---|---|---|
| Test Duration (hrs.) | 10 | 10 | 10 | 10 | 10 | **50** |
| Operational Time (min) | 564 | 565 | 568 | 627 | 630 | **2954** |
| Downtime (min) | 1 | 5 | 2 | 3 | 0 | **11** |
| Number of failures | 1 | 2 | 1 | 1 | 0 | **5** |
| Time to Repair (min) | 1 | 5 | 2 | 3 | 0 | **11** |
| Response Time (sec) | 508 | 457 | 459 | 506 | 517 | **2447** |
| Number of trials | 129 | 117 | 117 | 129 | 129 | **621** |

After calculation, the system achieved an uptime of 98.46%, Downtime of 0.37%, MTBF of 9.85, Reliability of 0.9, Average Response Time of 4 seconds and Availability of 99.82%.

**4.3 Phase Three**

This phase involved collecting user's perceptions about the usability and utility of using the tele-medicine system. 27 patients and 1 medical specialist were enrolled for the study. Seven patients dropped out of the pilot study for different reasons. Some of them highlighted anxiety when taking their BP as the main cause. Patients were provided with a Wrist BP monitor to enable them collect their BP readings while at home

**4.3.1 Usability Results**

System Usability Scale (SUS) questionnaire was used. Summarized SUS scores were as shown below:-

Table 2: A table showing frequency of patients with acceptable SUS scores

| **Acceptability Level** | **Number of Patients** | **Percentage (%)** |
|---|---|---|
| Acceptable | 17 | 85 |
| Not Acceptable | 3 | 15 |

17 out 20 patients had acceptable SUS scores. This means that they were satisfied using the system and hence found it effective in helping them manage their condition from home.

**4.3.2 Utility Results**

A tailor-made questionnaire was also administered to the patients. The results showed that all the 20 patients perceived the system to the useful in helping them save time, improve self-care, better manage their BP, and interact with doctor easily.

When asked whether they preferred using the tele-medicine or hospital visit, all the patients voted for tele-medicine system. When asked whether they would be willing to participate in another tele-monitoring exercise, all patients voted yes.

## V. DISCUSSION

In this section, we discuss the outcomes of the design and development and testing of the mobile tele-medicine system. With the development of the mobile tele-medicine system the patients were empowered in self-managing their BP from home. Using the Wrist monitors the patients were able to monitor their BP at least three times a day. The vital parameters measured were transmitted to the doctor immediately. The doctor then provided feedback to the patients in form of medication recommendations or general health tips, to help them lower their BP to normal ranges. From the research findings 17 out of 20 participants were satisfied by the daily monitoring of their blood pressure. We can therefore create a clearer picture of the mobile application overall usability. 85 percent of the study patients had usability scores above average and hence found the system acceptable and effective in helping them manage their condition while at home.

From the performance results, the tele-medicine system achieved an excellent reliability score of 0.91. This means that probability that the system will function as expected without failure(s) within a period of 10 hours is 0.9.In other words, out of 10 hours of operation, a failure will only occur in the ninth hour.

Similarly, the tele-medicine system achieved an availability of 99.82 % (2-nines). This translates to an acceptable downtime of 3.65 days per year. This downtime is not substantial to the users and may not affect the usability and utility of the system.

The design of the mobile tele-medicine, which is an android mobile application, is characterized by tasks that involve transmission and retrieval of data to and from a remote database. The Android client is connected to the remote server through PHP web services. As a result, it takes time for the remote server to give feedback to the users once a task has been performed. Therefore measures must be taken to ensure that the response time is not too lengthy, as too much delay has been proved to have a negative effect on user's satisfaction and productivity (causes frustrations) .In order to deal with the delay during processing of a user's request, process dialog indicators were used. This therefore means that the acceptable time limit, according to [8], for transmission and retrieval of data to and from a remote database is 10 seconds. From the research findings of this study the average response time for data transmission and retrieval from the remote database was 4 seconds, which is acceptable.

We can therefore conclude that, the excellent reliability and availability level, and the short response time contributed to the overall usability and utility of the tele-medicine system. Usability results showed that 17 out of 20 patients were satisfied with using the system, while all patients found the system useful in their process of self-care.

The current practice adopted by these hypertensive patients in managing and monitoring hypertension is making frequent visits to the health center as recommended by the medical specialists. Most of these patients claimed that the frequent visits were tiring and time consuming. The patients' also travelled for long distances to have their BP checked. This practice was therefore impractical especially for critically-ill patients. Consequently, most of these patients had neglected BP check-ups and had therefore focused on medication alone. This put the patient's at risk as uncontrolled BP could lead to devastating consequences.

With the development of the mobile tele-medicine system patients did not have to make hospital visits. Initially, patients were required to travel for long distances to have their BP checked. On average patients used to travel for at least 5 km and hence spent at least 2 hours of time. But with the introduction of tele-medicine system patients were able to monitor and manage their BP from home and this saved them the burden of having to visit the hospital for their BP checkup. From the statistics above, all patients, both male and female, perceived the system to be useful in helping them save time.

On average most patients had their BP checked after 60 days. This is after they made a visit to the hospital. But with the Wrist BP monitors patients were able to take their BP readings at least 3 times a day. This created self-awareness to the patients about their BP levels. It was therefore easy to take preventive measures early enough before the condition deteriorated. The vital parameters measured were transmitted to the doctor immediately.

The doctor provided feedback to the patients in form of medication recommendations or general health tips, to help them lower their BP to normal ranges. Through this continuous self-monitoring exercise, patients were there able to take good control of their BP. From the utility results, all patients perceived the system to the useful in helping them take care of their BP.

One important aspect to better BP treatment is ability to examine the trend of the BP data of the patients. This requires quality recording and ease of access of patient records. Initially patients were issued with a hospital card where BP treatment data were recorded. When asked to produce their hospital cards for the previous one month none of patients could manage. This means that if patients were to seek medical service from another hospital, new blind-treatment would be given. This unsystematic BP treatment procedure could lead to more serious consequences. To the doctor he complained of having to keep physical for the patients BP data. He claimed that retrieval of these documents was cumbersome. But with the introduction of this tele-medicine system, data was centrally located. Both the patients and the doctor could access the BP data from their mobile phone faster and on time.

During the 4 weeks of using the system in monitoring BP, some patients reported a significant improvement in their BP. However, this fact could not be well substantiated as the monitoring time was not adequate enough. Other factors such as, medication compliance, change of dietary habits, frequent physical exercises etc. may have contributed to improvement of BP.But our results maypartly support and augment the research findings by [9] which showed that the patient's BP improved significantly by approximately 10/4 mm Hg over the four months observation period.

These results are quite impressive and a long-term trial is hereby recommended. Research findings by [10] showed that an 8-week, randomized, controlled trial assessing a complex home BP tele-medicine system, demonstrated a significant fall in 24-h ambulatory BP of 5/2 mm Hg for systolic and diastolic BP, respectively, in hypertensive patients.

From the patients BP data history, it was clear that most of the patients adhered to the daily measurements that were requested by the medical specialist. This showed how passionate the patients were about the concept of BP self-monitoring. When asked whether they would be willing to continue using the tele-medicine system, all the patients said yes. At the same time, when asked whether they preferred their old practice of making hospital visits to tele-medicine system, all patients voted for tele-medicine system. Generally, the tele-medicine system provided great help to remote patients and medical specialist.

This research study was not without any limitations. First, only patient's with android-enabled phones were enrolled for the study. Patients who were passionate about monitoring their BP but didn't have android-enabled phones were therefore locked out. This problem can be addressed by developing a similar mobile tele-monitoring system to accommodate other mobile platforms.

Secondly, some patients felt frustrated especially when the mobile internet connectivity went down or was slow. They complained of not being able to login and send their BP readings quickly. This can be addressed by developing a similar mobile application that does not involve internet usage.

## VI. CONCLUSION

In this research, we have managed to develop a mobile tele-medicine system for hypertension management to help hypertensive patients monitor their condition while at home. Patients were able to collect and transmit their BP readings faster and on time. The doctor was able to provide regular feedback to the patients to enable control their BP. The tele-monitoring system has proved to be usable and useful to the patients in managing hypertension. It is now clear that the concept of tele-medicine can become a reality in Kenya. If adopted, it is therefore possible to extend health services to undeserved areas. The success of this mobile tele-medicine system may therefore be considered as a baseline towards achieving better management of chronic diseases. With the impressive results from the study, similar tele-medicine systems can also be developed for managing other diseases like diabetes, Tuberculosis etc.

The 4 weeks testing period of this study was not adequate enough to substantially quantify the benefit of drop in BP of the patients. As a result a long-term trial is therefore recommended.

### 5.1 Further Work

The following areas, arising from the research project are proposed for further research:-

- Data collection in this mobile tele-medicine system was done manually. Further research is required to ensure automatic transmission of the BP readings from the Wrist BP Monitors to the android application via Bluetooth technology.
- This mobile tele-medicine system was only restricted to users with android enabled mobile devices. Further research is required to develop a similar mobile tele-monitoring system which can run on any other mobile platforms like J2ME, Apple or Window phones.
- In order to ensure sustainability of this mobiletele-medicine system, further work is required to ensure that it is integrated with already existing Electronic health records (EHRs)systems.

## VII. ACKNOWLEDGEMENTS

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