

## An Assessment of Suitable and Affordable Smart armband for preeclampsia Management in Antenatal Care

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### Abstract

Blood pressure is one of the measurements that is taken during antenatal care visits. Though motherhood is a fulfilling experience in the society, it is connected to ill-health and even death in some women leading to maternal morbidity and mortality due to preeclampsia syndromes. United Nations' Sustainable Development Goal 3 aims to reduce global maternal mortality ratio to less than 70 per 100,000 live births. Therefore, this study sought to assess the suitability and affordability of smart armbands for preeclampsia management in antenatal care. An exploratory design was adopted in the study to assess the suitability and affordability of the device in antenatal care to ensure real time monitoring. Twelve categories were used in assessment to select the most suitable smart armband. It was found out that F1 smart armband was suitable and affordable. The study has shown great potential for actual adoption in health care systems in developing countries.

**Keywords:** Smart armband; antenatal care; Internet of Things; maternal care; preeclampsia.

### 1. Introduction

Motherhood is an optimistic and a fulfilling experience in the society. However it comes with some challenges especially during maternal period. Currently, there are maternal challenges that bring about long term effects if are not controlled such as preeclampsia. Preeclampsia is a syndrome related to high blood pressure (or hypertension) and protein in the pregnant mother's urine due to kidney problem and it normally starts after the twentieth (20th) week of pregnancy [1]. Preeclampsia syndrome represents one in three cases of severe obstetric morbidity, while hypertension is the leading single identifiable risk factor in pregnancy associated with stillbirth. This syndrome is strongly connected to foetal growth restriction, low birth weight, preterm delivery, respiratory distress syndrome, and admission to neonatal intensive care [2]. Mostly, blood pressure challenge doesn't cause signs or symptoms and a pregnant mother should attend every assigned prenatal care visits for check-up even when she feels okay.

Blood pressure is one of the measurements that is taken during antenatal care (ANC) visits, and while a pregnant mother should visit healthcare at least four ANC visits, this is never a reality to many due to social, family, and community context, and beliefs hence a major concern [3]. Poverty and lower education levels may make it more difficult for pregnant mothers to make the best choices about when to seek health care. Even for those who manage, it may never be feasible to closely detect hypertensive disorders within those four visits depending on the period of visits. Sometimes, women never get to have their blood pressure taken, and there is no opportunity to monitor even for women who are at risk of developing preeclampsia. Another cause of difficulty in testing hypertension is the accuracy of devices being used due to environmental condition such as stress.

During Antenatal care visit, the devices that are currently being used are standalone kits that a patient will collect data, record, and take the records to the health care provider for analysis and take of action. Mi bebe and MamiCare are apps developed in Mexico which connect women to specialized clinics in Mexico area and not in Kenya. While in Kenya, there are over the counter devices that helps one to read blood pressure then take it to a

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health care provider for analysis. There is little done in Kenya that automatically reads blood pressure fluctuations, analyse it, and send information to the cloud for healthcare notification. However, few pregnancy specific wearable health solutions have been introduced so far [4].

There are several online reviews of wearable devices, usually presenting different perspectives on the wearable devices rankings. However, the information provided is not matching the subjective findings that express further details about the devices, the participants in the experiments, or the particular reviewers involved. Further, there is no quantitative comparison table to show the results of subjects reviewed [5]. Online reviews rarely present objective and measurable comparison data, and the review content is usually based on bloggers opinions and not from the customers who consider purchasing a smart armband device that would guide them in meeting their needs. Several studies have provided a comparison among the leading wearable fitness-tracking devices available today, covering the accuracy, user-friendliness, and customer satisfaction. Therefore, the study sought to assess suitable and affordable blood pressure measuring smart armband that is applicable in preeclampsia management.

### **1.1 Preeclampsia during Maternal Care**

The burden of preeclampsia has been a major concern worldwide both in developed and developing countries making its prevention and management a major concern. Currently, there is no well-established measure for prevention of preeclampsia in the general population [6]. In developed countries, preeclampsia community guideline, has been laid down, which involves: mothers to be offered referral before 20 weeks gestation for specialist input to their ANC plan if they have high risk, women with no risk of preeclampsia visit ANC care 7 times, while mothers with high risk are reviewed in the community at least once every three weeks before 32 weeks and at least once every two weeks until delivery for a check-up of any symptoms of preeclampsia. Recommendations have been made for improving the accuracy of blood pressure measurement [6].

In a study carried out in Kenya [7] it was found out that maternal deaths due to preeclampsia are incredibly high with 14% of maternal mortality worldwide being due to hypertensive disorders of pregnancy with sub-Saharan Africa (Kenya) at 16% while the United States, death due to preeclampsia is as low as 4.8%. This points out that there is a huge difference in the rates of maternal mortality and preeclampsia which is caused by differential diagnosis and management of preeclampsia in Kenya and the United States. When preeclampsia is left unmanaged it is likely to progress into eclampsia hence respiratory issues, acute renal failure, obstetric embolism, or maternal death occurs.

### **1.2 Blood Pressure Reading Techniques**

There have been strategies that have been laid down to detect blood pressure fluctuation. Blood pressure measurement can be possible with the help of two different techniques which are Auscultatory technique and Oscillometric technique. Auscultatory technique operates by listening to korotkoff sound which gets created by body during the blood pressure measurement with the help of stethoscope while the correct measurement depends on cuff size, wrapping technique and release of the pressure while, oscillometric technique depends on measuring oscillation signals in the cuff which is quite easy and automated technique, and more accurate than that of oscillometric technique [8].

The auscultatory method uses mercury sphygmomanometer for office blood pressure measurement though is diminishing due to mercury use, with the widespread of hybrid sphygmomanometers. Due to the challenge, a hybrid devices are implemented to combine the features of both electronic and auscultatory devices such that the mercury column is replaced by an electronic pressure gauge, similar to oscillometric devices, but the blood pressure is taken in the same manner as a mercury or aneroid device, by health practitioner using a stethoscope and listening for the Korotkoff sounds [9].

Ogedegbe & Pickering (2010) stated Marey was the first to demonstrate oscillometric technique in 1876, and afterwards, it was shown that when the fluctuations of pressure in a sphygmomanometer cuff are documented during gradual deflation, the point of maximal oscillation agrees with the mean intra-arterial pressure. These

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fluctuations begin at approximately systolic pressure and continue below diastolic so that systolic and diastolic pressure can only be estimated indirectly according to some empirically derived algorithm. This method is advantageous in that, no transducer is required to be placed over the brachial artery, it is less susceptible to external noise, and that the cuff can be removed and replaced by the subject while monitoring. The main disadvantage is that such recorders do not work well during physical activity when there may be considerable movement artefact.

Another technique that is in use is an ultrasound technique. The devices integrating this technique use an ultrasound transmitter and receiver positioned on the brachial artery under a sphygmomanometer cuff. As the cuff is deflated, the movement of the arterial wall at systolic pressure causes a Doppler phase shift in the reflected ultrasound, and diastolic pressure is recorded as the point at which diminution of arterial motion occurs [9].

Finger cuff method of Penaz is a technique that works on the principle of the “unloaded arterial wall”. Arterial pulsation in a finger is detected by a photo-plethysmograph under a pressure cuff [9]. The output of the plethysmograph is used to drive a servo-loop, which rapidly changes the cuff pressure to keep the output constant, so that the artery is held in a partially opened state. This method gives an accurate estimate of the changes of systolic and diastolic pressure when compared to brachial artery pressures; the devices developed using the techniques enables readings to be taken over 24 hours while the participants are ambulatory, though it’s a bit cumbersome to undertake the process.

With the great support of contemporary technology, such as mobile applications and the Internet of Things (IoT), continuous monitoring, tracking, and transmitting personal health measurements in real time has become possible in more advanced ways than ever before techniques [10]. The advancement of these technologies have expanded the prospects for maternity health care [11] as Internet of Things connects devices such as smart wristbands remotely to servers, thus enabling the monitoring and data analytics through Web-based user interfaces from anywhere and at any time [12].

### **1.3 Technology for Preeclampsia Management**

Technology has brought great improvement of preeclampsia cause (blood pressure) detection. Several applications have been developed to detect blood pressure measurements. Some of these applications include: blood pressure tracker, which the patient has to enter details such as systolic pressure, diastolic pressure, heart rate, and the time of day the reading was taken. Then the color-coded calendar in the application marks green, if the blood pressure is normal, orange if the patient is on the verge of hypertension, and red if one has high blood pressure. The other application is the Omron Health Management Software (OHMS), which allows one to upload data from blood pressure monitor or pedometer directly to their personal computer by using the Health Management Software to keep track of their health and fitness data, and provide vital updates to the health care provider [13].

To achieve the Sustainable Development Goals (SDGs) and maintain better maternal health, researchers have critically examined new ways of using existing resources in the world to create improvements. Mobile technology infrastructure is one of the unprecedented technologies that are being adopted to increase access to health care and save the lives of pregnant mothers. The growth of mHealth solutions to improve health outcomes is largely embraced due to its convenience, user friendliness, and relatively low cost of mHealth applications [14].

In recent moments, sensor technology is an advanced technology that is being used to monitor maternal data. In addition, Internet of Things (IoT) technology in conjunction with modern sensor technologies such as RFID and ZigBee are currently being implemented for the success of automated tracking systems for patients, assets and records in a smart hospital environment [15]. In a study by, [16], proposed a cohesive observing system for maternal healthcare monitoring that gives instructions during operation by video conferencing and makes continuous contact with the attending physician at the hospital of the pregnant lady, getting information on routine nutrition diet and vital monitoring parameters like infant heartbeat, labour delivery time, blood glucose

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level, temperature, pressure, ECG of a mother for the entire period of pregnancy. Mobile foetal cardiocography was proposed to allow conducting dynamic monitoring over the cardiovascular system of the foetus and pregnant woman without the need for staying inside a medical institution and being under medical personnel's supervision [17].

In Mexico, a system called MAMICare was designed to ensure the proper monitoring and control of the patient's evolution by storing adequate information and following up data required in basic maternity-infant care and reduce failure to detect risk situations on-time. Mi bebe is also developed in Mexico that allows health professional and community health workers to continuously and remotely monitor women with high-risk pregnancies to provide early warning of abnormalities and to connect women to specialized clinics in a timely manner.

Kenya is not left behind; technology has been adopted to reduce MMR. An alliance by [14] showed a list of mHealth applications that are already implemented in Kenya which includes Mobile for Reproductive Health (m4RH) app that is text-based message service to deliver evidence-based information on family planning methods., changamka and m-Money For Women with Fistula apps that offer mobile financial services by allowing women to save toward delivery and postnatal care, ChildCount+ app that allows community health extension workers to use text-based messages to register new births and monitor community health events in pregnant women, and Capacity project app that support effective communication with health workers deployed to remote areas.

#### **1.4 Smart armband device**

Smart armbands are forthcoming devices in supporting health in everyday living by assisting in self-monitoring of personal human activity, obtaining response based on activity measurements, allowing for surveys to identify patterns of behavior for decision making, and supporting two-way communication within health care practitioners and family. However, this device is an emerging technology and research and is at evolving stage [18].

According to a study by [19] it was reported that there is a huge demand of smart armbands where the predicted growth of smart armband demand was 214 million units in the year 2018 and reported also that from a financial feasibility standpoint, current prices for smart watches start at less than \$100 USD for the Pebble Classic. The availability of smart watches have gained the attention of amusing users, but their use for health care decisions will require evaluation of these devices for that purpose by an expert.

The assessment of smart armband factors should be considered to ensure the suitability and affordability of the device in managing preeclampsia in antenatal care. Several studies have reported the need for greater battery power in smart armbands which will increase with the need for greater on-board processing of data prior to transmission to other devices [18] [20]. According to a study carried out by [21], one of the biggest issues with smart watches was found out to be that batteries within them don't last long before they get recharged. The average battery life is about 1 to 2 days at most whereby; Apple Watch Series 2 and Huawei Watch battery life lasts for one and half days, for Samsung Gear S3 lasts for 3 days, Pebble 2 lasts for 10 days but has the disadvantage of having a small RAM and storage space with minimal number of functionalities.

Physical factors also play a role in wearability of the device. According to [22] weight, size, and degree of comfort of a smart armband is said to play key roles in increasing its wearability. Rapid changes in technology are also a concern where one purchases a device and in two months period, the device is out of stock like in the case of [18] who found out that out of the nine different smart watch models employed in a review, two were no longer available and one was a last generation watch model. In addition to this [22] concluded that when researchers are planning for a study that involves technological devices, there is need to consider rapid progress of the technology since in their study, they experienced change of smart armband for one of the manufacturers exited the wearable technology market. Moreover, human computer interaction design is also a factor to be considered. According to a study by [21] it was reported that respondents claimed that small screen size of smart watches impaired usability of the device. An on-board display and an interactive mobile application,

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could encourage the contributors to wear the device [23]. Garmin Ltd smart wristband was reported to be chosen from the available, affordable price, devices due to its small size, smooth design on straps, waterproofness, and ability to estimate both steps and heart rate [22]. Its collected data was continuously and synchronized to the Garmin Connect website with the use of the Garmin Connect app. Other assessment factors that would require solutions related to privacy, confidentiality and security of smart watch data as well as the ethics of data ownership and use [24].

## 2. Materials and Methods

The search for and assessment of devices for their suitability and applicability is an exploratory process. Exploratory studies seek to look for patterns, ideas or hypothesis rather than to confirm any predetermined hypothesis [25]. Suitability in the context of BP readings refers to the ability of the selected devices to take real time readings from the target population for preeclampsia management. Suitability in this study has been considered with respect to the method of taking the readings, ability to transmit the readings to a mobile device for analysis and alert generation. Affordability on the other hand is a critical consideration especially in the low resource setting that is Kenya and other LMIC's if widespread adoption of a solution incorporating BP measurement devices is to be achieved.

The research considered review of documentation to give guidance on the selection of the device specifications for the smart armband. A rigorous, systematic and transparent approach was followed which consisted of writing the specifications for the documents reviewed.

## 3. Results

Three devices have been considered in detail: the F1 Smart bracelet [26], Huawei Band 2 Pro bracelet [27], and DigiCare bracelet [28]. The three smart armband devices in the assessment were purchased from website of jumia.co.ke which is one of the largest online retail store in Kenya. In addition they were the chosen for they were the ones that were available in the stock of the website, could read the blood pressure metric, and the device with the highest cost had Kshs. 15,000 thus affordable for purchase. Both devices have similar features and capabilities such as blood pressure monitoring, heart rate monitoring, sport pedometer, sleep monitoring, oximetry, fatigue measurement, call reminders and message reminders. They have a number of sensors such as the Six Axis sensor, blood pressure and a heart rate monitor. They both use Bluetooth for data transmission. The selected three devices were fitness trackers which had specifications for measuring blood pressure. Their specifications are shown in Table 1 shown below.

**Table 1: Analysis for suitable and affordable Smart Armband for Preeclampsia Management**

| No  | Smart armband device model           | F1                 | Huawei Band 2 Pro | DigiCare      |
|-----|--------------------------------------|--------------------|-------------------|---------------|
| 1.  | Bluetooth technology                 | 4.0                | 4.0               | 4.0           |
| 2.  | Waterproof                           | IPV67              | 5 ATM             | IP67          |
| 3.  | Blood Pressure measurement function  | Systolic/diastolic | Systolic only     | Systolic only |
| 4.  | StandBy after full charge            | 7 days             | 21 days           | 7 days        |
| 5.  | Operation                            | Single touch       | Single touch      | Single touch  |
| 6.  | Language                             | English/Chines     | English           | English       |
| 7.  | Material                             | Silicon +Pc        | TPU               | TPE           |
| 8.  | GPS                                  | No                 | Yes               | No            |
| 9.  | Standards                            | Open source        | Proprietary       | Proprietary   |
| 10. | Alerting messaging App               | No                 | No                | No            |
| 11. | Acceptance of a different Mobile app | Yes                | No                | Yes           |
| 12. | Price in Market (Kshs.)              | 6,999              | 14,260            | 8,999         |

#### 4. Discussions

The researcher analysed the suitable smart armband from the three devices purchased. This study focused on objective method where data was retrieved from the specifications from device user guides.

Twelve categories were classified in the form for analysis levels: Bluetooth technology, waterproof, Blood Pressure measurement function, stand by after full charge of the battery, user operation, language, and material for the case, GPS connectivity, standards, alert messaging, Acceptance of a different Mobile app, and price in the market. The suitable device selected based on the specifications was F1 smart armband device that used Wearfit mobile app. It led to selection because it had an open source standards that would allow programmer to modify the application in fitting his/her preferences. F1 device also had a Bluetooth 4.0 technology, which could work well with android operating systems. These specifications will help the device to collect real time data on blood pressure from pregnant mothers. The study concurs with the study [29] that concluded that users need continuous

Blood Pressure monitoring and thus thus, a home-based system with connectivity to the caregiver online network would be of interest. In addition, it is a waterproof device, has a 7 day stand by after full charge of the battery that can work well in low settlement areas without electricity. This is in accordance with previous finding [22] that the ease of use and long battery life are known to be important factors to use the devices. It has a single touch user operation, designed using English language which is the national language in Kenyan system, and uses Silicon +Pc material which does not cause the skin to sweat in case of hot weather condition. The cost of the band is also affordable being Ksh. 6,999 compared to other analyzed devices for measuring blood pressure.

Although, Huawei Band 2 Pro and Digicare smart armbands could have worked well in LMIC's countries due to its longest battery charge days, they were not selected because of other reasons such as proprietary standards, display systolic reading only for blood pressure, and could not accept a different mobile application except its only designed Huawei's Health app and Digicare App respectively. Moreover, the F1 Smart armband was not able to take readings from dark skinned users. This is due to the use of optical means to measure the time lapse between blood pulses on top of a blood vessel. In order for this to be successful the light used for reading must be able to penetrate the skin which is challenging for dark skins. Thus, the users are expected to use their tip fingers when reading blood pressure measurements.

#### 5. Conclusions

The assessment of suitable and affordable smart armband has shown great potential for actual adoption in health care systems in LMIC's to manage preeclampsia condition. However, the smart armbands should be able to be used by both dark and light skinned consumers. The human device interaction design of such a device need to be carefully evaluated. The results and findings of the research may be employed in future research and development projects that use smart armbands as a real time tool to measure blood pressure for preeclampsia management in antenatal care.

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