Mobile Application for Remote Monitoring of Vital Signs and Physical Activity of Pregnant Women in Peru

Dylan Delgado, Bachelor[1], Jose Donayre, Bachelor[2], and Richard Copaja, MBA[3]

[1, 2]Universidad Peruana de Ciencias Aplicadas, Peru, u201812147@upc.edu.pe, u201810301@upc.edu.pe
[3]Universiad ESAN, Peru, pcsircop@upc.edu.pe

Abstract—**Certain investigations have shown that, during the pregnancy period, pregnant women are exposed to various pathologies such as perinatal depression, gestational hypertension and excessive gestational weight gain, which lead to a notable mortality rate. This paper presents GEST, a mobile application which supports the control of prenatal health through the collection of data such as vital signs and physical activity that the mHealth Google Fit technology allows to collect. With the help of notifications, chat conversations, educative content (psychoprophylaxis guides) and dynamic graphics, GEST allows both pregnant women to achieve a healthier pregnancy and healthcare professionals to respond to vital alarm signs that represent a considerable risk for pregnant women, reducing the need for medical appointments. Without depending on a health center, this system is meant for private use, since it allows data access between the healthcare professional and her pregnant patient through a link code. As a result of the experiment, it was shown that the level of satisfaction of the GEST users was high due to the ease of use and the high precision of the results.**

Keywords—**eHealth, exercise, heart rate, mHealth, mobile app, obstetrics, pregnancy complications, prenatal care, remote monitoring, telehealth, wearable devices**

I. Introduction

In the stage of pregnancy, pregnant women experience changes such as an increase in blood volume, heart rate, weight gain, etc. Complications such as the development of diabetes, gestational hypertensive disorders, and impaired fetal growth are associated with an increased risk of early mortality of the mother [1], and the baby [2]. In the case of perinatal depression, the frequency of cases rises from 5% to 20% [3]. The prevalence of this disease ranges from 13% in high-income countries (HIC) and 19.8% in low- and middle-income countries (LMIC) [4]. In the Peruvian environment, it was found that the risk of depression in pregnant women is 30.5% [5]. Regarding hypertensive disorders, it is the first cause of maternal death in developing countries [6]. In addition, these were prioritized as one of the main causes of maternal mortality in Peru [7]. Maternal mortality caused by gestational hypertension induces approximately 10% to 16% in the world [1]. In addition, one of the most frequent reasons for mortality

in Peru is hypertension with 21.5%. On the other hand, gestational hypertension is related to an excessive increase in gestational weight. At least 50% of women in the world in a fertile state are overweight [8]. This problem causes negative consequences in the baby's body development (LGA), macrosomia, implementation of cesarean birth, gestational diabetes, preeclampsia, among others. In the Peruvian sector, of a total of 1,712,639 pregnant women belonging to the 24 departments of the country, between 2012 and 2017, 30.81% (527, 708) were overweight and 9.73% (166, 676) suffered from obesity [9].

To prevent these pathologies, various tips on physical activities have been disclosed in various health centers. According to the American College of Obstetricians and Gynecologists (ACOG) in 2015 and reaffirmed in 2017, at least 30 minutes of physical activity during pregnancy on most days of the week has been recommended [10]. Similarly, the ACOG also mentions that exercise significantly reduces the incidence of gestational diabetes according to a 2017 study involving 300 overweight and obese pregnant women with less than 13 weeks of gestation. Similarly, the Department of Health and Human Services (DHHS) Physical Activity Guidelines recommend engaging in at least 150 minutes of aerobic activity weekly during and after pregnancy [11]. In addition, there is evidence that exercise decreases the probability of cesarean deliveries in women suffering from type 1 and type 2 diabetes by 55% [12].

II. Related Work

Bump2Baby focuses on the advised implementation of an evidence-based system of care for overweight and obesity prevention using a combination of synchronous and asynchronous text messaging and video [13]. Similarly, the SmartMoms Canada app seeks to integrate and maintain healthy lifestyle behaviors, such as engaging in physical activity, eating a healthy diet, managing anxiety, and practicing proper sleep cycles [14]. In another study, through counseling, using a Fitbit wrist monitor and a mobile application, behavioral changes were evaluated to provide physical activity intervention in

pregnant women with type 2 diabetes or gestational diabetes (GD) [15]. Additionally, a mobile device with a telemedicine platform installed was used with the intention of treating pregnant women with pregnancy complications by transferring data to the indicated health center [16]. In 2015, the PREMOM study was applied to pregnant women at elevated risk of presenting hypertensive disorders of pregnancy (HDP) in which they received obstetric surveillance using a blood pressure monitor, an activity tracker and a scale [17].

III. MAIN CONTRIBUTION

In this research, the GEST mobile application offers to contribute to the remote monitoring of physical activity and vital signs of pregnant women with the aim of preventing pathologies such as perinatal depression, hypertension and excessive gestational weight gain through the data collected by Google Fit such as heart rate, blood pressure, weight, physical activity, etc. This solution is part of the technologies on remote patient monitoring (RPM) Telehealth, as it is intended to be used both by pregnant women and by a healthcare professional (an obstetrician) who supports said monitoring as represented in the physical architecture in Figure 1. Moreover, four objectives are proposed to be aimed: to analyze the requirements and technologies for monitoring vital signs and physical activity in pregnant women, to design an application that allows consulting the data on physical activity and vital signs of pregnant women, to validate the functionality of a mobile application that allows consulting the physical activity performed and vital signs of pregnant women through user tests and to propose a system continuity plan to ensure constant monitoring of pregnant women.
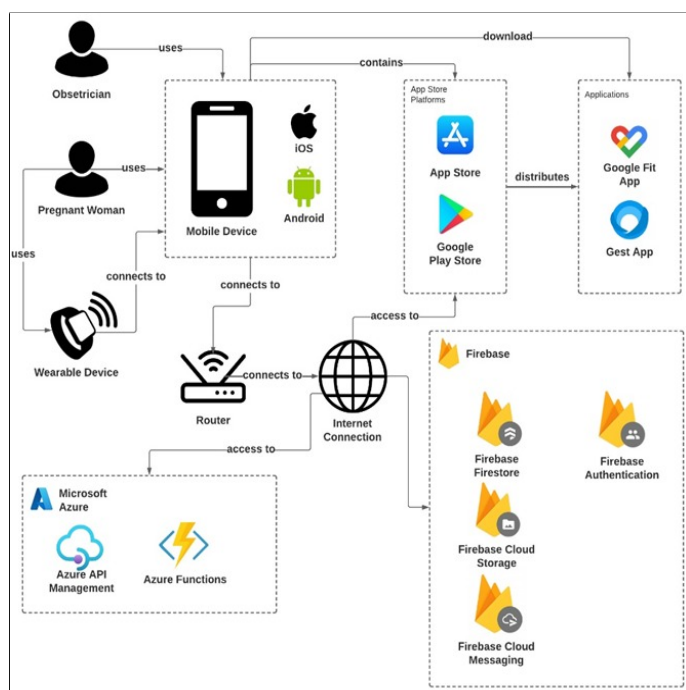

Fig. 1. Physical architecture of the GEST application.

A. Preparation of the test scenario

Through benchmarking models, the technologies for the development of the solution were chosen, such as the type of application to be developed, the mHealth Google Fit technology, the Flutter framework and the Backend-as-a-service cloud model shown in Figure 2, in addition to the main system requirements. In this manner, the mobile application was deployed to various Android mobile devices such as a Samsung Galaxy S9 and a Huawei P30 establishing a connection with our backend test environment in the cloud provided by Google Cloud Platform and Microsoft Azure Services.
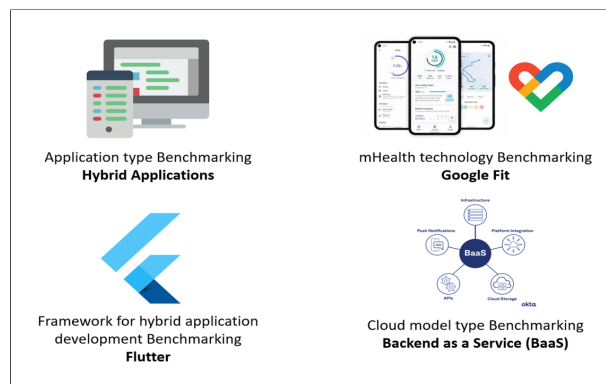

Fig. 2. Implemented technologies in the GEST application.

Health professionals will have the function of monitoring pregnant women linked by means of a code. To streamline communication, a chat to talk with patients was implemented, as well as receiving notifications for warning signs in the recent records of the pregnant women. In the same way, the health professional can record physical activity goals with the objective of promoting physical activity to the pregnant women through reminders. Figure 3 shows the application interfaces for the health professional.

As pregnant women, with the help of smart watches data will be recorded automatically, which allows an in-depth analysis of their health. Pregnant women will have access to their data presented in charts, psychoprophylaxis guides for a healthy delivery and a section for registering laboratory tests. In the same way, the application will give them reminders so that they do not lose the continuity of their records. Finally, the application integrates a chat to facilitate the interaction between them and their health professional. Figure 4 shows the application interfaces for pregnant women.

B. Process to follow

Once the development phase has been completed, the process represented in Figure 5 will be followed for the validation phase of the solution.

C. Definition of Indicators

Solution validation consists of evaluating user satisfaction and user experience. Satisfaction is measured by the Customer
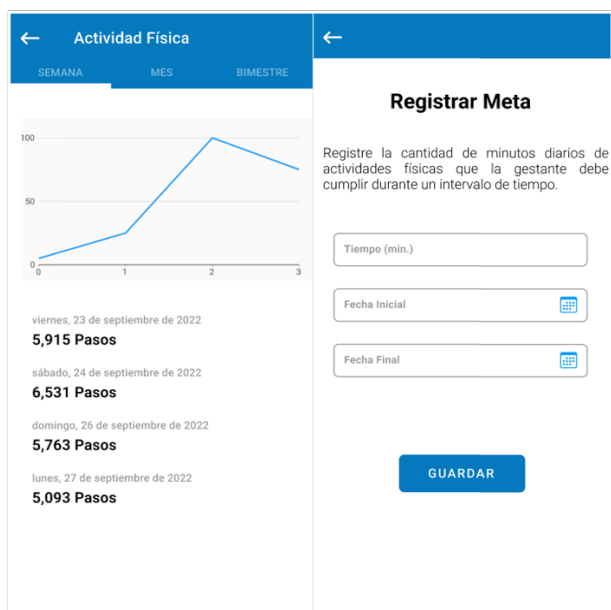
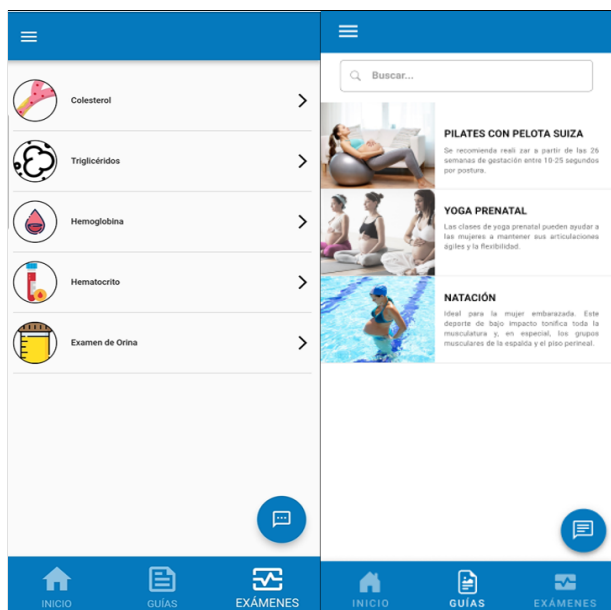Fig. 3. Application interfaces for health professionals.

Fig. 4. Application interfaces for pregnant women.

Satisfaction Score (CSAT) and Net Promoter Score (NPS) metrics, while the user experience is measured by the Customer Effort Indicator (CES) in analysis experience, visual attraction, and speed of operation. According to these metrics, Table I defines the indicators that validate the operation of the solution.

IV. EXPERIMENTS

A. Experimental protocol

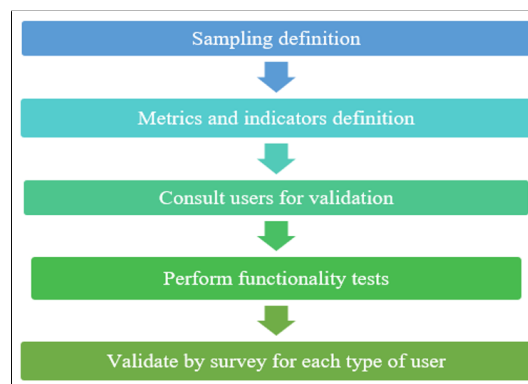To conduct the validation process, the following characteristics of the mobile device were specified for both types of

Fig. 5. Validation process.

TABLE I
SATISFACTION AND USER EXPERIENCE INDICATORS

ID	Indicators
IND01	Average CSAT between patient and health professional greater than or equal to 80%
IND02	Patient NPS greater than or equal to 80%
IND03	CES by analysis experience of the health professional greater than or equal to 80%
IND04	CES for speed of use of the health professional greater than 90%
IND05	Percentage of patients satisfied with the interaction with their health professional greater than or equal to 80%
IND06	Percentage of health professionals satisfied with the goal of continuously monitoring vital signs and physical activity greater than or equal to 80%

users:

- Operating System: For optimal results we suggest using the Android 10 (API 29) mobile operating system. However, the built application will be able to be evaluated in mobile devices with Android 4.4 (API 19) and later updates.
- Storage: The mobile phones used for the experiment require at least 50 MB of storage.

In addition, it is necessary the use of wearable devices that allow a connection to the mobile devices and capture heart rate and physical activity data.

B. Theoretical evaluation

The solution will be used independently of the hospital administration, in other words, the use of the application starts when pregnant women link their profile with a health professional. Therefore, the validations were conducted in small clinics starting by downloading the Google Fit and GEST application on their own mobile devices. For at least a week, health professionals proceeded with the interaction of the solution. At the end of the week, the satisfaction and user experience surveys were resolved by both types of users.

C. Experimental comparative evaluation

To obtain adequate validation results, 6 questions were developed for each type of user: health professional and patient, answering from dissatisfaction to satisfaction. The

questions are based on validating the ease of interaction of pregnant women with their assigned health professional, and the follow-up and analysis of the data given by the doctors. For this reason, Table II represents the questions that we consider necessary to meet the success indicators obtaining 4 quantitative responses by rating the main features (Q1-Q4) and 2 qualitative responses by having opinions (Q5 and Q6).

TABLE II
QUESTIONS FOR COMPLIANCE WITH THE INDICATORS

ID	Indicators
Q1	How would you rate your entire experience with our product?
Q2	Considering your experience with our products and services, how likely are you to recommend us to a friend or family member?
Q3	How would you rate our product in the review experience?
Q4	How would you rate our product in speed of use?
Q5	Do you feel that the app facilitates your interaction with your health professional?
Q6	Do you think that the application fulfills the objective of monitoring vital signs and physical activity remotely?

For questions Q1, Q3 and Q4, the answers "Satisfied" and "Very satisfied" will be taken into consideration; for question Q2, from the value of 8 and for questions Q5 and Q6, the positive answers. The results of the indicators will be based on the mathematical model of the arithmetic mean, that is, the opinion of the users will be evaluated in a general way:

$$A = \frac{1}{n} \sum_{i=1}^{n} a_i \qquad (1)$$

A = arithmetic result

n = total answers

a_i = total responses considered for compliance with the indicators

D. Results

Table III presents the results after conducting the validation process.

TABLE III
VALIDATION PROCESS RESULTS

ID	Expected percentage	Percentage achieved
IND01	$\leq 80\%$	90%
IND02	$\leq 80\%$	88.8%
IND03	$\leq 80\%$	80%
IND04	$\leq 90\%$	100%
IND05	$\leq 80\%$	100%
IND06	$\leq 80\%$	100%

The evaluation process proceeded with the collaboration of 5 health professionals and 9 pregnant patients in different obstetric and gynecological centers, resulting in the scope of the defined indicators being satisfactory. Regarding the IND01 indicator, it was found that among health professionals (80%) and patients (100%), 90% of users rate the complete experience of the product as very satisfactory or satisfactory. The results to validate the IND02 indicator demonstrate reaches the expected percentage with 88.8% of pregnant users with 8 or

more points of probability of recommending the product. On the other hand, regarding the rating of analysis experience and speed of use, an average of 80% and 100%, respectively, was obtained. Finally, all pregnant women and health professionals agree that the solution facilitates and fulfills the objective of remotely monitoring the vital signs and physical activity of pregnant women.

V. CONCLUSIONS AND PERSPECTIVES

By analyzing the results obtained after completing the process of validation with the collaboration of 14 users between pregnant women and health professionals, we conclude that the presented solution meets the objective of monitoring vital signs and physical activity allowing the prevention of certain pathologies such as perinatal depression, gestational hypertension, and excessive gestational weight gain. According to indicator IND06, 100% of health professionals states that the application meets the general objective of the project. Furthermore, the use of wearable devices will enhance the data capture. Its choice will rely on the access it has with GoogleFit, such as OPPO Watch, Amazfit Bip U, Xiaomi Mi Watch, Fitbit Versa 4, among other popular ones on the market.

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