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PAPER

Enhancing Motor Development of Premature Infants: A Mobile App to Support Hospital-Home Intervention Program

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ABSTRACT

The integration of mobile devices into different sectors of society is an increasingly common process; however, their integration as part of medical monitoring for treatments carried out at home is still new, especially their application to the motor development of premature children. This work determines the elements that a mobile application must have to support a hospital-home intervention program aimed at improving motor development in premature infants. The application is designed to work in Android and iOS platforms for mobile devices and to support the hospital-home strategy developed at the Universidad de La Sabana. In this study, an evolutionary device was created, developed and validated along with itsUnity3D tool. The result is an intuitive application that allows parents to strengthen the motor development of their children through a series of 10 exercises designed to stimulate the baby. It consists of a registry of babies, fundamentals, exercise modules and follow-up procedures. The conclusions indicate that although the application is intuitive, some parents have difficulty accessing a mobile device, so it is necessary to create a web version of the application.

KEYWORDS

educational technology, mobile app, educational software, motor development, premature infants

1 INTRODUCTION

In recent decades, the use of information and communication technologies (ICTs) has been increasing, transforming the way people communicate, interact, relate, and learn through various tools [1]. One of these tools is mobile devices, which have become the most rapidly adopted technological device by society due to ease of transportation and access to information at any time or place. The devices are cheaper than laptops, have similar computing power, and provide easy access to

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communication and various applications, with the ability to customize and adapt content based on users' abilities and skills [2].

ICT has been incredibly useful in improving different processes applied to health care, including the use of mobile devices to promote health and disease prevention. These devices allow the collection of information on the conditions and lifestyles of users by health professionals to identify risks early and apply timely interventions that are safe and effective [3]. Mobile applications are software to be used on mobile devices, allowing direct communication with the aim of obtaining reliable and updated information on a subject at any time [4].

In health care, these technologies give users dedicated care and follow-up, enable them to be in constant contact with their caregivers [5] and promote learning and teaching of specific health topics [6]. For this reason, a mobile application (app) was implemented as part of the Hospital Hogar project to provide adequate education to parents about premature babies and to monitor the motor development of these babies discharged from the Neonatal Intensive Care Unit (NICU) to their homes. This strategy was developed by the University of La Sabana and the University of Boyacá to promote and monitor the intervention strategies carried out by parents in their homes to promote the motor development of their premature children.

A premature child is one who is born before the 37th week of gestation. The World Health Organization [7] estimates that approximately 15 million premature babies are born every year, and this number is on the rise. Premature children, compared to full-term children, have lower performance in the acquisition of motor skills, especially in the first year of life, manifesting in slower processes of turning on their own axis, sitting, crawling, standing, and walking [8,9]. According to Fernández, Matzumura, Gutierrez & Zamudio [10], one of the main complications in premature newborns is the delay in motor development, affecting 42.63% of them, an aspect that, if not addressed with adequate therapies, can result in functional limitations and disabilities.

These limitations occur because premature infants, unlike full-term infants, may have different neurological findings in the formation and suboptimal growth of structures such as white matter, corpus callosum, cortex, cerebellum, and grey matter, which have a high impact on motor development [11]. One of the most frequent findings is transient hypertonia because of the early loss of physiological flexion of the foetus and the extended positions in which children are placed in incubators. This favours the acquisition of atypical extension postures that hinder the ability to align the head and trunk before traction tests [12].

For premature infants to be safely discharged from the hospital, it is necessary to develop follow-up programs beginning in the Neonatal Intensive Care Unit (NICU), with strategies aimed at integrating the neurological subsystem with the environment [13]. Among the most commonly used strategies to avoid complications is the skin-to-skin program, which focuses on the care, handling, and positioning of infants and has been shown to improve motor function [14]. In turn, health professionals play a crucial role in the NICU by maintaining regular contact with premature infants and their families through the establishment of care plans from hospital stay until discharge to prevent possible sensory-motor complications.

It is imperative to initiate interventions in premature infants early in the NICU to reduce the consequences of motor and respiratory risk factors [15]. Several studies have found that early interventions for motor development that are provided to premature infants in the NICU can minimize delays, reduce existing or emerging disabilities, prevent functional deterioration, and promote parental adaptation [13,14].

However, the problem with these interventions, which is addressed by this study, is a lack of follow-up and support for parents when they take their children home.

Once at home, parents caring for a preterm infant may apply the intervention program designed for their child inadequately due to lack of knowledge; further, health professionals may be unable to verify whether the interventions are being carried out correctly. This leads, for example, to parents resorting to unreliable sources of guidance, such as advice from relatives, if they do not have access to an appropriate technological tool [16,17], and to children failing to achieve motor development they need to avoid spinal cord deviations that can lead to functional limitations and disability [11,12].

In response to this problem, one of the objectives of this project was to design and validate a mobile app for educating and monitoring parents using strategies to promote the motor development of their premature children. To achieve this, the incremental design methodology was used to encourage parents to adopt the app and to adhere to the Hospital Hogar intervention program.

This mobile app, available for Android and iOS platforms, allows health care staff to monitor the child's intervention program and provides parents with the necessary resources to implement the different strategies planned in the intervention. This article presents the process of creation, development, and validation of a mobile app as a fundamental tool to be used in monitoring programs for premature infants.

The findings of previous studies on the integration of mobile devices in the care of premature children are presented below, followed by a description of the methodological design used in this study and its different phases, the results obtained in the design of the app and its validation, and finally, the main conclusions of the study.

2 LITERATURE REVIEW

Mobile devices have been used in different educational fields ranging from education to the teaching-learning of astronomy [18], the teaching of science [20] and the learning of chemical elements by integrating the use of augmented reality [21]. However, regardless of the topics, objectives, or competencies to be strengthened, the integration of these devices strengthens the training processes, complements traditional learning [21], and improves learning outcomes [20]; further, these devices are much more striking and interesting when gamification is used [18,22].

Regarding the use of these devices to train patients in the application of at-home practices to continue treatments begun in the hospital, few experiences are found, even fewer regarding training for parents of premature babies, who require specialized care and follow-up.

However, a review of the literature finds that these devices are being used to monitor vital signs such as heart rate and respiratory rate, track feeding and diaper changes [23], and improve health care outcomes through data collection and real-time monitoring [24]. Further, mobile apps promote communication between health professionals and caregivers and mobile health interventions [25]. Remote monitoring of oxygen saturation and heart rate allows early detection of hypoxemia and other health problems [26], as well as improving feeding and weight gain in preterm infants through monitoring by a nursing professional [27].

According to a study by Waddington et al. [25], the use of mobile health technologies improves parental engagement, reduces the length of hospital stay, and decreases readmission rates. Similarly, a study by Nourani et al. [17] found that mobile technology improved the quality of care, increased caregiver confidence, and reduced anxiety levels in parents of preterm infants. However, all these experiences are related to the follow-up and monitoring of the preterm infant and not to the education of parents about how to facilitate the development of their preterm infant.

In this regard, the review identifies that mobile devices have been used to promote communication between health professionals and parents or caregivers of premature infants when they cannot be physically present, allowing them to see their children through videoconferencing, follow their evolution, and participate in medical decision-making, thereby reducing the stress and anxiety that parents may feel when they cannot be with their children [25].

At the level of motor development, mobile devices have been used to improve gross motor skills, head control, and turning over through daily exercises that parents perform with their children at home [28]. However, these exercises have not been part of a program aimed at improving the total motor development of children. Another study used a mobile app to provide parents with educational videos and exercises to promote their children's motor development, achieving improvements in fine and gross motor skills as well as cognitive and language development [29]. However, these studies are usually developed by health professionals from a specific specialty such as nursing or physiotherapy, and motor development needs interventions that look at motor development from different disciplines.

The use of mobile devices in the care of premature infants also poses numerous challenges. One is the potential for device-related distractions, which can lead to errors in attention and communication [25,26]. Another challenge is the potential for information overload, which can make it difficult for health care personnel to interpret the data collected by mobile devices and act accordingly [27]. To address these challenges, it is necessary to train health care professionals in the proper use of mobile devices and establish protocols for their use [28,29].

3 METHODOLOGY

This research is descriptive because it aims to describe the characteristics of a mobile app used to support the education and monitoring of parents as they implement strategies that promote the motor development of premature children. This study also contributes to the design and validation of the application of the Mobile-D methodology that consists of five phases: exploration, initialization, production, stabilization and system testing [19]. This methodology was selected because it has an agile approach [18] in development and because in other research-oriented fields of education, it achieves interactive app design and development [20]. It is important to mention that due to the type of service that the app offered, it was decided that stakeholders would participate in the different phases of this methodology together with the development team.

3.1 Exploration

This phase is slightly different from the other parts of the production process because it is dedicated to establishing the project plan as well as defining the scope and functional and nonfunctional requirements of the project. The process is carried out in three stages: stakeholder establishment, scope definition, and project establishment.

The stakeholders of the project are the users of the app (parents of premature children), the research groups involved in the development, and finally the universities that sponsored the research (Universidad de La Sabana and Universidad de Boyacá).

The scope was parents who participated in the Hospital Hogar intervention program. The sample consisted of 57 parents.

The project was established after the interviews were conducted with the stakeholders. The requirements shown in Table 1 were identified.

Table 1. Requirements

ID	Description
R001	The application must be compatible with any mobile device using version 9 or higher of the Android operating system and for devices with the iOS operating system
R002	The application must allow parents to access the motor development program for premature children.
R003	The application must store information about the parents, the premature child, the activities performed, and the motor development progress.
R004	The system should allow parents to communicate with the nursing staff through instant messaging.
R005	The application should show the progress of the child's activities.
R006	The application must allow video playback.
R007	The application must be intuitive because users have little experience in handling mobile applications.

3.2 Initialization

In this phase, all the necessary resources for developing the project were prepared, including hardware, software, and team training. The project architecture and navigation flow were also defined.

The architecture of the project and the development of the app were worked in layers. The user interacts with the presentation layer to log in and participate in the home–hospital intervention program, whose functionalities and contents are established in the business layer. Within this layer, the logical component of the app oversees providing the contents, videos, resources, and activities proposed in the intervention program and communicates with the data layer to store all the data in the Mysql database, as shown in Figure 1.

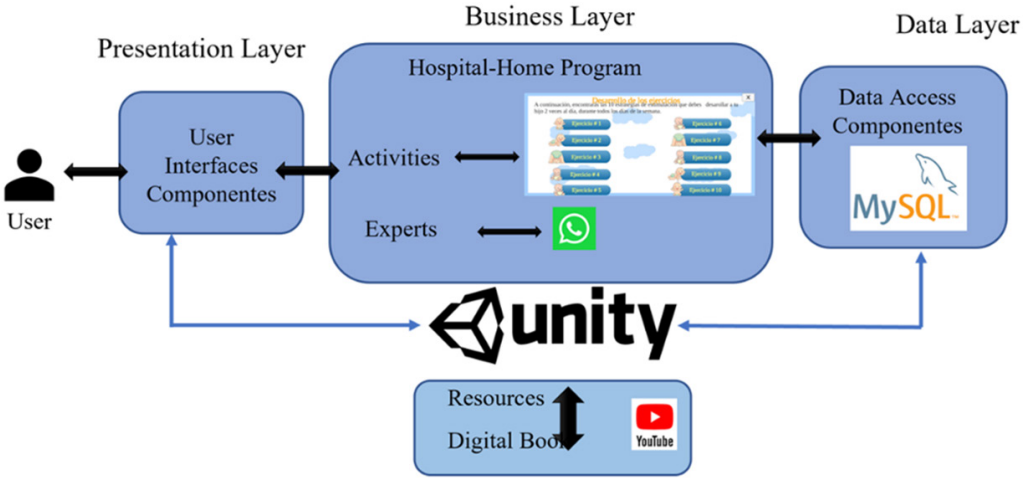

Fig. 1. Project architecture adapted from [18,20]

Navigability: The navigation flow starts with the parents' access to the intervention program when they enter their account data. From there, they are taken to the main menu where they have access to all the functionalities of the system, such as the registration of their child's data, the multimedia resources, the module of the motor development intervention program, the communication module, as well as the opportunity to write a letter to their child and to exit the application. The navigation of the app will be described in more detail in the results section.

3.3 Production

In this phase, both the development of the application and its interfaces were initiated. The process began with a review of the different disciplinary and pedagogical aspects that the app should contain to allow parents to take ownership of the intervention program on the motor development of premature infants. Subsequently, the Storyboard was created in PowerPoint, as shown in Figure 2. The main menu of the app can be seen in Figure 2(a) and activities of the intervention program in Figure 2(b).

Fig. 2. Initial storyboard of the mobile application

Next, we proceeded to develop the interfaces for the different sections of the app, as shown in Figure 3. presentation of the program in Figure 3(a) and example of exercise in Figure 3(b).

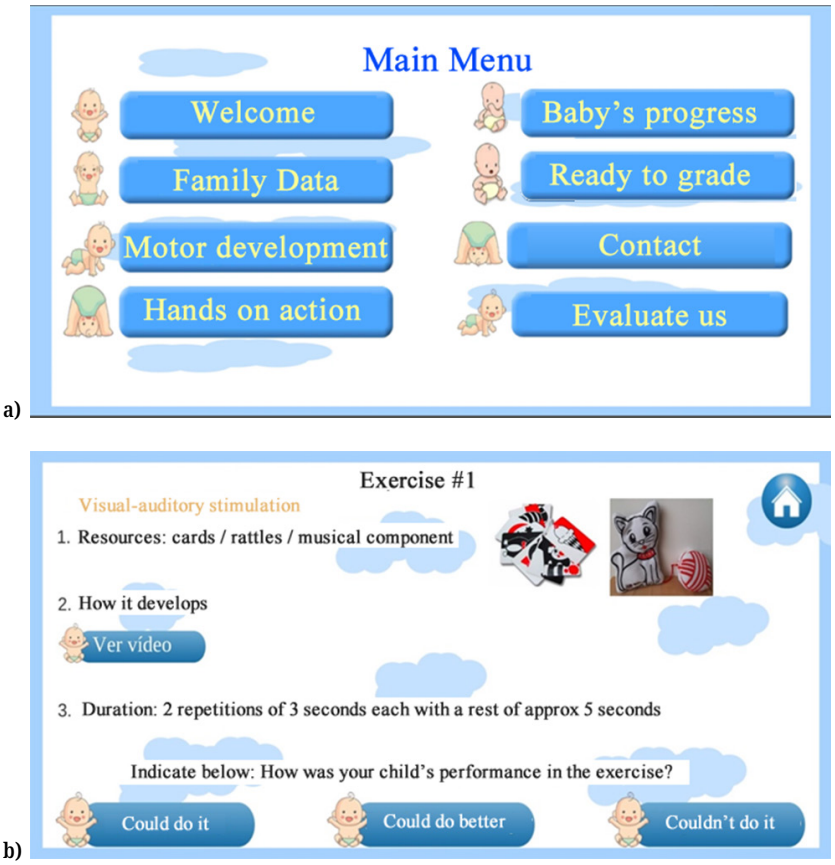

Fig. 3. Presentation layer interfaces

Finally, all business layer services were produced, as shown in Figure 4.

Fig. 4. Business layer services

3.4 Stabilization

At this stage, adjustments and integration of the app modules were made, stabilizing the correct operation. Figure 5 shows the code in visual studio software to monitor the baby's performance during the exercises.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using UnityEngine.Networking;


public class CtrlEjercicios : MonoBehaviour
{
    public Button Mregistro1, Mregistro2;
    string estado;
    string bebeURL = "http://www.oscarboude.com/prematuro/ejercicios.php";
    // Start is called before the first frame update
    void Start()
    {

    }
    private IEnumerator datos()
    {

        string Urldatos = bebeURL + "?usuario=" + UnityWebRequest.EscapeURL(Ctrl_login.usuario)
            + "&ejercicio=" + UnityWebRequest.EscapeURL(selecNivel.nombrescena)
            + "&estado=" + UnityWebRequest.EscapeURL(estado);
        UnityWebRequest www = UnityWebRequest.Get(Urldatos);

        //Debug.Log("el usario es: " + Ctrl_login.usuario);
        yield return www.SendWebRequest();

        if (www.isNetworkError || www.isHttpError)
        {
            Debug.Log(www.error);

        }
        else
        {
            string Eregistro = www.downloadHandler.text;
            Debug.Log(www.downloadHandler.text);
            if (Eregistro == "1")
                Mregistro1.gameObject.SetActive(true);
            else Mregistro2.gameObject.SetActive(true);

        }


    }
    public void realizo()
    {
        estado = "Realizado";
        StartCoroutine("datos");
    }

    public void Norealizo()
    {
        estado = "No realizado";
        StartCoroutine("datos");
    }

    public void mejorar()
    {
        estado = "Puede mejorar";
        StartCoroutine("datos");
    }
}
```

Fig. 5. Code for the follow-up of the exercises carried out

3.5 Test

The researchers reviewed and tweaked early interim versions of the app to improve the user experience and graphical interface. The experts evaluated the last intermediate version and indicated adjustments to the activities and writing of the text. In addition, some parent volunteers evaluated the latest version, suggested adjustments to the wording and indicated the difficulty they had in completing all the data on the family tree. Therefore, this section was removed in the final version of the app.

4 RESULTS

The results obtained during the project will be presented in two sections: the first oriented to the development of the app and the second oriented to the use of the app by parents and its role within the intervention program for the motor development of premature infants.

4.1 Mobile application development

The app was developed to be intuitive for parents of premature babies; however, during the implementation, it was observed that 40% of the parents required support from the students supporting the research to install the app, which was due to the emotional situation the parents were in. Likewise, when they arrived home, 80% of them required daily reminders to use the app because they were adapting to taking care of a premature baby at home.

Due to the above, much time was devoted to the design of the user interface to make it not only intuitive but also visually pleasing to parents, as shown in Figures 3 and 4.

However, during the development of the app, its production was divided into three modules–program presentation, program development, and interaction with parents–to facilitate the adjustments requested by users during the testing phase. The purpose of each module is indicated in Table 2.

Table 2. Application modules

Module	Description
Program presentation	The Welcome to the motor development program introduced parents to the home–hospital intervention program. In Family data, parents registered the baby's primary data at the time of birth, such as weight, height, and weeks of gestation. The Motor development option provided parents with all the necessary resources to understand the importance of the intervention program in the motor development of their child.
Program development	The Hands-on work section outlined the exercises to be completed daily as part of the intervention program for children, along with evaluations of their performance. Parents could track their child's progress in exercise development in another section. Additionally, a feature called "Ready to Grade" permitted parents to compose and save letters to their child as images on the device during the intervention program.
Interaction with the parents	Messages is a component that allowed parents to communicate with the nurses, through the WhatsApp application. Evaluate us is a component that allows the evaluation of the app by parents.

4.2 Parents' use of the application

The app was used to support follow-up of the hospital-home program for 57 premature infants in the cities of Tunja and Chía, which are distributed as shown in Figure 6 according to generation Figure 6(a) and gestational weeks at birth Figure 6(b). Likewise, the system registered the data of 56 parents because one of the parents had twin children.

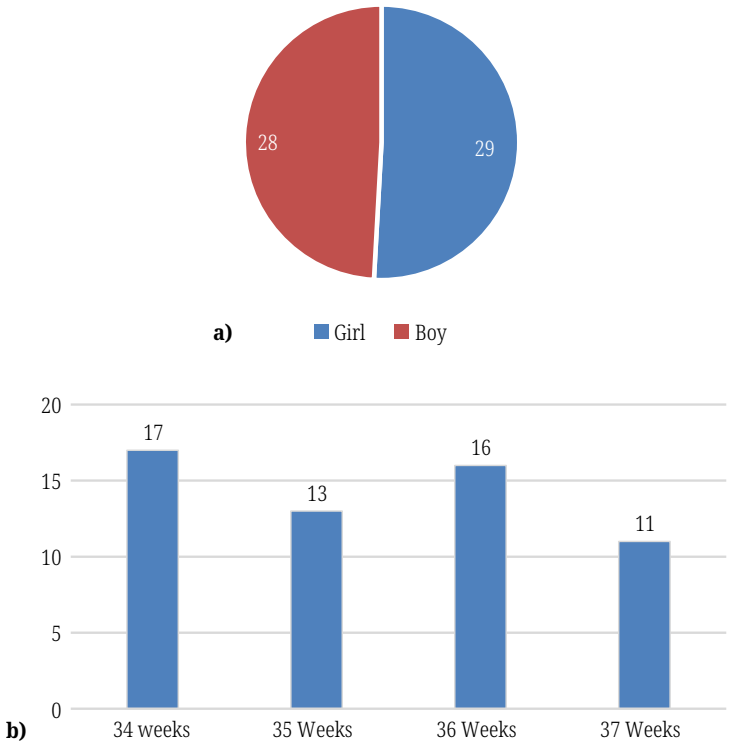

Fig. 6. Demographic data

Regarding the use of the app by the parents, it was possible to identify that the first users of the app entered their data and those of their baby on several occasions. However, to solve this problem, adjustments were made to the training process given to parents before their children were sent home, indicating that only in the case of multiple pregnancies should they fill in the baby's data again. However, 30% of them filled in their child's data more than once.

The second finding was that parents do not consistently record the follow-up of their child's performance within the app, and the reasons given by parents can be seen in Figure 7.

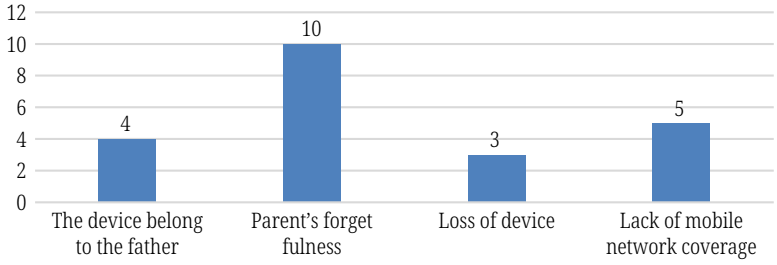

Fig. 7. Reasons given by parents for intermittent recording of child tracking

The third finding is that all of the exercises in the program were performed and recorded by the parents, which indicates that once the parents started the program, most of the time they finished it, as shown in Figure 8. This is fundamental for the motor development of children since it is necessary to perform all the exercises every day for the duration of the program.

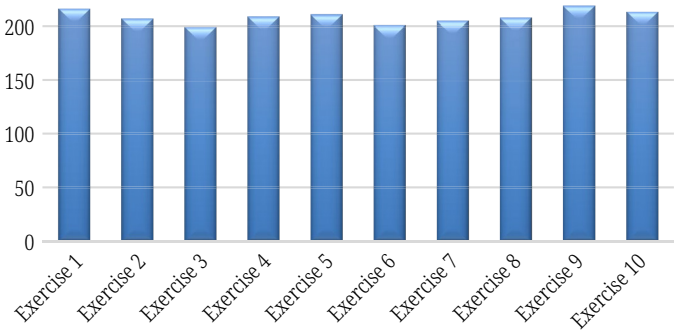

Fig. 8. Number of records for each exercise

However, the data also showed that 45% of the babies participating in the study did not achieve adherence to the program, which was reached once the children had completed at least 50 exercises recorded in the app, as shown in Figure 9.

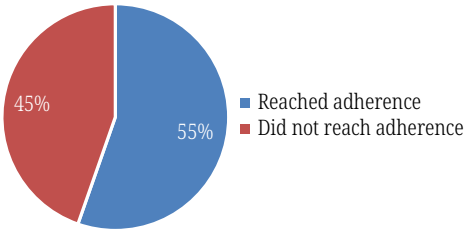

Fig. 9. Program adherence

In this regard, most of the babies who managed to overcome the level of adherence to the program performed more than 90 exercises, and a large percentage were between 100 and 200 exercises; only one participant performed 500 exercises. This case caught our attention because, as seen in Figure 10, it is an extreme outlier. When the mother was asked about it, she indicated that she had the support of the baby's grandmother to help perform the exercises.

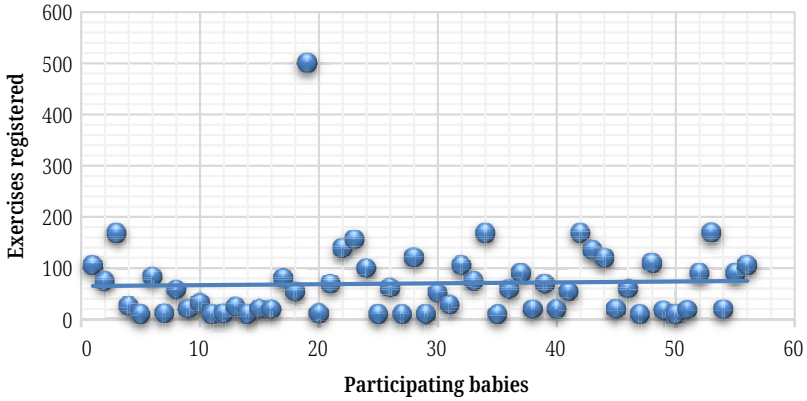

Fig. 10. Number of exercises performed by each baby

Finally, an interview was conducted to ask parents about the usability of the app as well as the elements that could be added or modified. The results are shown in Figure 11.

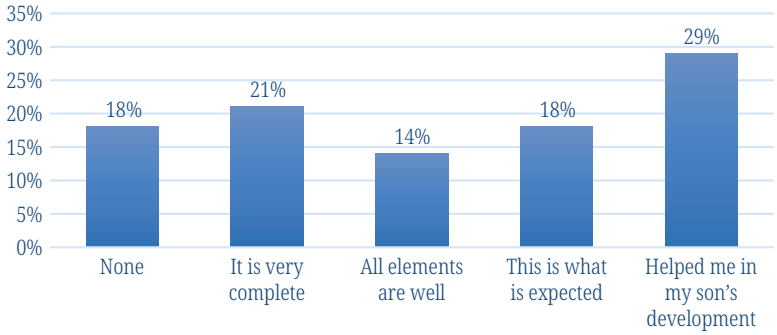

Fig. 11. Elements of the application that you would add or modify

5 DISCUSSION

The main objective of this research was to determine the elements that a mobile app should have to support a hospital–home intervention program aimed at improving the motor development of premature infants. For this purpose, it was decided to use the agile development methodology Mobile-D and to involve stakeholders in the different phases of development. This benefitted the development of the app, as the Mobile-D methodology allowed for the rapid development of multiple prototypes [18,19,20] that defined the elements that the app should have to support the intervention program.

The participation of stakeholders in the development process allowed the developers to generate empathy for parents and be more sensitive to their needs, which allowed the design of an app that uses a language that is easy for parents to understand and an intuitive navigation system. This is an important contribution of this project because unlike other types of development [18,20,21,22], this type of app not only seeks to educate parents about a home intervention program but also to ensure their adherence to the program. Therefore, the development must be empathetic to the emotional burden that parents are experiencing; as found in this research, unlike the findings reported in the literature [23,24,25,27], any difficulty in managing the app could mean that parents abandon their child's intervention program.

Parents who had no technical difficulties with the app remained engaged throughout the intervention program [17,25,27]. However, as indicated by [31,32,33], it is important to accompany parents of preterm infants during the first days, as they feel lonely, despondent, and confused about how to stimulate their child when they get home. Particularly in this project, the accompaniment during the first week provided the parents with confidence and security. Similarly, it is important that support is provided by telephone or videoconference [25,32], especially when parents live in rural areas with low internet connectivity.

In this regard, another important contribution of this work is the finding that parents living in rural areas need more support, as they have additional difficulties such as lack of support from a family network, lack of space and time to consult the strategies in the App, a low level of technical skills, old mobile devices, and an inability to pay for cellular data access; further, there is low internet coverage in rural areas in contrast to the findings reported in [31,32,33,34]. This is likely due to

the difference between countries in terms of sociocultural aspects and technological infrastructure. However, in developing countries such as Colombia, it is essential to have alternatives to meet the diverse needs of the population in rural areas.

Finally, unlike what has been proposed in the studies reviewed [26,27,28,29,30], if the aim is to strengthen the motor development of premature infants through the support of a mobile application, the participation of different specialists from paediatrics, nursing and physiotherapy in the design of the application and the intervention program is essential. The perspectives of all of the specialists provide a holistic vision of the baby's needs and thus allows inclusion in the app all of the resources needed by the parents to feel safe. However, we should not forget the importance of personal guidance for parents during the first days of understanding and managing the care of a premature baby at home.

6 CONCLUSION

The development of the project allowed the design and implementation of a mobile app that strengthened the motor development of premature infants who participated in the interdisciplinary hospital-home program. However, during its development, it was necessary to make several adjustments to both the app and the monitoring process to achieve good adherence of parents to the hospital-home program.

Among the main difficulties encountered from the technological point of view were problems in the installation of the app on older cell phones, as well as the lack of cell phone network coverage in the rural areas where the parents lived.

During the intervention, it was identified that, even with follow-up, some parents do not respond to the program because they do not have space and time to consult the strategies or cannot apply them continuously. In addition, when evaluating the knowledge, practices and attitudes acquired by parents in relation to motor development, it was observed that sociodemographic factors such as educational level and family support network influence the understanding of the topics and the application of the motor stimulation strategies. In addition, it was observed that parents had fearful attitudes towards the application of some exercises at home.

To conclude, a second version of the app may be developed for earlier versions of Android and iOS to make the app accessible to any parent who wants to promote the motor development of a premature child.

7 ACKNOWLEDGMENT

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