**Mobile Applications in Childhood Immunization: A Systematic Review**

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**Abstract** – The central objective of this paper is to distinguish the impact of different cell phone applications on child vaccination completion. A systematic literature review was conducted to determine how mobile applications have improved the acceptance, education, and fulfillment of vaccines. To this end, an analysis of the aspects, objectives, and differentiated technologies that have fostered the growth of mobile applications and new technologies in childhood immunization is presented. In addition, the obstacles to achieving positive results reported in the scientific literature are identified. Lastly, suggestions are made for future work to improve childhood immunization coverage.

**Keywords** – mobile application, app, vaccination, health, immunization, children, infant, neonate.

1. Introduction

The presence of Covid-19, in addition to putting health systems around the world in check, also prompted a paradigm shift, allowing them to offer health services to the population [1], through digital technology and the internet, widely used by society, in such a way as to promote the reduction of mortality and morbidity from preventable diseases [2], eliminating or reducing the lack of information and medical assistance, delays in immunization and refusal of vaccination, among others [3], [4], [5].

Thanks to vaccination, children are more protected and keep their families and communities safe from diseases, as it is considered today as one of the most beneficial ways to boost well-being worldwide [5], in this context, thanks to technology, the health field enjoys the opportunity to reform itself, to propose more particular, collaborative, and precautionary services. Within this environment of modern technologies adapted to the health field, cellular phone applications benefit follow-up and immunization monitoring [6], [7].

Despite advances in technology and society’s growing need to integrate into public health, the adoption of digital innovations in healthcare remains low and slow, partly due to the existing digital divide [7], in that context, health-oriented mobile apps have led to a potential transformation of healthcare delivery around the world [8]. Health applications generate advantages for users, such as ease of management, economic savings on their self-management of appointments, increased patient attendance, and quality health information [9]. Promoting mobile health applications (mHealth) improves satisfaction and access to medical services [10]. The main objective is to provide support and backup in medical processes, diagnosis, and treatment of diseases [11].

Furthermore, with the increased use and availability of cellular phones, digital techniques promise effective information communication to heterogeneous and dispersed population segments and the delivery of programs to diverse communities [12], [13]. All this promotes the development of mobile applications for vaccinating children and neonates. There is already some research regarding the outcome of mobile applications in vaccination, such as the GEVap trial [14], the use of SMS for vaccination reminders in children [15], and MorbiQuiz [16].

Several systematic literature review papers have been developed regarding this topic; Their contributions are detailing the methods of selected studies using SMS vaccine reminder system to understand it [17], to assess the effectiveness of childhood vaccination support apps in increasing immunization rates [18], [19], and to assess the knowledge, decision-making, usability, and consumer opinion of these applications [18] compared to non-digital interventions [19].
However, some studies on the research of mobile applications in childhood vaccination mention the aspects of the application, the technology used, and the impact of these mobile applications in childhood vaccination.

This literature research has as its objective the documentary analysis of the purpose that promoted the development of mobile applications, what differentiated technologies were used, and what effects they had on childhood immunization in different countries; the purpose of this study is to identify the principal sources of information in the field of mobile applications for childhood and neonatal vaccination. This work helps to identify the principal authors of the subject, the most relevant articles, and the challenge in this exploratory field. Likewise, it intends that this literature research reinforces the current theoretical framework, which in future research will serve as help and support in research related to the vaccination of children and newborns. To achieve the goals mentioned above, a systematic literature review is planned from 2018 to 2022.

This work presents the following structure: Phase 2 presents the methodology used to review the available evidence. Phase 3 analyses the results of the formulated questions; Phase 4 presents the discussion and conclusions; and Phase 5 presents the identified limitations and future research.

2. Methodology

For the documentary analysis, the research methodology established by Kitchenham and Charters [20] will be used, setting the following phases: this is shown in figure 1.

Figure 1: Process adapted from Kitchenham and Charters [20] for systematic review

1. Literature review planning: This stage allows a review of the analysis and considers the study questions.
2. Execution of the review: At this stage, the primary studies were selected using an analysis with exclusion and inclusion criteria.
3. Research report: This phase shows the statistical part and the analysis of the articles.

A. Literature Review Planning

To understand the use of mobile applications in childhood vaccination, whether the experiences are optimistic, or which mechanisms and techniques are most suitable to obtain a favorable effect, the literature should be considered the use of mobile applications for childhood vaccination. Therefore, the available evidence review planning process provides the most appropriate methods for gathering and analyzing primary research [20].

The sources of indexed scholarly articles used were the following Springer Link, ScienceDirect, Scopus, IEEE Xplore, ACM, Wiley, and ProQuest. A scoping protocol was also created to identify search needs to define research areas on experiences, activities, or theories related to mobile applications for childhood immunization. The specific research questions for the information search are listed in Table 1 below:

Table 1. Literature search questions.

<table>
<thead>
<tr>
<th>ID</th>
<th>Search question</th>
<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>What aspects have encouraged the growth of mobile applications and new technologies for childhood immunization?</td>
<td>Health issues have stimulated the growth of mobile applications and new technologies in childhood immunization.</td>
</tr>
<tr>
<td>P2</td>
<td>What differentiated technologies were used for childhood vaccination?</td>
<td>Characteristics of mobile applications and new technologies for infant vaccination.</td>
</tr>
<tr>
<td>P3</td>
<td>What are the goals of mobile applications and new technologies in the context of childhood immunization?</td>
<td>Discover the goals of mobile applications and new technologies in the context of childhood immunization.</td>
</tr>
</tbody>
</table>

B. Execution of the review

Initial search

The scientific article search began on 30 November 2022 using the terms 'vaccination,' 'mobile application,' 'newborn,' and 'children' in the available search engines of IEEE Xplore, Scopus, ACM, ScienceDirect, Wiley, and finally, Springer Link.

Then the author performed a search using AND OR operators, combined with the terms 'mobile,' 'children,' technology,' and 'vaccination.'

The results show a regular number of matches, many of which are duplicates, different topics, or not very useful, leaving a primary selection on the variety of terms that should be much more effective in the search.
Due to the lack of results found in IEEE Xplore, Springer Link, Wiley, and ACM, and the absence of contributing or included studies in the various available databases, the author decided to separate them from this study and make the PubMed electronic library available.

Systematic search

The systematic search was resumed, of which the search engines Scopus, ScienceDirect, ProQuest, and PubMed limited the results of publications from 2018 to 2022.

With the combination of the words, a result was obtained in the different electronic libraries, shown in Table 2.

Based on the first results, the use of the best-performing terms in the virtual libraries was determined as follows:

Table 2. String for literature search.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Revision search string</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>(((MOBILE AND VACCINATION) AND CHILDREN) AND TECHNOLOGIES)</td>
</tr>
<tr>
<td>P2</td>
<td>(((MOBILE AND VACCINATION) AND CHILDREN))</td>
</tr>
<tr>
<td>P3</td>
<td></td>
</tr>
</tbody>
</table>

Exclusion and inclusion rules

Table 3. Shows the exclusion and inclusion criteria used.

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any publication related to mobile applications for childhood vaccination.</td>
<td>Any article not meeting the inclusion criteria.</td>
</tr>
<tr>
<td>Publications containing the technologies used for the mobile application in childhood immunization.</td>
<td>Excludes books, thesis, bulletins, review articles, and reports.</td>
</tr>
<tr>
<td>Publications mention the aspects that promoted the development of mobile applications for childhood vaccination.</td>
<td>All articles related to mobile applications oriented to adult vaccination are excluded.</td>
</tr>
</tbody>
</table>

Additional filters:

To provide further support in the selection of items, filters were applied:

First filter:

Reading the abstract about the title: submitting to a literature review.

Second filter:

Analysis and complete reading of the articles that passed the first filter: Reading the full text. After performing the above filters, the author opted to use the snowball method, which allows the filtering of articles found [21]; these can provide content to the systematic reviews because the initial search string did not detect them. From the result of 121795 articles, an inferential analysis was performed using an exclusion and inclusion criterion, and after that, a more thorough analysis was performed, resulting in 32 primary studies. It is established in a flow chart and shown in Figure 2.

Figure 2: Diagram of article search

C. Execution of the review

After performing the analytical search, all of this is shown in Table 4, which contains the aspects and technologies used to increase vaccination coverage and the impact these studies had on society.

The documentary analysis found different technologies and applications for childhood vaccination, showing the impact and aspects that promoted the development.
Childhood vaccination dropouts and missed childhood immunizations have resulted in 3 out of 10 children not being fully vaccinated. This is the reason for this research that increases vaccination completion through SMS text message reminders.

To achieve completion of childhood vaccination appointments, four experiments were implemented: short text message (SMS) reminders, calls, SMS health education, and routine care at a different hospital, with the first experiment (SMS) significantly improving the complete and timely receipt of all recommended vaccinations.

Table 4. Search result.

<table>
<thead>
<tr>
<th>Ref</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[22]</td>
<td>Development of a mobile application called Child Vaccine to digitize the vaccination card and thus have access to the vaccination data record for its management, also allowing access to parents and health personnel of the process and compliance with the child’s vaccination (under five years). This application is beneficial because it reduces the time to register the immunization in the system from 8 minutes to 2 seconds; also, the punctuality for the appointment improved from 65% to 90%, and the scheduling of appointments was reduced from 5 minutes to 4 seconds.</td>
</tr>
<tr>
<td>[23]</td>
<td>Use virtual reality (VR) to reduce somatic symptoms after vaccinating children under seven. It also indicates that the efficacy of this technique is in reducing visit time. One of the limitations was the time needed to isolate the patient and obtain consent and questionnaire data (5 minutes).</td>
</tr>
<tr>
<td>[24]</td>
<td>Use geospatial technology to collect, analyze, model, and visualize geographic information to make more effective decisions about childhood immunization campaigns in developing countries. Identify missing settlements and population centers with the highest number of children missing doses as a target for increasing childhood immunization coverage.</td>
</tr>
<tr>
<td>[25]</td>
<td>The author of this research implemented a chatbot that aimed to increase childhood vaccination by modifying variables such as vaccination information, motivation, self-efficacy, and vaccination behavior. In addition, the target groups received reminders about their vaccination schedule and vaccine information through a booklet, while the experimental group received motivational reinforcement through a chatbot. The latter group achieved the highest target scores.</td>
</tr>
<tr>
<td>[26]</td>
<td>Pentavalent vaccination in Nigeria declined by 33% in 2017 due to a diminished knowledge of immunization sites, the timing of vaccination, and the need for vaccination. Hence, this research aimed to develop a vaccination recall and notification SMS service to promote education and recall parental childhood vaccination.</td>
</tr>
<tr>
<td>[27]</td>
<td>After implementing the messaging application (Kilkari) to curb mortality and morbidity in unvaccinated children, the impact of the application was evaluated by assessing parental knowledge of immunization and immunization practice (compliance and timeliness) for children aged 0-12 months. This intervention increased parental knowledge and improved the immunization score at birth, although it did not increase maternal knowledge or improve children's complete and timely immunization (0-12 months).</td>
</tr>
<tr>
<td>[28]</td>
<td>With a low vaccination rate in Pakistan due to a lack of awareness, forgetfulness of the immunization schedule, and misconceptions or misinformation about vaccines, the researchers sought to understand parents' attitudes about the acceptability of mobile applications for infant immunization. It resulted in most participants agreeing that vaccination is vital in preventing diseases that cause illness and death in their children. They also highlighted the benefits of appointment-based visits to the vaccination center to reduce delays. They were interested in Artificial Intelligence (AI)-based behavior modification applications, applications in their native language, and using Short Message Services (SMS) to remind them of their child's vaccination appointment.</td>
</tr>
<tr>
<td>[29]</td>
<td>Using text messaging (SMS) and incentives to improve the timeliness and coverage rate of vaccination against problematic measles infections in children in rural Kenya, they used 3 study groups (one control, one receiving SMS reminders, and one receiving SMS reminders plus a financial incentive) with 179 caregivers and their babies each. The researchers speculate that the campaigns will increase coverage and be effective in many inaccessible populations.</td>
</tr>
<tr>
<td>[30]</td>
<td>To increase childhood immunization coverage in rural Guatemala, SMS text messaging was implemented as a reminder to mothers. Participants were infants older than five weeks and younger than seven months with medical clearance to receive the first dose of the 3-dose infant primary vaccination series. The data suggest that MSS might be a more effective way of reminder in the city population than the peasant population.</td>
</tr>
<tr>
<td>[31]</td>
<td>Childhood vaccination dropouts and missed childhood immunizations have resulted in 3 out of 10 children in Ethiopia needing to be fully vaccinated. This is the reason for this research that increases vaccination completion through SMS text message reminders.</td>
</tr>
<tr>
<td>[32]</td>
<td>To achieve completion of childhood vaccination appointments, four experiments were implemented: short text message (SMS) reminders, calls, SMS health education, and routine care at a different hospital, with the first experiment (SMS) significantly improving the complete and timely receipt of all recommended vaccinations.</td>
</tr>
</tbody>
</table>
To boost the vaccination of 1100 children (up to 15 months of age) in Zaatarí refugee camps, a mobile application (CIMA) was developed to facilitate the registration by parents of children's vaccination records in the app, which was feasible. The languages used to publish material were English and Arabic. The app contains educational health information and uses automatic reminders for vaccination. In addition to the above, the CIMA app was updated with COVID-19 and vaccination information.

A reminder was sent by text message and telephone calls for compliance with pentavalent vaccination, which defends against diphtheria, pertussis, tetanus, hepatitis B, and Haemophilus influenza in children under three months of age. The sample consisted of 541 mothers. Cell phone reminders were effective and improved the compliance rate with the pentavalent vaccine in the population studied.

Due to non-attendance and delayed childhood immunization schedules, the SMS text messaging reminder system was developed to reduce attrition and increase the immunization rate in Ethiopia. A pilot test was conducted with 30 participants who received the text messages.

In rural India, there needs to be more childhood immunization. To increase immunization, they used a cloud-based biometric software platform for identifying and registering target groups. They sent SMS reminders with and without incentives linked to compliance with their childhood immunizations. They concluded that incentives related to compliance are an essential intervention to improve immunization coverage and timeliness.

Automated combined voice and text reminders were used to complete vaccinations for infants under five. They opted for combining these two technologies because of the barriers in rural sub-Saharan Africa, where the population has low literacy. They concluded that automated call and text message reminders significantly improve vaccination completion and timeliness.

We wish to know the relationship between the benefits provided by a health-oriented mobile application and the effort expended for sending SMS text reminders for return visit compliance for childhood immunization (including vitamin A supplementation), antenatal care, and family planning in urban communities in Lagos, Nigeria. We conclude that SMS text reminders led to a substantial increase in return visits for childhood immunization, while no significant increase was confirmed for the other health services.

To increase immunization coverage, they developed reminder (SMS) and mobile incentive programs (mCCT), which deliver cost-effective interventions through immunization compliance. They concluded that small mobile phone-based conditional cash transfers (0.6 - 1.8 USD per immunization visit) improve immunization coverage and timeliness, costing as low as 23 USD per additional fully immunized child in low-income countries.

Use of algorithms in data mining with a collaborative approach with information on vaccination data to solve many problems in planning the vaccination of children through the geographic mapping of vaccination records, allowing the planning of vaccine administration by health personnel.

The development of the application (Tika Vaani) is aimed at the low-income population of India, which has abysmal indicators of child immunization, which is a health priority. The application seeks to educate and train parents via voice phone reminders with relevant information on childhood immunization.

Development and applicability of the mobile application for registering and monitoring child vaccination (Teeko App). This application aims to track and record in real-time mass vaccination campaigns using the global positioning system (GPS) technology and verification of the sending of photos of the child's vaccination, allowing the monitoring of children with incomplete vaccines; it also allows the sending of texts, automated robotic calls as reminders about the vaccination schedule and upcoming visits, and awareness videos on systematic vaccination.

To eradicate polio in Pakistan and compliance with all its vaccines set by the health authority, customized and automated one-way SMS text message reminders in the local language were developed. These SMS messages promote childhood vaccination through reminders. Further studies are still needed to know whether one-way SMS reminders alone can strongly impact parental attitudes and behavior to improve coverage and timeliness of immunization coverage.

Post-vaccination fever and the not very frequent occurrence of febrile convulsions originating after the child's vaccination suggest the risk that parents may no longer wish to vaccinate their children or may delay vaccination; to prevent this situation we developed the mobile application (Fever Coach) which aims to identify post-vaccination fever patterns and the ability of antipyretic drugs to influence the results of these patterns along the data collected from a mobile application. Concluding that fever after vaccination has its mark, which is a function of the type of vaccine and the presence of antipyretic drugs, and that temperature monitoring after vaccination can alleviate fever phobia and avoid unnecessary use of antipyretics in medical care.

Voice and text message (SMS) reminders via cell phone were used to increase the coverage and completion of childhood vaccination to finalize the child's vaccination appointments. As a result, the intervention group that received SMS voice message reminders increased their vaccination by 20% more than the control group.

SMS text message reminders and monetary incentives were comparable to SMS reminders alone, although they would be more costly to implement.
Due to the low childhood vaccination rate in Indonesia, which has a high mortality rate, the government developed a mobile application (PrimaKu) to inform about vaccines and send reminders to complete the childhood vaccination schedule. They concluded that it would be essential to conduct comprehensive education and improve mothers' literacy to use the application to take advantage of its benefits.

To complete and uptake the COVID-19 pediatric vaccine in rural areas, the mobile application (MoVeUp) was developed to increase child vaccination motivation through weekly and monthly push notifications targeted to parents. The intervention through push messages is given through information in the form of short stories that include images, and the text content is tailored to the registration demographics of the participants.

Uganda's low childhood vaccination rate promoted the development of SMS text message reminders targeted to the infant's parent, who would receive the messages one day before the child's vaccination appointment. It concludes that automated text reminders favor the uptake of health interventions, so their use is encouraged and should be evaluated with scientifically rigorous study designs.

To increase childhood vaccination coverage in Tanzania, cell phone reminders will be implemented with monetary incentives through a cell phone airtime top-up code for each on-time vaccination. The study includes 400 pregnant women aged 16 years and older in late gestation from rural and urban health centers and surrounding communities. It concludes that the results have implications for the design and possible effectiveness of other grant or incentive programs to improve health and healthcare-seeking habits.

To encourage the completion of children's immunization doses in Canada (Alberta), SMS reminders that include a link to immunization information available on the web in different languages were sent to alert parents of their child's immunization visit at 18 months—concluding that the study supports the use of SMS text message reminders as a convenient and effective means of minimizing parental noncompliance and decreasing the likelihood of missed appointments.

Near Field Communication (NFC) technology in collars with or without voice call reminders did not directly increase child compliance and timeliness through DTP3. However, the study data suggest that the collar has the potential to be a helpful tool in immunization seasons.

The articles show a great interest in using mobile applications and some new technologies for childhood vaccination, as shown in Table 5.

Table 5. Years of publication of articles

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>5</td>
<td>[30], [36], [40], [43], [52]</td>
</tr>
<tr>
<td>2019</td>
<td>6</td>
<td>[50], [29], [35], [37], [44], [45]</td>
</tr>
<tr>
<td>2020</td>
<td>4</td>
<td>[38], [41], [42], [46]</td>
</tr>
<tr>
<td>2021</td>
<td>10</td>
<td>[49], [24], [14], [25], [26], [27], [28], [31], [32], [47]</td>
</tr>
<tr>
<td>2022</td>
<td>7</td>
<td>[22], [23], [33], [34], [39], [48], [51]</td>
</tr>
</tbody>
</table>

3. Analysis of the results obtained.

P1. What aspects promoted the development of mobile applications and new technologies for childhood vaccination?

From the systematic search, we found studies that show the main aspects and challenges regarding childhood vaccination, which promoted the development of applications and new technologies, as shown in Table 6.

A significant concern in child mortality and morbidity is the poor level of vaccination, either because of fear of the side effects caused by the vaccine, lack of health centers in the area where the family lives, forgetfulness, lack of knowledge, poor information received, insufficient health education or indifferent on the part on the infant’s parents/caregivers of the infant, which is why mobile applications are being developed whose function is to remind parents of child vaccination [14, 22, 25, 26, 27, 28, 29, 31, 32, 34, 36, 37, 38, 39, 41, 42, 43, 45, 46, 47, 49, 50, 51, 52]. However, it is also being used as a vaccine safety control [53] and even more so with the issue of new vaccination technologies applied to COVID-19.

Table 6. Aspects that promoted the development of mobile applications and new technologies.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Studies found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration and monitoring</td>
<td>[22], [33], [42]</td>
</tr>
<tr>
<td>Access to information</td>
<td>[22], [25], [40], [42], [44], [46]</td>
</tr>
<tr>
<td>Increasing coverage</td>
<td>[22], [24], [14], [26], [29], [30], [35], [39], [42], [47], [52], [29], [46], [48], [50]</td>
</tr>
<tr>
<td>Reminders</td>
<td>[22], [14], [25], [26], [27], [28], [29], [31], [32], [34], [36], [37], [38], [39], [41], [42], [43], [45], [46], [47], [49], [50], [51], [52]</td>
</tr>
<tr>
<td>Education</td>
<td>[25], [26], [27], [33], [41], [42], [44], [28], [47]</td>
</tr>
<tr>
<td>Decrease in anxiety and pain.</td>
<td>[23]</td>
</tr>
<tr>
<td>Decision making</td>
<td>[24], [33], [40], [42]</td>
</tr>
<tr>
<td>Follow-up and compliance</td>
<td>[24], [40], [42], [43], [44], [47], [50]</td>
</tr>
<tr>
<td>Increasing vaccination awareness</td>
<td>[27], [28]</td>
</tr>
</tbody>
</table>
One of the most important aspects for health personnel is the registration and monitoring of vaccinated and unvaccinated children [22, 33, 42], allowing health personnel and parents to know and have access to information on their controls and vaccinations [22, 25, 26, 40, 42, 44, 47], to increase vaccination coverage [14, 22, 24, 26, 29, 30, 35, 39, 42, 47, 52, 29, 46, 48, 50], this is possible thanks to the development of mass monitoring software.

An essential problem during post-vaccination is the anxiety and pain caused to the child. To minimize this and achieve greater acceptance of the vaccine, software was developed to distract the infant from the pain, thus having better attention and satisfaction of the parents [23].

Disease prevention education through vaccination is another vital issue that needs to be addressed in developing countries [30]. This is done through studies developing new technologies and mobile applications that promote education about the importance of vaccines [25, 26, 27, 28, 33, 41, 42, 44, 47].

Mobile technology applied to healthcare is relatively young, i.e., studies are still underway to develop better methods or to effectively use a combination of them in such a way that leads to an increase in demand and awareness of vaccination [27], [28] since the results differ in each context, in that sense, different methods, applications, and technologies are born, technologies that allow increasing vaccination coverage in their realities [22, 24, 14, 26, 29, 30, 35, 39, 42, 47, 52, 29, 46, 48, 50], some of them to digitalize the vaccination card [22, 25, 40, 42, 44, 47, 26], other new health technologies, allow health personnel to make decisions to have a more solid health sector, with much greater scope; This favors the implementation of vaccination campaigns and decreases the mortality rate [24, 33, 40, 42] by monitoring the infant's compliance with the vaccination schedule [24, 40, 42, 43, 44, 47, 50].

P2. What differentiated technologies were used for childhood vaccination?

It was possible to identify different technologies aimed at childhood vaccination, with other purposes, but to increase the number of vaccinated children and avoid mortality, as shown in Table 7.

The creation of cellular phone’s applications, combined with the use of technologies and knowledge of the context in which they are applied, allows for achieving objectives such as increasing vaccination using SMS text messages and voice messages [14, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 41, 42, 43, 45, 46, 47, 49, 50, 51, 52], this allows the sending of reminders and informational messages that educate parents/caregivers about the importance of vaccination [25, 26, 27, 28, 33, 41, 42, 44, 47], taking greater relevance in populations with higher illiteracy rates [33]. Other studies incorporate SMS and the electronic wallet to encourage parents to vaccinate their children [14, 39, 46, 50]. Other applications implemented GPS technology to carry out mass vaccination campaigns, reduce the gap of infants with incomplete vaccination, and transfer this information to a geographic information system [42] or geospatial information system [24] to aid decision-making. It is important to note that apps usually have two parts: (1) input of data and (2) a website for presentation of the data [42].

<table>
<thead>
<tr>
<th>Table 7. Technologies used for childhood vaccination.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>SMS messaging</td>
</tr>
<tr>
<td>Voice messaging</td>
</tr>
<tr>
<td>Virtual Reality</td>
</tr>
<tr>
<td>Geospatial</td>
</tr>
<tr>
<td>Virtual wallet</td>
</tr>
<tr>
<td>Chatbot</td>
</tr>
<tr>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>Data mining</td>
</tr>
<tr>
<td>GPS</td>
</tr>
<tr>
<td>NFC technology</td>
</tr>
<tr>
<td>PUSH Messaging</td>
</tr>
<tr>
<td>Biometric software</td>
</tr>
</tbody>
</table>

Chatbots are also valuable tools for promoting vaccination, providing reminders and real-time messaging support for consultations (for example, during the COVID-19 epidemic) [25]; other technologies use PUSH messaging, and for this, the mobile must be connected to the internet network and be a mid-range or high-end device [27], [33], [48].

Post-vaccination in children can bring anxiety due to pain about the vaccine administration; facing that case, virtual reality (VR) technology decreases fear, anxiety, and stress, favoring the continuation of vaccination doses [23].

A different method used cloud-based biometric technology along with SMS text messaging, which allows mass enrollment, sending accurate information to mobile applications, and sending reminders to increase vaccination coverage [36].
As a method for a mobile application, NFC technology was used for vaccination appointment reminders in conjunction with call reminders to follow up with the child and increase immunization coverage [52].

Although this study did not produce the expected results regarding increased demand for vaccination, the mobile terminal has the means to assist at vaccination times.

Also, the application of new technologies such as data science algorithms through a collaborative approach can solve problems such as the organization of childhood vaccination, provision of vaccines, and tracking and monitoring of unvaccinated children, together with geographic mapping technology that allows detecting areas where the population lacks any vaccine and proceeding with an action plan. Combining these technologies allows for better data-driven decisions for immunization programs [40, 24]; another burgeoning mobile technology is the application of AI-based behavior change transformation, which may improve vaccination rates and punctuality in our environment [28].

P3. What are the goals of mobile applications and new technologies in the context of childhood immunization?

As shown in Table 8, the implementation of applications with new technologies is mainly aimed at increasing vaccination coverage [14, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52]. Although most of these studies have been successful, it is essential to emphasize that the applications were implemented in different realities (native language [28], parental education, customs, beliefs, low, middle, and high-income countries, rural areas, or city, a friendly digital environment, text messages or images tailored to each user, etc.) and that this does not guarantee success or the same success if a copy of the same technology were to be implemented in another environment, so more studies are needed to tailor the technology to the needs of the users, this includes some method of prior appointment to reduce waiting time [28].

On the other hand, some applications aim to reduce post-vaccination pain and anxiety in infants [23]. Further studies are still needed to determine whether this type of technology can distract the infant so that they have less anxiety and pain. It can also be pointed out that this study gives light to extend its application to other lines of medicine, such as pediatrics.

### Table 8. Studies with positive effects on the use of mobile applications and new technologies.

<table>
<thead>
<tr>
<th>Effects</th>
<th>Studies identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased vaccination coverage</td>
<td>[22], [23], [24], [14], [25], [26], [27], [29], [30], [31] [32], [33], [34], [35], [36], [37], [38], [39], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52]</td>
</tr>
<tr>
<td>Decreased post-vaccine anxiety</td>
<td>[23]</td>
</tr>
<tr>
<td>Vaccine side effects</td>
<td>[44]</td>
</tr>
<tr>
<td>Others</td>
<td>[28], [40]</td>
</tr>
</tbody>
</table>

Also, another quite important application is the characterization of symptom patterns (e.g., fever) behind vaccination and the potential for drugs to affect these patterns along the data collected from a mobile application. By doing so, patterns of side effects in people immunized with vaccines that are available or under investigation can be characterized [44].

4. Limitations found and future research.

The present work does not incorporate concepts of mobile technologies, but it does examine practically all the peer-reviewed papers of the last five years. The questions asked in the study were written in clear language, trying to prevent bias. The results obtained in this work are guiding us in future developments of research projects that are currently underway.

Concerning future research, it is essential to know the obstacles and facilitators that hinder the adoption or dissemination of mobile technology locally or globally. For this reason, it would be advisable to carry out a SWOT analysis to identify the forces, opportunities, risks, and threats of the context in which we intend to work and to select or develop the most appropriate mobile methodology for the implementation of mobile technology. If to all this, we add the connection to a national health network, where all private and public health institutions are included (so that information can be shared among them). It is also significant to be able to visualize through the application the health centers closest to the location of the parent/caregiver; the services offered; to be able to schedule appointments or schedule emergency care (for cases that warrant it); have short narratives (with images) with a final message and target them based on the participant's demographics.
This method of voice and images would allow the inclusion of less favored groups, such as people with lower levels of education. In addition, it is essential that the mobile application can assess symptom patterns following the use of new vaccination technologies or other preventive services or the combined use of medications. Furthermore, the feasibility of incorporating a Generative Pre-trained Transformer (GPT) for interaction with the user (answering questions), generating text, and translating it into the caregiver’s language.

It is also essential to implement mobile applications in new devices such as necklaces, bracelets, and watches, among others, to meet the demand for vaccination in areas where the physical supply does not reach.

5. Conclusions

With the documentary analysis conducted on the results of the research associated with cellular phone applications and new technologies for childhood vaccination, it is concluded that:

Mobile health is a burgeoning field that has the potential to deliver public health programs more efficiently than conventional interventions, whereby the adoption of successful and recognized technologies, which have significantly impacted other fields of science, for the development of multidisciplinary applications in the health sector is becoming more and more widespread. Although many research studies obtained in the literature have indeed had positive results, the reality is that these projects come to an end, so the translation of these experiences to public health requires a greater effort from many partners, including the state, to sustain it over time; for the time being, mobile health policies are deficient; this is because the barriers and enablers that hinder adoption and its more widespread diffusion in the local or global context are still not well understood, resulting in successful projects in some places and their replication in other places not showing a significant effect [30]. This reinforces the need to understand the environment in which interventions are delivered (usually with limited resources), which is essential for successful program uptake, replication, and development [30].

To apply a particular mobile technology in the health area, specific requirements must be met, such as they must be cost-effective (know the number of people who own mobile devices, the range of equipment, etc.) and easy to use for each environment and the participation of different stakeholders (use of mother tongue, among others) and easy to use to the needs of each domain and the involvement of different stakeholders (use of mother tongue, among others), so it is essential to take into account the experiences and attitudes of parents when designing and evaluating the effectiveness of interventions; along with this, it is necessary to strengthen other complementary lines such as: decreasing illiteracy, training health personnel and the population in specific digital skills (digital literacy), improving internet connectivity, translating the content of these applications into the mother tongue, the physical presence of health personnel in the community (since not everything can be replaced by technology), strengthening the health system, the involvement, whenever possible, of both spouses, and messages in mass media, since they can be an essential point of awareness, acceptance, and timeliness of vaccination services.

Further research is needed to investigate the impact of analogous interventions in increasing the uptake of other preventive and childhood immunization services and to determine the appropriate oversight and motivational or incentive structure, if any.

References:


