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# The Impact of the Decline in Childhood Immunization in Latin America: A Regional Analysis

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***Abstract*– Childhood vaccination is of utmost importance to prevent diseases, although in Latin America the decline in childhood vaccination has advanced rapidly. Circumstances such as socioeconomic inequality and poor health systems have exacerbated this situation and have been compounded by the covid-19 pandemic. The literature review reveals a worrisome picture of millions of children not receiving their essential vaccines, increasing outbreaks of preventable diseases. These findings highlight the urgency of raising public awareness and adopting innovative technologies. Addressing these challenges is therefore fundamental for the sustainable development of the region.**

***Keywords*-- Childhood immunization, Coverage, Management, Web application.**

## I. Introduction

Immunization of children is one of the most essential foundations of public health, because it prevents severe infectious diseases that significantly affect quality of life. In Latin America, immunization programs have played a crucial role in reducing infant mortality, eliminating diseases such as polio. However, in recent decades, the region has suffered an alarming reduction in vaccination rates, with present figures resembling those recorded more than thirty years ago.

The decrease in child vaccination rates has set off alarm bells in several international organizations such as WHO and UNICEF [1], which have warned about the potential risk of the resurgence of preventable diseases. According to data obtained by these organizations, diseases that had been under control are appearing again in several regions of Latin America, this scenario demonstrates the need to take measures to strengthen immunization systems.

This phenomenon could be the result of a mixture of elements such as socioeconomic and geographic inequity that limit access to health services, especially in rural areas and marginalized communities. In addition, there is a lack of information and mistrust in health systems. It has led to a phenomenon called "vaccine hesitancy" which gained momentum with the advent of the COVID-19 pandemic, slowing down vaccination programs and intensifying inequalities in access to vaccination.

In addition, a recurrent problem that contributes to the decrease in vaccination is the loss of the vaccination card and/or forgetting the date for the continuation of the scheme. Since no accessible record is kept, this makes it difficult for parents to follow the vaccination schedule [2].

This article aims to examine this issue from a systematic perspective, addressing the elements that influence declining vaccination rates for children, the public health implications, and possible tactics to counteract this trend. This review seeks to provide a holistic perspective to help create sustainable solutions to increase vaccination coverage in the region.

This study combines a systematic mapping with the development of a web platform, providing evidence of the effectiveness of digital tools in vaccination management.

## II. Methodology

This article is developed in a systematic literature mapping approach. It seeks to analyze and understand the information collected through the state of the art to provide a broad perspective on the use of technology in the management of the childhood immunization schedule and the impact it has generated.

### *A. Definition of the research questions*

The main objective of this research is to analyze and understand the relevant literature to understand how technologies have impacted management and monitoring of the childhood immunization schedule helping to identify those challenges that may be faced. To achieve this, the following research questions have been formulated:

- **RQ1:** What results have been obtained in terms of increased vaccination rates?
- **RQ2:** What technologies have been implemented in other health institutions to improve the management of childhood immunization?
- **RQ3:** What are the main difficulties faced by health personnel and parents in the control and follow-up of the childhood vaccination schedule?
- **RQ4:** What are the factors that favor the increase of the vaccination rate in children with the implementation of a software tool for the management of the vaccination schedule?

These questions seek to help provide a broader vision in the research and search for effective and efficient solutions applied to the decline of childhood vaccination.

### *B. Definition of search criteria*

The search for articles was performed using keywords based on the research questions which were combined with Boolean

operators as shown in Table 1 and Fig. 1 to maximize the relevance of the results in the selected databases.

- Keywords:
  - "vaccination"
  - "Vaccination in children"
  - "Web page"
  - "application"
  - "software" o "software

TABLE I
CATEGORIES OF KEYWORDS WITH THEIR BOOLEAN OPERAND

| Keyword 1 | Boolean Operator | Keyword 2 | Boolean Operator | Keyword 3 |
|---|---|---|---|---|
| **"Childhood vaccination"** | OR | "Vaccination in children" | AND | "Web page" |
| **"Childhood vaccination"** | AND | "Vaccination in children" | OR | "application" |
| **"Vaccination in children"** | OR | "Web page" | AND | "software" |
| **"Childhood vaccination"** | AND | "application" | OR | "software" |
| **"Vaccination in children"** | AND | "Web page" | AND | "application" |
| **"Childhood vaccination"** | OR | "software" | OR | "Web page" |
| **"Vaccination in children"** | OR | "application" | AND | "software" |
| **"Childhood vaccination"** | AND | "Vaccination in children" | OR | "Web page" |
| **"Web page"** | AND | "application" | AND | "software" |
| **"Childhood vaccination"** | OR | "application" | AND | "Web page" |

Four widely recognized academic databases were selected:

- Scopus (9 selected articles).
- ScienceDirect (11 selected articles).
- IEEE Xplore (13 selected articles).
- ACM Digital Library (15 selected articles).

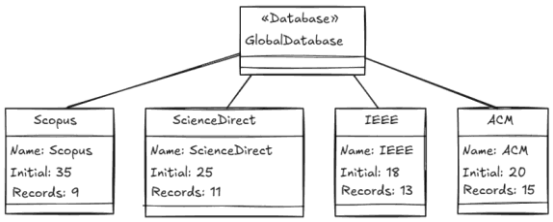


Fig. 1 View of article filtering.

*C. Definition of inclusion and exclusion criteria*

To define these criteria, a set of strict rules were implemented so that the selected research has a high relevance contributing to the objectives of the systematic mapping hence this research directly addresses the problem of the decline of childhood vaccination including those technologies used.

**Inclusion criteria:**

- Studies were published between 2012 and 2023.
- Articles in English.
- Publications related to technologies applied to childhood immunization management.
- Research with relevant quantitative data or statistical analysis.

**Exclusion criteria:**

- Duplicate or incomplete articles.
- Papers without relevant information.
- Studies that do not directly address childhood vaccination or its technological management.

An initial filtering of 98 articles was performed, resulting in a final selection of 9 from Scopus, 11 from ScienceDirect, 13 from IEEE and 15 from ACM, for a total of 48 relevant studies as shown in Figure 1. This process ensured the selection of studies aligned with the research objectives and quality criteria. A quantitative analysis shows that 40% of studies focus on mobile applications, 35% on web platforms, and 25% on desktop systems. Most publications increased after 2020, highlighting growing interest in digital vaccination solutions.

*D. Determination of the classification scheme*

To organize in an orderly manner, the articles selected in the review process were classified according to the topics addressed in each study, obtaining a category according to their approach, thus facilitating the analysis of the data extracted. The defined categories and their relevance in the context of the research are detailed below:

**Impact on Vaccination Rate.**

This category groups together research that analyzes how technology has helped to improve the decline in childhood vaccination rates. They present quantitative and qualitative evidence on the direct impact of technology on childhood immunization coverage.

**Applied Technologies**

This category includes research that describes all the tools used to manage and monitor child immunization schedules.

**Identified Barriers**

This category includes studies that document the difficulties encountered in the implementation and use of technology for the management of childhood immunization. These studies demonstrate barriers such as cultural, logistical and economic barriers, showing the main problems that affect the successful use of technology.

**Success Factors**

This category gathers studies that identify the important strategies that guarantee the effectiveness of the implementation of technologies in the management of childhood vaccination.

This analysis allows the identification of relationships between the different studies, addressing the barriers that are presented in the face of this problem and offering possible solutions to the impact on the rate of childhood vaccination.

## III. Results

In Latin America, vaccination has been a fundamental tool for public health, and through various immunization programs it has been possible to prevent numerous diseases. During the last decades, the countries of the region have implemented immunization programs that have made it possible to achieve high vaccination coverage in the child population. However, despite the implementation of these strategies, in the last decade there has been a decrease in vaccination rates. According to UNICEF, by the year 2023, one out of every four children will not comply with the mandatory vaccination schedule.

The health of the population in Latin America is facing a series of concerns that affect their progress and quality of life, health being one of the main ones. In Latin America, countries are confronted by a series of concerns that affect their progress and quality of life, health being one of the main ones. In the study period between 2000 and 2015, the effectiveness of vaccination programs ranged from 77 % to 99 %, while the percentage of ineffectiveness moved within a range from 1 % to 23 %. Vaccination programs in Latin America focused on protecting children under 5 years of age (0 to 1 and 2 to 5 years) from diseases such as measles, polio, pertussis, diphtheria, tetanus and tuberculosis present variations in their implementation depending on the country.

- In Peru, for example, most mothers (76%) are not informed about the vaccination of children under five years of age, according to 2020 reports, in contrast, only 24% of mothers do have this knowledge [4].
- The Expanded Plan of Immunization (EPI) in Colombia has improved vaccination coverage and contributed to the reduction of infant mortality. However, vaccination goals were not met between 2010 and 2011, falling below the expected 90%. A survey in Mexico found that the number of children vaccinated in 2010 and 2011 was lower than in 2011 [2].
- A survey in Mexico found that about 51. 2% of households with children aged 0 to 4 years were able to confirm the vaccination of minors, but 36. 3% mentioned not having access to show proof of vaccination [3].
- Brazil and Cuba have one of the highest vaccination coverage rates in the Latin American region, and the subsistence rate is above the average for the region. In relation to the vaccination rate of children under 4 years of age, the vaccination coverage rate is higher than the average for the region. In Brazil, the vaccination rate is higher than the average for the region.
- In relation to the vaccination rate presented by the countries: Argentina, Brazil, Cuba, Mexico and Uruguay are among the countries that have the best childhood vaccination programs, and the coverage and survival rate of children under 5 years of age is among the best. In addition, the vaccination coverage and survival rate of children under 5 years of age is one of the best in the region.

Overall, the studies highlight the role of digital technologies in improving vaccination monitoring, while barriers such as misinformation and limited access remain key challenges.

### *A. Contributing factors*

There are different elements that affect compliance with the vaccination program in localities with low coverage, such as fear of post-vaccination reaction, socioeconomic, geographic and security circumstances of the inhabitants, working conditions of vaccination personnel, administrative and economic challenges, and limited development of information systems, see Table 2.

- Misinformation, beliefs and attitudes of citizens, and cultural elements. For some parents, fear of post-vaccination reaction, such as pain and fever, is one of the reasons why vaccines are not given to children under five years of age [8].

TABLE II
FACTORS INFLUENCING COMPLIANCE WITH THE IMMUNIZATION SCHEDULE IN CHILDREN

| Influencing factor | Characteristic | References |
|---|---|---|
| **Misinformation, beliefs and attitudes of the public** | The risk of such doses having adverse effects is almost nil < 1 case/1,000,000 doses. | [12] |
| **Socioeconomic and geographic characteristics** | 1.7 million children are "zero-dose", and three times as many of them belong to poor families. | [13], [14] |
| **Institutional context of services** | Example: Soacha and Quibdó, cities in Colombia with low vaccination coverage due to this situation. | [15] |

- Socioeconomic and geographic characteristics: according to those in charge of vaccination, war conflict, criminality and remoteness become an obstacle to access to these individuals and, therefore, influence the decision not to vaccinate or not to do it at the right time. In 2018, two in five children, globally without immunization resided in vulnerable or conflict-impacted environments [9][10].
- Institutional context of services: Vaccination teams experience saturation and low incomes and sometimes do not possess the necessary equipment to provide immunization service. In Latam countries, the working conditions of vaccination teams, administrative restrictions, information systems at the local level can be detrimental and delay the processes to carry out 100% immunization. Participation in any health insurance program was 82.42% and access to health services was 60.03 [5], [11].

In many areas of this region, fears and misconceptions about vaccines still prevail, as well as lack of knowledge about free

immunization. In addition, there are certain factors that seem to be more dominant in each municipality, although those with lower coverage and different population density also create a social environment that represents a challenge for collective immunity, see Table 3.

In the case of Mexico, the gap of the decline in childhood vaccination can be evidenced, since in 2012 3.3% and 17.9%, in 2018 it continued to increase to 5.5% and 36.5%, by 2021 13.1 - 72.5%. Therefore, the decline in vaccination is evident [16].

TABLE III
COVERAGE BY REGION

| Region | Coverage |
|---|---|
| **Latin America and the Caribbean** | 81% (below the world average) |
| **África** | 74% |

## B. *Public health impact*

The decline in immunization among children in Latin America can be attributed to a variety of reasons. Clearly, these environmental, social, political and economic factors have led to increased disparities. Inequality in the health sector in the region and declining investment in certain countries have left disadvantaged communities with restricted access to basic health services. The COVID-19 pandemic exacerbated these challenges because immunization of children was largely suspended due to restrictions in health systems, isolation and quarantine strategies. Consequently, there is evidence of reduced confidence in vaccination among many parents [9], [10], see Fig. 2 and Fig. 3.

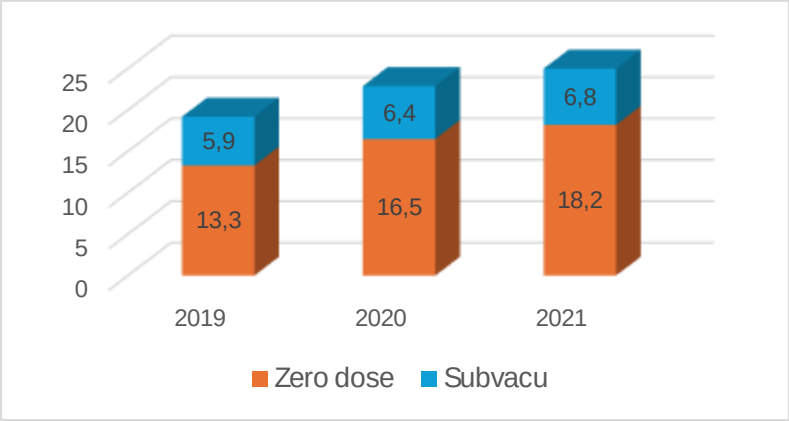


Fig. 2 National immunization coverage estimates.

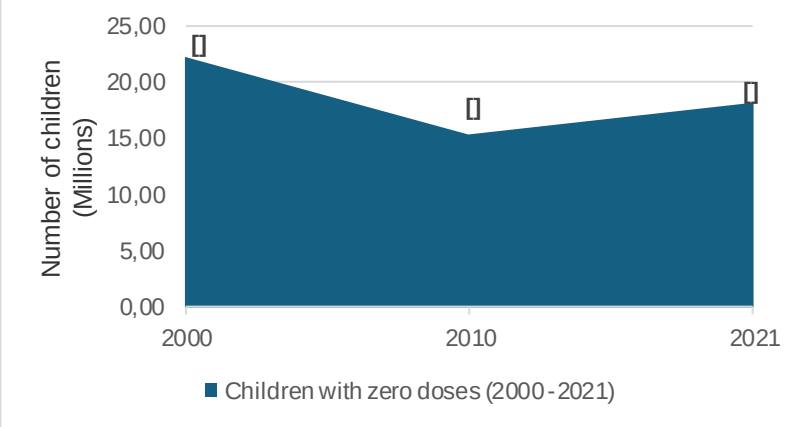


Fig. 3 National immunization coverage estimates.

## C. *Cases and outbreaks in the region*

Immunization has facilitated the eradication of smallpox, an often-fatal condition that in the 20th century alone claimed the lives of nearly 300 million people [17]. In addition, remarkable progress has been made on the broad road to eradicating polio: today, most people live in countries that are free of a disease that

once deprived so many individuals of the ability to walk [18], [19].

Once again, the effectiveness of immunization was demonstrated during the COVID-19 pandemic. According to the World Health Organization (WHO)[20] the disease caused the death of 14.9 million individuals, both directly and indirectly, between 2020 and 2021, and altered the lives of many people globally, particularly children.

*D. Comparison of vaccination rates before and after the covid-19 pandemic*.

But even before the pandemic, too many children were unvaccinated. Many live in the poorest and most marginalized communities. The disruptions caused by the pandemic interrupted childhood vaccination almost everywhere and pushed vaccination rates back to levels not seen since 2008.

*E. Digital innovation to optimize the coverage and follow-up of the childhood vaccination scheme*.

Over the years, Latin America has implemented various technologies that help to effectively improve child vaccination to increase them, these technologies aim to reduce the gap in coverage by improving access to information and strengthening health systems [21], [22], [23], see Table 4.

TABLE IV
TECHNOLOGIES FOR THE MANAGEMENT OF CHILDHOOD VACCINATION

| Technology | Description | Benefits | References |
|---|---|---|---|
| **Mobile application** | Mobile application that allows consulting the vaccination schedule with the record of vaccines administered. | Allows parents to keep track of their vaccination schedule from anywhere. | [11], [23], [24], [25], [26], [27], [29], [30], [32], [33] |
| **Desktop application** | An electronic system that records the vaccinations given to each child and generates automatic reminders. | Reduces errors, facilitates the consultation of information and improves coverage. | [21], [34], [35], [36], [37], [38], [39] |
| **Web application** | Platform that allows individualized registration of each child's vaccination, with access to data by parents and health personnel. | Improves tracking, avoids duplication and allows for reporting. | [40], [41], [42], [43], [44], [45] |

*F. Influence of software on improving vaccination rates*

The implementation of software tools has proven to be an effective strategy to increase the rate of child vaccination [46], due to the fact that parents have a better organization with the follow-up of the vaccination schedule as well as it helps health personnel to perform their work quickly [28], [31], [41], now well among the main factors are:

- Automation of reminders: Sending automated notifications to parents about the vaccination date helps them not to forget it [38], [47].
- Accessibility to information: Parents can consult the vaccination schedule from any device anywhere with internet access [2], [48].
- Reduction of errors: As the information is related and centralized, duplicated data or lost information is avoided [26].
- Generation of reports and statistics: By having accurate data and statistics, the authorities in charge can plan effective vaccination campaigns [49].

In addition, the implementation of these child vaccination management systems helps to generate greater awareness of the importance of vaccination in children because parents can better understand the benefits of vaccination for the health of their children [50], breaking the barrier of superstition about vaccination and thus strengthening trust in health services, which leads to a more active participation in the fulfillment of the vaccination schedule [11], [51].

## IV. VAKU: WEB APPLICATION FOR THE MANAGEMENT OF CHILD VACCINATION AT THE EMIRO QUINTERO CAÑIZARES HOSPITAL IN OCAÑA

Childhood vaccination is of utmost importance to prevent diseases, although in Latin America the decline in childhood immunization has progressed rapidly. Circumstances such as socioeconomic inequality and weakened health systems have exacerbated this situation and were further intensified by the COVID-19 pandemic. The literature shows a worrisome panorama in which millions of children are not receiving essential vaccines, increasing the incidence of preventable disease outbreaks. These findings highlight the urgency of raising public awareness and adopting innovative digital technologies to strengthen immunization systems. Addressing these challenges is therefore fundamental for the sustainable development of the region.

Building upon this context, the article introduces Vaku, a web-based solution designed to improve the management of childhood vaccination records in Ocaña, Norte de Santander (Colombia) [52]. The study underscores a persistent structural problem: the frequent loss, deterioration, and inaccuracy of physical vaccination cards, which worsened during the COVID-19 pandemic and exposed the limitations of existing digital systems for immunization tracking.

Using an applied and mixed-methods approach, the authors conducted interviews with healthcare workers, surveys with parents, and usability testing to identify key requirements for a digital vaccination management tool. The qualitative results reveal recurring challenges including loss of physical cards, lack of centralized traceability, inconsistent information updates, and absence of automated alerts. The quantitative phase, involving a representative sample of 384 adults, confirmed high acceptance and strong intention to use a centralized digital solution for monitoring vaccination schedules. The evaluation showed high

acceptance, with 88% willing to use the system and 84% highlighting the usefulness of reminders. Additionally, 86% found it easy to use and 81% improved vaccination tracking.

To address these gaps, the article presents a functional prototype built with Spring Boot, React, and PostgreSQL, offering differentiated access for healthcare personnel and parents. Key functionalities include vaccination registration, schedule visualization, PDF card generation, and automated notifications for upcoming or overdue doses. Usability testing demonstrated high levels of satisfaction, intuitive navigation, and a strong perceived benefit, reinforcing the solution's potential for adoption by regional health centers.

In conclusion, the article provides robust empirical evidence supporting the need for digital systems to enhance childhood immunization follow-up. It demonstrates that a locally contextualized web platform can improve traceability, reduce errors, centralize immunization data, and ultimately contribute to increasing vaccination coverage in vulnerable regions.

## V. Conclusions

Systematic mapping demonstrates that technology enables the management of childhood immunization schedules to help significantly increase the rate of childhood immunization, as web or mobile applications with reminder systems have proven to be effective due to their easy accessibility, allowing parents and health personnel to have greater control over follow-up, addressing common problems such as forgetfulness and lack of access to information.

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