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VaxTrack : Smart, Automated Child Vaccine Tracking Mobile Application

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Abstract:

Every child is a precious gift, and the parents always want to ensure the health and safety of their children. Vaccines are the most powerful tool for preventing serious diseases that can harm children of all ages. Ensuring timely and complete vaccination for children in Egypt is a serious public health concern. However, parents tend to encounter challenges of misplacement of records, missed appointments, and lack of awareness about the vaccination schedule. VaxTrack is smart, automated child vaccine tracking mobile application which is inexpensive yet effective instrument for systematically recording the vaccines received by a child. Moreover, VaxTrack can enhance health professionals' ability to make clinical decisions, empower parents/caregivers in the health care of their children, and support public health monitoring. VaxTrack addresses these problems by creating a safe mobile environment for storing vaccination records of child vaccination, sending automated reminders for approaching vaccinations, providing educational resources in the context of Egypt,

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and utilizing location-based services to show the nearest vaccination centers. In addition, VaxTrack allows the addition of essential health information including a record of birth data such as the birth date and birth weight, a visual record of the child's growth, factors that may affect the child's ability to develop normally or adapt to a new environment, as well as a continuous and permanent record of the child's development by recording the medical and social history. By improving accessibility and awareness, this app aims to improve vaccination compliance, hence promoting the health and well-being of children in Egypt.

Keywords: Vaccination Automated Systems; Mobile applications; Vaccination; Automation; Records; Awareness

1. Introduction

Vaccinations are especially important in preventing infectious diseases—especially in children—and are fundamental for public health. The World Health Organization (WHO) estimates that vaccination quits 2 to 3 million deaths yearly (WHO, 2017). Though the Ministry of Health provides free vaccination campaigns, adherence remains poor in Egypt due to several logistical and informational obstacles (UNICEF EGYPT, 2021). Many parents forget appointments, misplace paper records, or lack knowledge of the vaccination schedule, so missing or postponing vaccinations.

VaxTrack is a smartphone software that attempts to make vaccine monitoring easier and provide parents with up-to-date information. Through digital engagement, the goal is to support Egypt's public health strategy and reduce the prevalence of diseases that can be prevented by vaccination. This research paper describes the creation, implementation, and evaluation of VaxTrack, a mobile health (mHealth) application designed to improve child vaccine adherence in Egypt. The initiative addresses common problems faced by Egyptian parents, such as missed appointments, misplaced immunization records, and a dearth of educational resources. The study employs a mixed-methods approach that includes questionnaires, app analytics, and literature analysis. The findings suggest that VaxTrack significantly improves vaccination schedule adherence, parental understanding, and user happiness.

Beyond providing personal protection, timely and comprehensive childhood vaccination is essential for establishing herd immunity and halting vaccine-preventable disease epidemics at the community level. To protect the health of Egypt's sizable and expanding youth population, high vaccination rates must be maintained. However, attaining ideal immunization levels is severely hampered by the previously noted issues of record management, appointment adherence, and parental knowledge. These barriers may result in children not receiving their vaccines on time or at all, putting them at risk for avoidable diseases and possibly endangering public health. For the sake of Egyptian children's welfare and the country's general health security,

it is crucial to address these systemic problems with creative and easily attainable remedies.

Leveraging mobile applications offers a possible way to address these persistent issues with vaccination tracking and adherence, given the growing adoption of mobile technology throughout Egypt's socioeconomic strata. The promise of mobile health (mHealth) interventions has been shown in a number of healthcare sectors, providing practical and affordable means of providing health information, support, and reminders. Through the utilization of smartphones, a considerable segment of the Egyptian populace can be addressed using applications intended to streamline the immunization procedure, enhance communication between parents and medical professionals, and eventually promote a proactive health management culture. The creation and usage of a user-friendly, culturally relevant smartphone application, like VaxTrack, has the potential to greatly improve Egypt's child vaccination programs' efficacy and efficiency.

1.1. How Does Vaccination Tracking Apps Work?

- Numerous responsibilities are made really simple for you by vaccination tracking programs. As seen in the blog post above, the majority of children must receive multiple doses of vaccines. Missing the vaccination or medication shot may not be affordable,
- regardless of whether you receive it at home, a local dispensary, or a particular hospital. Therefore, a vaccine monitoring app makes sure that your hectic lifestyle doesn't affect your health.
- The parent whose vaccination schedule needs to be monitored and informed can register using your details in the vaccine tracking app. You can enter the type of vaccination, the quantity, the next dose, the hospital name, the vaccination schedule, and any other pertinent information. When it's time to get vaccinated, the app will notify you about it.
- It may appear to be a common alarm function that a smartphone can do without the need for a special app. However, there is much more to a vaccination monitoring app than just spreading the word about vaccinations. The first thing you may do is see if there are any spots left for the immunization. You can reserve one for yourself if you are successful in locating the open spaces. The software also assists

in answering often asked questions about the necessity of specific vaccinations, potential adverse effects, post-vaccination side effects, necessary precautions, etc. Additionally, you may observe the population receiving the vaccination, etc.

1.2. Features the children Vaccination Tracking App Should Offer

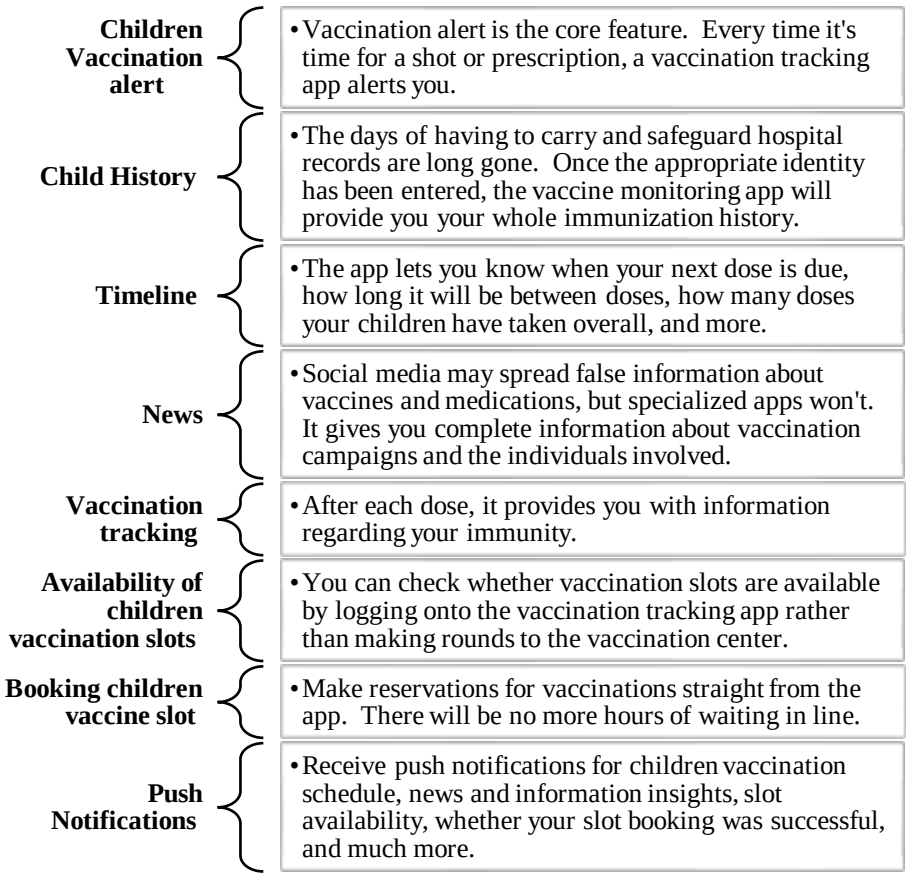

Figure 1 shows features the children vaccination tracking application should offer.

Fig. 1. Features the children Vaccination Tracking App Should Offer

2. Literature Review

The effectiveness of mobile health interventions in enhancing the outcomes of healthcare has been demonstrated by a large number of

studies. The results of a meta-analysis conducted by Free et al. (2013) demonstrated that mobile-based reminders significantly improved compliance with preventive healthcare treatments, such as vaccinations (Free, et al., 2013). Similarly, Brown et al. (2016) demonstrated that the use of SMS reminders led to a 22% increase in the number of people who received vaccinations (Brown, Oluwatosin, Akinyemi, & Adeyemo, 2016).

mHealth tools such as ImmunizeCA in Canada and MomConnect in South Africa have demonstrated remarkable performance in developing regions (Jahan, Huang, Jib, & Zou, 2020) (Atkinson, et al., 2015). Nevertheless, localization and interaction with regional health systems are frequently lacking in these instruments. Due to Egypt's distinct sociocultural and infrastructure circumstances, a local context-specific solution such as VaxTrack is required (EPI Egypt, 2022).

Hesitancy to get a vaccine is another problem. By offering reliable information, Oslon et al. (2020) contend that digital education can lessen vaccine hesitancy (Olson, Berry, & Kumar, 2020). VaxTrack thus incorporates instructional modules that are in conformity with Egyptian health procedures and WHO norms (WHO, 2017).
Implementing vaccination apps requires careful consideration of security, especially when sensitive health data is handled. To protect user data, the majority of contemporary applications use multi-factor authentication (MFA) and end-to-end encryption. For example, VacMobile uses secure login procedures and cloud storage that complies with HIPAA (Atkinson, et al., 2015).

Among the common architectural patterns found in safe vaccination applications are:

- Secure Data Storage: SSL/TLS and AES-256 encryption both in transit and at rest
- Access Controls: User-level permissions and role-based access systems
- Authentication: Password hashing, tokens, or biometrics

Audit Trails: Recording data changes and access attempts Despite these advantages, a lot of apps have trouble in low-resource environments with poor internet access and low levels of digital literacy. As a result, hybrid models—like MomConnect—that combine

offline functionality and SMS reminders are becoming more and more well-liked.

The top worldwide online vaccination applications are compiled in the following table, which also includes information on their deployment environments, security protocols, and platforms of use. Comparing the state of digital immunization tools and evaluating their advantages, disadvantages, and suitability for public health requirements is beneficial, particularly in different socioeconomic contexts:

Table 1. A survey literature on online vaccination applications

Ref. and Publication year	Application	Country	Key functionalities	Contextual Notes
(Atkinson, et al., 2015) Wilson et al., 2015	Immunize CA	Canada	Immunization tracking, reminders, and education modules	Canada-specific; lacks localization for multilingual or low-resource settings
(Agarwal , et al., 2016) Agarwal et al., 2016	eVIN	India	Cold chain management, digital inventory, vaccination logistics	Backend health logistics system, not intended for direct public interaction
(Barron, et al., 2018) Barron et al., 2018	MomConnect	South Africa	SMS-based vaccine alerts and maternal health education	Excellent for rural outreach; does not store personal data in a digital app
(Olson, Berry, & Kumar, 2020) Kumar et al., 2020	VacMobile	USA	Family vaccine management, provider sync, digital credentials	High-security architecture tailored for U.S. families and care networks

There are several different mHealth vaccination strategies available, each suited to a particular target demographic and set of circumstances. The usefulness of SMS-based reminders in increasing vaccine uptake has been the subject of numerous research, especially in

low- and middle-income nations (Agarwal , et al., 2016). Particularly in places where smartphone adoption is low, these text-based solutions provide a simple yet frequently efficient form of communication. More advanced services like computerized record-keeping or the provision of rich educational information, however, are frequently beyond their capabilities.

Smartphone applications, on the other hand, provide a wider range of features, such as multimedia resources, interactive interfaces, and the ability to integrate with other health services. Analyzing the design tenets and user engagement tactics of current immunization applications, like ImmunizeCA in Canada (Atkinson, et al., 2015) , offers important insights into data security, user interface design, and the incorporation of features like appointment scheduling and digital vaccination schedules.

Furthermore, it's critical to comprehend the contextual elements that affect how well mHealth interventions work. The usefulness and uptake of mobile applications can be greatly impacted by cultural quirks, language obstacles, and disparities in digital competence. The significance of adjusting communication tactics and content to the particular requirements and tastes of the target group is shown by initiatives such as MomConnect in South Africa (Barron, et al., 2018), which uses SMS messaging and a web page to engage expectant moms and women (Jahan, Huang, Jib, & Zou, 2020).

3. Materials and Methods

3.1. Problem Analysis & Requirements Gathering

In the first step, a thorough needs assessment was carried out to uncover recurring challenges encountered by Egyptian parents when managing their children's immunization schedules. Interviews and informal talks with healthcare professionals and parents were conducted to acquire qualitative insights. An assessment of available vaccination applications, both locally and globally, identified deficiencies such as the lack of Arabic language support, integration with Egypt's healthcare infrastructure, and no reminder systems adapted to national immunization protocols. These limitations highlighted the necessity for a solution that was tailored to the specific circumstances.

Figure 2 shows data collection of VaxTrack mobile application.

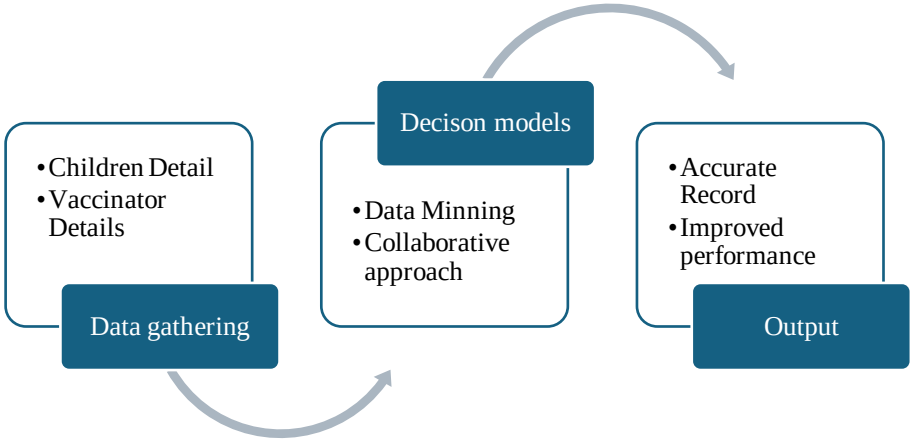

Fig. 2. Data collection of VaxTrack Mobile Application

3.2. Application Design & Prototyping

An interactive vaccination schedule based on Egypt's official immunization calendar, secure digital storage of vaccine records, and automated reminders in line with upcoming doses were among the prototype's key features.

A user-centered design approach was used to ensure accessibility and usability for Egyptian parents. The app interface was made to be intuitive, even for users with low digital literacy. The prototype was designed using Figma, which allowed for quick iterations based on feedback. Special attention was paid to UI/UX principles, including clear navigation, culturally relevant graphic design, and interchangeable language content.

Visual mockups and prototype screenshots were developed to demonstrate core app functionalities and interface design. Figures below illustrate key aspects of the user experience:

Figure 3 shows Home Interface Overview that displays the main dashboard with a child's vaccination progress bar and upcoming appointments.

Fig. 3. Home Interface Overview of VaxTrack Mobile Application

Figure 4 shows Educational Resource Page providing parents with vaccine-related guidance tailored to Egypt's immunization schedule.

Fig. 4. Educational Resource page of VaxTrack Mobile Application

Figure 5 shows the Digital New Child Record Screen which shows how a new child is recorded and the information needed.

Fig. 5. Digital New Child Record Screen of VaxTrack Mobile Application

Figure 6 shows the Digital Vaccination Record Screen which shows how individual vaccine doses are recorded, stored, and marked as completed.

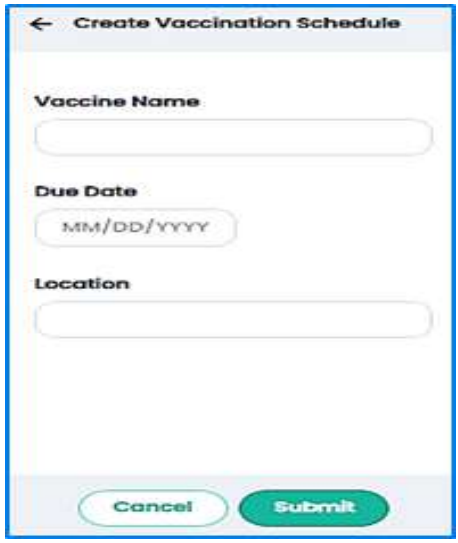

Fig. 6. Digital Vaccination Screen of VaxTrack Mobile Application

Figure 7 shows the Reminder Notifications Screen which illustrates how users configure push or SMS reminders based on the child's age.

Fig. 7. Digital Vaccination Screen of VaxTrack Mobile Application

Figure 8 shows the children list Screen which illustrates how users configure push or SMS reminders based on the child's age.

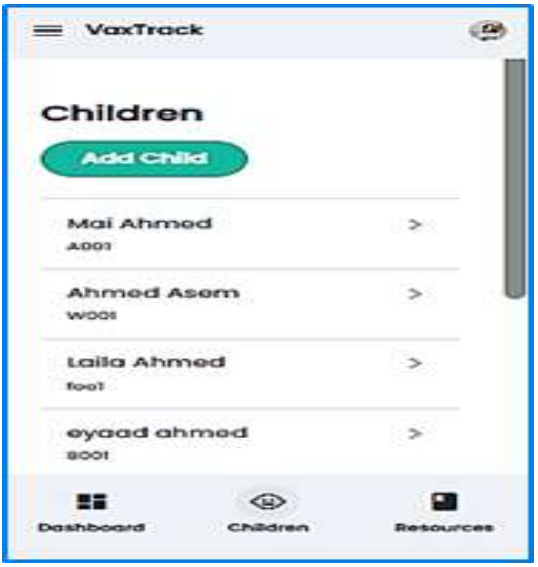

Fig. 8. Children list Screen of VaxTrack Mobile Application

Figure 9 shows the Edit Child Data Screen which used to edit age, length , BMI and Medical History of the child.

Fig. 9. Children list Screen of VaxTrack Mobile Application

3.3. Implementation

During the development phase, Flutter—a Google UI toolkit that facilitates cross-platform app development for both iOS and Android—was used. This decision made it possible to quickly deploy and maintain a consistent user experience across devices. Firebase provided scalable cloud infrastructure, real-time database capabilities, and strong security features like data encryption and email/password authentication to support the backend. Reminders were automated using push notifications, which were based on the child's birthdate and the dates of their related vaccinations. Every feature underwent independent testing to guarantee responsiveness and operation across various devices.

3.4. Testing & Iteration

The prototype was tested on a sample of parents in several iterations. Time on task, user satisfaction, and task completion success rate were the main focus of usability testing. Structured questionnaires and follow-up interviews were used to gather feedback. Several improvements were made in response to the findings, such as making buttons larger, making alerts' language simpler, and modifying color contrasts to make them easier to read. The testing stage was essential

for identifying user problems and making sure the app achieved its goals of enhancing parental involvement, accessibility, and vaccination tracking. The final version was more polished and useful for everyday use because iterative development made sure that user feedback was consistently incorporated into the design process.

Figure 10 shows a summarization for the above steps.

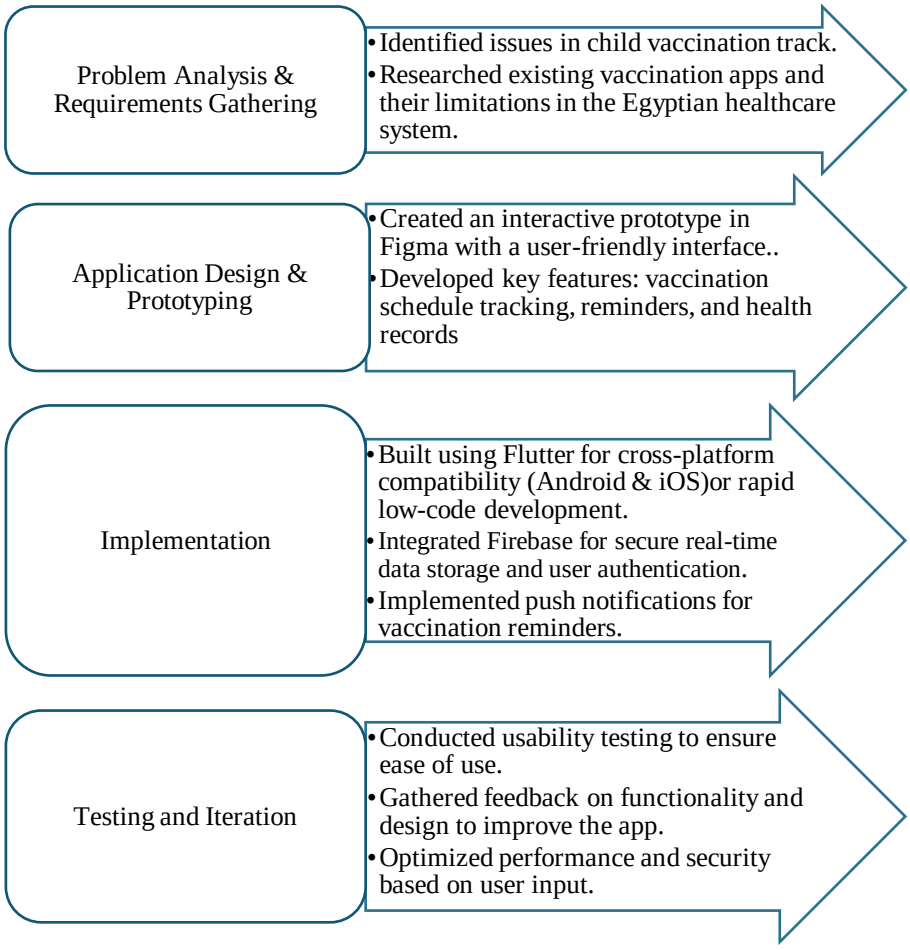

Fig. 10. Materials and Method summarization steps

4. Results

The VaxTrack smartphone app provides a comprehensive strategy to greatly enhance child immunization adherence and tracking in Egypt. As mentioned in the introduction, one of the main obstacles to regular vaccination schedules is lost paper-based records, which VaxTrack immediately addresses by digitizing and safely storing vaccination information on a mobile platform. Parents and medical professionals can be sure that the immunization records are accurate and easily available thanks to this digital repository. One of the main causes of incomplete immunization is missed vaccination appointments, which is proactively addressed by the integrated, automated reminder system. These timely alerts, which may be tailored to the national immunization schedule of Egypt, are intended to improve parental adherence and guarantee that kids get their shots at the appropriate times.

Additionally, VaxTrack includes teaching materials that are contextually appropriate and intended to raise parental knowledge and comprehension of the Egyptian vaccination schedule and the vital significance of receiving vaccinations on time. The program aims to enable parents to make knowledgeable decisions about their children's health by offering easily comprehensible information, which may help to alleviate problems associated with vaccine hesitation or ignorance. A creative way to increase access to immunization services is through the thoughtful integration of location-based services. VaxTrack can simplify the process for parents by locating and showcasing local medical facilities that provide vaccinations. This lowers logistical obstacles and may boost vaccination uptake, especially in underprivileged areas.

Future study will be essential to assess VaxTrack's practical impact, even if the current paper establishes the foundation for its development and suggested functions. Future research will concentrate on the creation of the application, its implementation among Egypt's various demographic groups, and a thorough evaluation of its efficacy in raising vaccination rates, encouraging parents to follow suggested schedules, and maximizing the effectiveness of medical personnel in overseeing and monitoring children's vaccination records. Changes in vaccination coverage rates, parental satisfaction with the application,

feedback from healthcare providers regarding its usability and integration into current workflows, and the effect of the educational materials on parental vaccination knowledge and attitudes are all examples of key performance indicators.

The usefulness of location-based services in enhancing access to immunization sites and the efficiency of the automated reminder system in decreasing missed appointments will also be important areas of research. The ultimate measure of VaxTrack's success will be its observable impact on bettering child health outcomes by establishing a more effective, easily accessible, and knowledgeable immunization program in Egypt.

5. Discussion

The VaxTrack prototype's development and early testing indicate that mobile technology may be crucial to improving Egypt's kid vaccination compliance. Parental challenges including forgetting, losing paper records, and not having access to scheduling information are immediately addressed by the application's key features, which include digital vaccination records and real-time reminders. Accessibility is guaranteed even for populations with low levels of computer literacy because to the user-centred design, which includes streamlined interfaces.

While many current solutions are successful in their particular countries, a comparative examination with similar worldwide programs like ImmunizeCA and MomConnect, shows that they frequently lack cultural and infrastructure localization when used in North African or Middle Eastern contexts. The distinctive advantages of VaxTrack include its compatibility with Egypt's national vaccination schedule and its ability to interface with the systems of the Ministry of Health.

Another crucial component of the application's architecture is security. The application, which makes use of Firebase, offers user-level privacy, secure authentication, and encrypted data handling—features that are comparable to those that are generally advised for mobile health apps. Furthermore, the possibility of AI-driven customisation and real-time health record integration presents chances for further improvements.

During early user assessments, the application prototype's interaction and visual design was well appreciated; nevertheless, formal usability testing with a larger, more varied sample is still required. The app's encouraging reception, however, confirms that digital tools can effectively serve public health policy.

This research has a number of limitations despite its encouraging aspects:

VaxTrack is still just at the prototype stage; it has not yet been fully integrated with national health databases or subjected to widespread deployment. Limited Evaluation Period: Because user feedback was gathered in a short amount of time, it was not possible to perform a thorough measurement of the impact of adherence in the actual world (such as fewer missed appointments).Insights from rural populations, non-Android users, and people with low smartphone penetration are not included in the sample demographics because testing was restricted to urban consumers using Android devices. Not yet available offline: The lack of offline capabilities, despite its planning, could make it more difficult to use in places with poor internet.Self-Reported Feedback Bias: A strong reliance on user-reported data in the first evaluation may have been caused by overestimations of ease of use or social desirability.Despite the implementation of Firebase security features, no independent security assessment was carried out at this time.

6. Conclusion

A promising mHealth option for Egypt's vaccine adherence is VaxTrack. It improves organization, accessibility, and awareness—all of which are essential for enhancing the health of children. If more widespread use is combined with the current healthcare system, it could help achieve national public health objectives.

Here is a comparison table between VaxTrack and other mobile vaccination applications mentioned in the literature review (ImmunizeCA, MomConnect, and WHO tools), based on features, localization, and integration capabilities:

Table 2. A comparative study between different mobile vaccination applications

Feature / App	VaxTrack (Egypt	Immunize CA (Atkinson, et al., 2015)	Mom Connect (South Africa) (Barron, et al., 2018)	WHO EPI Tools (Global) (WHO, 2017)
Target Population	Egyptian parents of children	Canadian parents	Pregnant women and mothers in South Africa	Global low-resource settings
Platform	Android	iOS & Android	SMS-based with web portal	Web and basic mobile tools
Digital Record Keeping	✔ Yes	✔ Yes	✗ No (text-based messaging only)	✗ Limited
Vaccination Reminders	✔ Automated app & SMS reminders	✔ App push notifications	✔ SMS reminders	✔ In some adaptations
Educational Content	✔ Localized, in Arabic	✔ General Canadian-focused	✔ Pregnancy & child care content	✔ WHO global guidelines
Language Support	English (Arabic planned)	English, French	Local South African languages	English and adapted in some versions
GPS Health Center Locator	✗ No (planned for future)	✗ No	✗ No	✗ No
Integration with Health System	Planned (Ministry of Health)	✗ No direct integration	✔ Yes (government backed)	Depends on country implementation
Offline Functionality	✗ No (planned for future)	✗ No	✔ Yes (SMS-based)	✔ Some components
User Feedback Loop	✔ Post-use survey and analytics	✔ Ratings and feedback	✔ SMS surveys	✗Not standardized
Data Security & Privacy	✔ Encrypted, user-authenticated	✔ Yes	✔ Yes	Varies
Cultural Localization	✔ Egyptian context specific	✗ No	✔ South African focused	✗General guidelines
Scalability Potential	High (with government collaboration)	Medium	High (national adoption)	High (framework model)

A powerful and potentially revolutionary method for monitoring and ensuring that children receive their vaccinations is the VaxTrack mobile application, which was created especially for the Egyptian market. As can be seen in Table 2, which contrasts VaxTrack's features with those of other mHealth programs for vaccination, VaxTrack has a number of essential features designed to specifically address the issues seen in Egypt. Importantly, VaxTrack seeks to offer thorough digital record-keeping, a function that is either lacking or restricted in the WHO EPI Tools (Global) and MomConnect (South Africa) apps.

Misplaced paper-based records are a major obstacle to Egypt's constant vaccination regimens, and its digital repository directly addresses this problem. In order to actively involve parents, VaxTrack also incorporates automated reminders through the application and SMS, taking advantage of Egypt's high mobile phone usage. In order to potentially maximize reach and effectiveness, this dual-reminder system seeks to enhance ImmunizeCA's (Canada) app-only notification strategy and MomConnect's SMS-only strategy. A feature that is less highlighted in the more broad ImmunizeCA and WHO EPI Tools, VaxTrack's dedication to cultural relevance is demonstrated by the incorporation of localized educational content in Arabic, which is scheduled for future implementation. In order to improve parental comprehension and address possible vaccine hesitancy within the Egyptian cultural context, this tailored approach is essential. Although VaxTrack and the successful MomConnect initiative both have planned integrations with the national health system, VaxTrack stands out for concentrating on a specific mobile application that has the potential to offer rich features like digital record-keeping and GPS-based health center locators (planned).

In contrast to the SMS-based MomConnect and certain elements of the WHO EPI Tools, the original VaxTrack design did not provide offline capabilities, which could be a drawback in places with erratic internet connectivity. This worry might be allayed, though, by the offline features that will be included in later versions. Using post-use surveys and analytics, VaxTrack's user feedback loop displays a dedication to user-centered design and continual improvement, which is consistent with best practices seen in other mHealth programs. Furthermore, handling sensitive health information raises important

ethical issues, which are addressed by the focus on data security and privacy, encrypted access, and user authentication.

All things considered, the comparative study in Table 2 indicates that VaxTrack provides a special set of characteristics catered to the Egyptian environment, expanding on the knowledge gained from other global projects while attending to particular regional requirements. It is positioned as a prospective instrument for bolstering the national immunization program and ultimately improving child health outcomes in Egypt due to its great scaling potential, especially with government involvement. To reach its full potential, future studies that concentrate on the creation, application, and thorough assessment of VaxTrack's effects will be essential.

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VaxTrack : تطبيق جوّال ذكي وآلي لتتبع تطعيمات الأطفال

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المستخلص:

كل طفل هبة ثمينة، ويحرص الآباء دائمًا على ضمان صحة وسلامة أطفالهم. تُعد اللقاحات أقوى أداة للوقاية من الأمراض الخطيرة التي قد تُصيب الأطفال من جميع الأعمار. يُعد ضمان التطعيم الكامل وفي الوقت المناسب للأطفال في مصر مصدر قلق بالغ على الصحة العامة. ومع ذلك، غالبًا ما يواجه الآباء تحديات تتعلق بفقدان السجلات، وتفويت المواعيد، وقلة الوعي بجدول التطعيم. تطبيق VaxTrack هو تطبيق جوال ذكي وآلي لتتبع لقاحات الأطفال، وهو أداة فعالة وغير مكلفة لتسجيل اللقاحات التي يتلقاها الطفل بشكل منهجي. علاوة على ذلك، يُعزز VaxTrack قدرة المتخصصين في الرعاية الصحية على اتخاذ القرارات السريرية، وتمكين الآباء/مقدمي الرعاية في رعاية أطفالهم الصحية، ودعم مراقبة الصحة العامة. يعالج VaxTrack هذه المشكلات من خلال إنشاء بيئة جوال آمنة لتخزين سجلات تطعيم الأطفال، وإرسال تذكيرات آلية بمواعيد التطعيمات القريبة، وتوفير موارد تعليمية في سياق مصر، واستخدام خدمات تعتمد على الموقع لإظهار أقرب مراكز التطعيم.

بالإضافة إلى ذلك، يتيح تطبيق VaxTrack إضافة معلومات صحية أساسية، بما في ذلك سجل بيانات الميلاد، مثل تاريخ الميلاد ووزنه، وسجل مرئي لنمو الطفل، والعوامل التي قد تؤثر على قدرته على النمو بشكل طبيعي أو التكيف مع البيئة الجديدة، بالإضافة إلى سجل مستمر ودائم لنمو الطفل من خلال تسجيل تاريخه الطبي والاجتماعي. ومن خلال تحسين إمكانية الوصول والتوعية، يهدف هذا التطبيق إلى تحسين الالتزام بالتطعيمات، وبالتالي تعزيز صحة الأطفال ورفاهيتهم في مصر.

الكلمات المفتاحية:

أنظمة التطعيم المؤتمتة؛ تطبيقات الهاتف المحمول؛ التطعيم؛ الأتمتة؛ السجلات؛ التوعية