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TBI Score - use of a mobile score system to aid the diagnosis of tuberculosis in children in Brazil

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Abstract

Tuberculosis (TB) is a bacterial infectious disease that mainly affects the lungs and remains as one of the biggest public health problems in the world. The treatment methods currently available can cure almost all cases. Due to the difficulty of bacteriological confirmation of TB in children, the Brazilian Ministry of Health recommended the use of a scoring system for the diagnosis of pulmonary TB in childhood, covering aspects of clinical, radiological and epidemiological data. The general objective of this work is the development and availability of a mobile application based on the score described in the Manual of Recommendations for TB Control in Brazil. The application was organized to make the questionnaire flow linear, while maintaining the accordance with the structure presented in the manual. The score adapted to the Brazilian context allows health professionals to underpin their decisions with reliable information.

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1. Introduction

The relationship between tuberculosis (TB), poor living conditions and poverty has long been known. In Brazil, the impact of TB on its population occurs since the late nineteenth and early twentieth centuries, when half of the individuals affected by the disease died. Its causality could only be established with Koch's discovery, in 1882, of the *Mycobacterium tuberculosis* [1]. The treatment methods currently available can cure almost all cases. Even so, Brazil remains with a high incidence, with about 95,000 new cases per year and annual mortality of approximately 7,000 deaths [2].

Timely initiation of treatment is critical for effective TB care and control in children. Of the estimated 233,000 children that die from TB each year, 96% did not receive treatment [3]. For primary care providers in TB endemic settings, challenges with confirming a TB diagnosis in children and concern of adverse effects with empiric treatment (i.e., without microbiological confirmation) are key barriers to initiating anti-TB treatment [4].

In Brazil, TB is a compulsory notification disease, each case diagnosed must be informed to government entities. The notification is done by filling in specific instruments and/or by using computerized systems. Due to the complexity, scope and particular characteristics of the Brazilian public health system (SUS), the management of data, knowledge and health services must be carefully executed, so that quality care can be offered at all levels of care [5].

Thus, health data is often found scattered across independent systems and fragmented into closed data silos. In addition, the software available is primitive, inconsistent and static. Such factors can cause information quality problems. Despite the intense volume, information remains decentralized without being able to assist the decision-making process [6].

In this sense, some researchers point to the need for new methods and tools that help in the diagnosis, as well as improvements in the search for communicators [7]. However, although several advances are described in the literature about childhood tuberculosis, such as the improvement of epidemiological models, the standardization of treatment regimens and the adoption of faster diagnostic methods, tools to aid decision-making remain inaccessible.

Much of this progress is concentrated in rich countries, and consequently, countries with a high burden of tuberculosis still lack access to these resources, mainly due to high costs and lack of infrastructure [8]. TB in children has specific features that should be considered during its diagnostic investigation. The pulmonary form differs from that of adults, as it is usually negative on bacteriological examination. In addition, children are not able to eliminate secretions through coughing, that is, they are unable to expectorate [9].

The diagnosis of pulmonary TB in childhood is therefore based on a combination of clinical and epidemiological criteria, associated with a non-specific immunological test for tuberculosis infection and a chest X-ray. There is no gold standard for its diagnosis, nor a universal diagnostic algorithm [10]. Considering the particularities of the diagnosis of TB in children, the Brazilian Ministry of Health has developed a scoring system to aid the diagnosis of pulmonary tuberculosis in children and adolescents that covers aspects of clinical, radiological and epidemiological data and does not involve the bacteriological confirmation, known to be difficult in childhood [9].

This paper aims to present the development and availability of a score-based mobile application to aid in the diagnosis of pulmonary tuberculosis in children and adolescents, as described in the Manual of Recommendations for Tuberculosis Control in Brazil. Next section introduces the methods, and the third section the main results, followed by a comprehensive discussion in the fourth section. The final section pinpoints the main conclusions and future work

2. Methods

2.1. Study Design

For this qualitative study, the action research methodology was adopted. With a dynamic and flexible nature, this type of approach is characterized by the researcher's involvement with the investigated situation. It is worth noting that, during the development of the mobile application, the free software model was adopted, which reduces royalties due to the need to pay for software licenses, leading to greater sustainability of the digital inclusion process and encouragement to all stakeholders [11].

To ensure best practices are in use, the systems have been developed based on software design standards. In software engineering, design patterns refer to a reusable solution to common development problems. The rationale for following standards is to create code with less complexity, using solutions that are already tested and, therefore, more understandable and easier to maintain and reuse. Within this type of research, the socio-technical approach was adopted, allowing the application of software engineering without fragmentation between technical and non-technical characteristics, such as the consideration of human, organizational, ethical, political and social aspects. Technology and people in a work system are interdependent and therefore technology affects people's behavior and people's behavior affects how technology works [12].

2.2. Manual of Recommendations for Tuberculosis Control in Brazil

The Manual of Recommendations for Tuberculosis Control in Brazil proposes national guidelines for the control of the disease, including standardized clinical procedures, laboratory procedures, surveillance systems, biosafety measures and service agencies. Although it contains clinical recommendations on the standardization of actions to search for cases and treatment, the manual is aimed at public health actions and is not intended to be a clinical guideline for the disease. Therefore, it cannot replace textbooks and academic publications that identify good clinical practices in relation to respiratory symptoms and tuberculosis patients [9].

TB in children has specific characteristics that should be taken into account at the time of diagnostic investigation, such as, the pulmonary form that differs from adults and the symptoms that can be confused with other common childhood infections. Usually, the frequency of symptoms is low, however, when persistent they become of great value in the diagnosis of TB in children. In teenagers (10 years of age or older) symptoms are similar to those in adults. The Ministry of Health recommends the diagnosis of TB based on the scoring system for children and adolescents that present a negative bacilloscopy exam or with an undetected rapid molecular test [9].

The score is calculated based on questions divided into four groups: clinical-radiological condition, contact with adults with TB, tuberculin test, and nutritional status. Into each one group has a maximum range to be considered according to the symptoms or conditions described on the protocol. Each "answer" has a pre-established score in the manual. In the end, after the sum of points is made, the score must be interpreted based on pre-defined intervals, as presented in table 1.

Table 1. Score for Childhood Tuberculosis - Brazilian Ministry of Health - Adapted.

<table>
<tr><th colspan="2">Clinical-radiological condition</th><th>Adult contact with TB</th><th>Tuberculin (PPD) Test</th><th>Nutritional status</th></tr>
<tr><td rowspan="2">Fever or symptoms such as cough, adynamia, sputum, weight loss, sweating for 2 weeks or more</td><td rowspan="2">Hilar adenomegaly or miliary pattern
AND/OR
Condensation or infiltrate (with or without excavation) unchanged for 2 weeks or more
AND/OR
Condensation or infiltrate (with or without excavation) for 2 weeks or more, progressing</td><td rowspan="2">Close, in the last 2 years</td><td>PPD between 5-9mm
5 points</td><td rowspan="2">Severe malnutrition (weight < 10th percentile)</td></tr>
<tr><td>PPD >= 10mm</td></tr>
</table>

15 points	with worsening or without improvement with antibiotics for common germs **15 points**	**10 points**	**10 points**	**5 points**
Asymptomatic or with symptoms for less than 2 weeks **0 point**	Condensation or infiltration of any kind for less than 2 weeks **5 points**	Occasional or negative	PPD =< 10mm	Weight ⩾ 10th percentile
Respiratory infection with improvement after use of antibiotics for common germs or without antibiotics **-10 points**	Normal radiography **- 5 points**	**0 point**	**0 point**	**0 point**

There are 3 different interpretations for the score, namely: a) it is recommended to start the treatment of tuberculosis (>= at 40 points, a very probable diagnosis); b) indicative of tuberculosis, it is recommended to start the treatment at the physician's discretion (30 to 35 points - possible diagnosis); c) the investigation of the child must be continued through complementary diagnostic methods (< 25 points - unlikely diagnosis).

2.3. Application development

After discussions and observations of requirements with 3 specialists (a physician, a developer and an expert in biomedical informatics) the analysis and gathering of application requirements was prepared. The starting point of development took place from the identification of the actors (Table 2). A prototyping iteration was quickly planned and submitted for the specialist's appraisal. After approval of the prototype, Unified Modeling Language (UML), use case and activity diagrams were produced describing the flows and interactions between the actors.

Table 2. TBI APP score - list of actors and roles.

Actor	Action	Role
Health agent	User accessing the application	Has access to the mobile app and is responsible for asking the questions to the person in charge of the patient and inserting the answers into the application.
Person in charge for the Patient	Legal person in charge for the child who will be evaluated, who will answer the questions to the Health Agent	He does not have access to the application, he is responsible for answering the Health Agent's questions.
Application	TBI Score mobile app	Responsible for presenting the entire health questionnaire, receiving information, performing the necessary calculations to generate the score and presenting the results.
Percentile API	Responsible for presenting the entire health questionnaire, receiving information, performing the necessary calculations to generate the score and presenting the results.	Receives the parameters weight, sex and age and returns the nutritional status, containing the percentile.
Storage API	Application Programming Interface responsible for receiving the information collected and generated by the Application and storing it in a Relational Database	Receives all responses and information generated by the application and stores it in a database.

The database was structured in nine tables where the main entity is the answers, responsible for saving all the information collected in the application, including latitude and longitude, patient information and the score. Tables that have the prefix oauth in their name were created for the OAuth 2.0 implementation to ensure API security. MariaDB was chosen as the database management system for the development of the TBI (TB = tuberculosis, I = infant) Score. All data are stored on a cloud server at the University of São Paulo.

React Native was the adopted framework for application development because of the possibility of faster mobile development, with more efficient code sharing on iOS, Android and the web, without sacrificing the end-user experience or the quality of the application [13]. For the backend, the PHP framework Laravel was adopted [14].

3. Results

The clinical diagnosis of childhood tuberculosis is still a challenge. To standardize the diagnosis and provide more reliable information for decision-making in clinical practice, the Ministry of Health created a score adapted to the Brazilian context. Although there is a need to increase access to the score and facilitate its use among physicians, the score is a tool that can mainly help regions that have few technological resources. This study intends to show the conception, development and availability of a multiplatform mobile application to calculate the tuberculosis score in children and adolescents.

The expected outcome is a versatile app that is free and available for a variety of devices through the most popular digital app distribution service platforms. In addition, due to its offline operation characteristics, the application is expected to contribute in places with limited or without internet access, in addition to being effective in calculating the score and consequently supporting the routine of care.

The application was organized to make the questionnaire flow linear, while maintaining compliance with the structure presented in the manual. Thus, each stage of the TBI Score must be completed, so the score can be calculated on the client side, that is, in the application itself. The values of each answer and also the interpretation values were inserted in the application logic via JavaScript code. In this way, it is guaranteed that, even without internet access, the user can complete the flow and obtain the final score along with its interpretation.

The application starts with an introductory screen that presents the user with a link to access the Manual of Recommendations for Tuberculosis Control in Brazil, along with the main recommendations and the average time needed to go through the entire flow. By clicking on Start Assessment, the health questionnaire is started, divided into 7 steps (Fig. 1).

The first step is the collection of patient data which, when completed, triggers an asynchronous call to an Application Programming Interface (API), that is, a service available on the web that performs the percentile calculation. The second step of the questionnaire is to determine whether or not the patient had symptoms for a period longer than two weeks, and if so, collect what those symptoms were. Then, the third step asks if the patient has had any other respiratory infections and has recovered with or without common antibiotics.

The fourth step is responsible for collecting the radiological condition, questioning whether or not the patient underwent radiography, and if so, what were the results. Inconsistent answers are automatically validated. The fifth step asks whether the patient had contact with an adult diagnosed with tuberculosis.

The sixth step aims to collect the result of the patient's tuberculin test, if available. The seventh and last step is consultative and allows the user to view the return of the percentile calculation performed via the API, as well as check the information previously provided and used to obtain the percentile.

By pressing the button “Generate Score”, the application calculates the final result based on the collected answers and presents the probable diagnosis, according to the manual. By pressing the “Finish” button, the data is sent to the TBI Score API, which asynchronously stores it in the database, and, then, the application returns to the initial introduction screen, where a new test can be carried out.

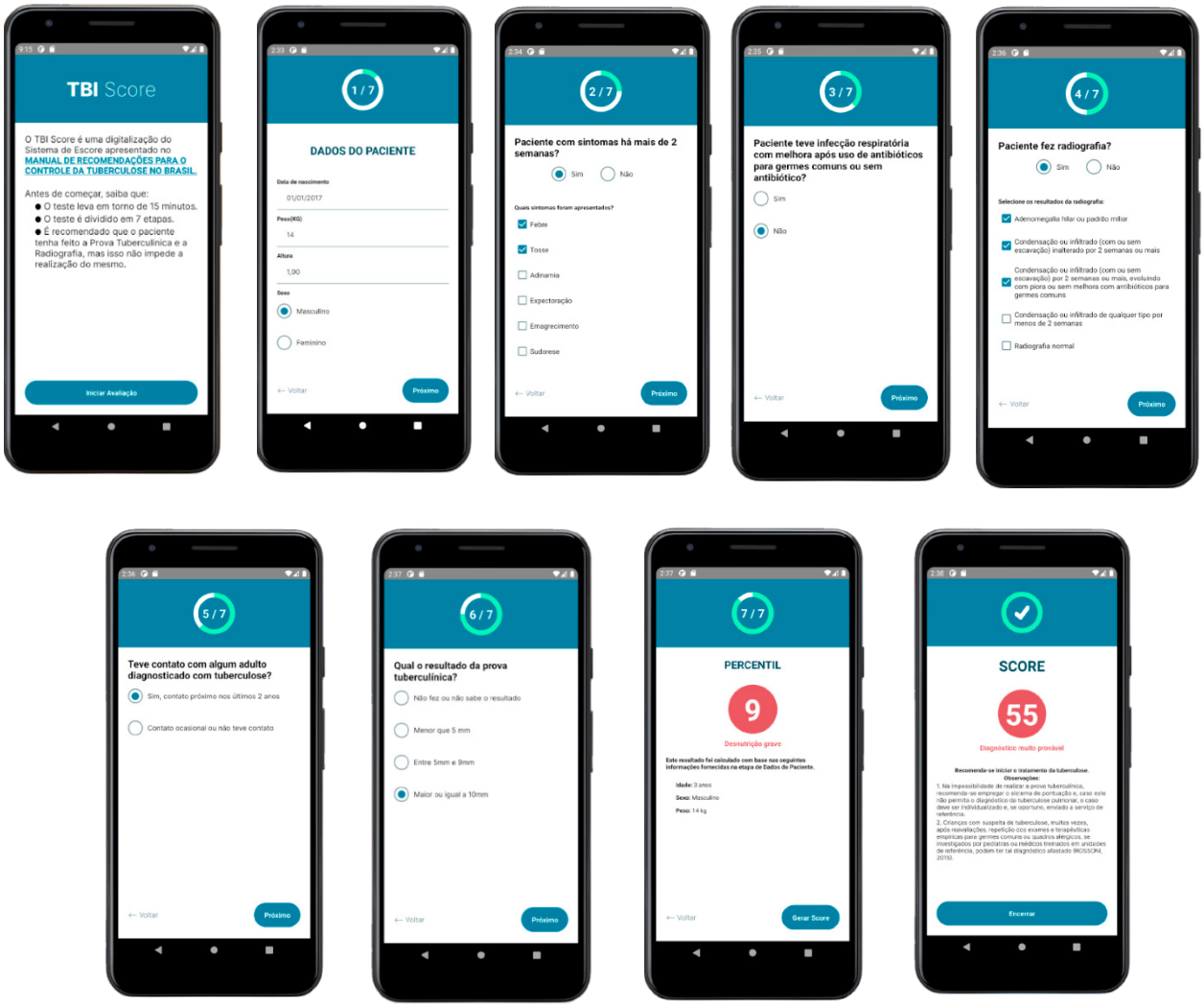

Fig. 1. The app health questionnaire workflow.

4. Discussion

In this study, we developed an application to support the clinical diagnosis of TB in children. Although TB is an ancient disease, it continues to cause significant morbidity and mortality throughout the world, including among children. Appropriate TB screening, diagnostic testing, and treatment recommendations are vital for reducing mortality of TB in children.

The use and development of health information systems can significantly aid decision-making processes. They help to organize data and retrieve it quickly, allowing health professionals to obtain information when needed. By simplifying data access, it is possible to make the process viable, fast and intuitive [15].

An app needs to be simple, efficient and reliable. An objective, clear and intuitive interface contributes a lot to these prerequisites. For the development of the application, some relevant factors were taken into account in order to serve less experienced users without, however, harming the performance of the system. One of the most basic guidelines for improving application usability is to provide clear feedback [16]. For this, a counter of steps is displayed in the screens so the user is aware of where he/she is in the process, in addition to showing the average time to finish the entire questionnaire on the home screen.

The functionalities in the application's interface were defined to simplify and streamline usability. As a general interface, maximum textual clarity was valued in order to collaborate with the uniformity of the receiver's understanding and promote a more pleasant and practical visual harmonization, allowing the user to experience a satisfactory environment, in addition to the concern with colors and amount of visible information to avoid visual confusion. For the assembly of the interface, an attempt was made to relate some of these colors to a distinct function, such as, for example, the final score presented in red, alerting to a very likely diagnosis.

The maintenance of the application can be carried out according to the need to implement other modules, according to the observation of new requirements. Based on the good development practices recommended by the Word Wide Web Consortium (W3C), this is possible thanks to the different layout materials produced during this study [17].

Furthermore, unidentified access logs are captured to carry out statistical monitoring of the regions that most use the application. In the searches for applications for tuberculosis in children in the literature, similar studies were not found.

5. Conclusion and Future Work

The score created and adapted for the Brazilian context allows health professionals to base their decisions on a scoring system with reliable information. Although there is a need to increase access to scores and facilitate its use among professionals to safely optimize time and resources, this mechanism is not yet digitally available in the Brazilian scenario. This study demonstrated the process, from the conception to the development, of a cross-platform mobile application to calculate the tuberculosis score in children based on guidelines from the Brazilian Ministry of Health.

As the project has not yet been exposed to massive tests, several improvements can still be applied to the system. As the application is used, new requirements will be detected and thus new features can be developed, providing a better interface and synchrony between the health agents and the system. The introduction of new technologies in the healthcare area is challenging. In this specific scenario, the challenges are even more profound, as it is an auxiliary diagnostic method that requires comparisons to validate the usability and effectiveness of the application in a clinical setting.

As future work, usability validation with specialists is foreseen to guarantee that the use of the TBI Score brings real benefits to the daily activities of health agents. Furthermore, an embedded database solution to ensure that information is saved on the device until the Internet connection is available will ensure satisfactory communication with the API. Yet, a data analysis model for scoring pattern recognition based on regions of the country is essential to support decision making, and becomes possible once the collected information reaches the final database.

Finally, the applied development model has the potential to be used in other scenarios and must be tested in similar scoring processes that are not necessarily related to Tuberculosis, so that a replicable and scalable method can be created and available for future projects and research.

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