Mobile application for the management of diabetic foot ulcers
Aplicativo móvel para o cuidado da úlcera do pé diabético
Aplicación móvil para el cuidado de úlceras de pie diabético

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Abstract

Objective: To develop and validate a mobile application that help nurses in the decision-making process with regard to topical treatment in diabetic foot ulcers.

Method: Methodological study carried out in four stages: Definition of requirements and construction of the conceptual map of the application; Generation of alternatives for implementation and prototyping; Tests; Implementation. The software Nativescript for Android was used for the development of the application. Usability tests were carried out with 18 participants, considering Nielsen's heuristics and adaptations of usability heuristics for mobile devices.

Results: The application provides current information about the concept of diabetic foot ulcer, ulcer assessment, principles of treatment, clinical recommendations for better healing and dressings for topical care.

Conclusion: The methods used for development and validation proved to be adequate to achieve the proposed objectives. The implementation of this technological tool is expected to contribute to a better management of diabetic foot ulcers, contributing to an evidence-based nursing practice.

Resumo

Objetivo: Desenvolver e validar um aplicativo para dispositivos móveis que auxilie enfermeiros no processo de tomada de decisão do tratamento tópico na úlcera do pé diabético.

Métodos: Estudo metodológico realizado em quatro etapas: Definição de requisitos e elaboração do mapa conceitual do aplicativo; Geração das alternativas de implementação e prototipagem; Testes; Implementação. Para desenvolvimento do aplicativo utilizou-se *software* Nativescript para plataforma Android. Testes de usabilidade com 18 participantes, considerando as heurísticas de Nielsen e adaptações das heurísticas de usabilidade para dispositivos móveis.

Resultados: O aplicativo oferece informações atuais sobre a lesão do pé diabético como conceito, avaliação da úlcera, princípios do tratamento, recomendações clínicas para melhor cicatrização e os curativos para o cuidado tópico.

Conclusão: Os métodos estabelecidos para o desenvolvimento e validação revelaram-se adequados para atingir os objetivos propostos. Com a oferta dessa ferramenta tecnológica espera-se contribuir para o melhor cuidado da úlcera do pé diabético, contribuindo para uma prática de enfermagem baseada em evidência.

Resumen

Objetivo: Desarrollar y validar una aplicación para dispositivos móviles que ayude a enfermeros en el proceso de toma de decisiones del tratamiento tópico de úlceras de pie diabético.

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Conflicts of interest: none to declare.

Métodos: Estudio metodológico realizado en cuatro etapas: definición de requisitos y elaboración del mapa conceptual de la aplicación; generación de alternativas de implementación y prototipo; pruebas; implementación. Para el desarrollo de la aplicación se utilizó el *software* Nativescript para plataforma Android. Pruebas de usabilidad con 18 participantes, considerando las heurísticas de Nielsen y adaptaciones de las heurísticas de usabilidad para dispositivos móviles.

Resultados: La aplicación ofrece información actual sobre úlceras de pie diabético, como concepto, evaluación de las úlceras, principios del tratamiento, recomendaciones clínicas para una mejor cicatrización y vendajes para el cuidado tópico.

Conclusión: Los métodos establecidos para el desarrollo y validación demostraron ser adecuados para alcanzar los objetivos propuestos. Con la oferta de esta herramienta tecnológica se espera contribuir para un mejor cuidado de úlceras de pie diabético y para una práctica de enfermería basada en evidencia.

Introduction

The epidemiology of *diabetes mellitus* (DM) is alarming. Wordlwide, one in every eleven people is affected by this metabolic syndrome (around 463 million adults aged 20–79 years) and every eight seconds someone dies from diabetes (approximately four million deaths). It is estimated that by 2045 one in every 10 adults (700 million) will have DM. Brazil is the country with the third largest number of children and adolescents with type 1 DM and the fifth largest number of individuals with DM (16.8 million).[1]

It is important to highlight that the increase in the prevalence of DM can lead to a concomitant increase in its complications. The most common complications, affecting 50% of people over 60 years of age, are peripheral neuropathy and diabetic foot (DF).[2-4]

Peripheral neuropathy is characterized by a range of clinical syndromes that affect the sensory, motor and autonomic nervous systems. Its main outcome is foot ulcers associated with ischemia, deformities and/or infections, the so-called DF.[5] This combination is common and is responsible for a substantial increase in morbidity and mortality rates among individuals with DM.[6,7]

It is estimated that every 20 seconds a lower limb is lost due to diabetic foot ulcers (DFU). This not only affects the patient's quality of life, but also increases the risk of contralateral limb amputation by 50 to 60% after three to five years.[8-10]

Therefore, the decision process in the management of DFU aims to achieve primary healing and avoid progression to amputation, providing the best possible outcome for the patient and healing the ulcer in the shortest possible time, which is not always achieved.[11,12] A well-executed and timely in-tervention is crucial to avoid progression to DFU and amputation.[13]

In this context, nurses have a fundamental role in the facilitation and use of Evidence-Based Practice (EBP) and are responsible for providing care and guidance for patients.[14] EBP is based on the integration of the best available evidence and clinical expertise and values, with the objective of facilitating decision-making. The use of EBP can also be essential for improving nursing care.[15-17]

Over the past fifteen years, the expectation that EBP would be applied in health informatics has grown. This concept is called evidence-based health informatics and is defined as the conscientious, explicit and judicious use of current best evidence to support decision making with regard to the introduction and use of information technology (IT) in health care environments.[18]

The use of mobile applications (apps) in education has been growing, opening space for mobile learning, which involves the use of the mobile technology, either alone or in combination with other IT to enable learning.[19] Mobile devices, mainly smartphones, bring new opportunities and challenges for IT and for society, such as ubiquitous access, portability, democratization of access to information, opportunities for interaction and reduced complexity.[20]

In nursing, the development and use of IT is increasing and becoming a contemporary didactic approach that favors the automation of processes and increases safety in the decision-making process in care.[21] In this perspective, some studies with virtual learning environments were developed, with the objective of providing means to support the learning of activities such as wound assessment and treatment, management and psychiatric nursing.[22-25]

Therefore, it is essential to implement systematic and evidence-based care, and IT can have tools

capable of providing an integration between theory, practice and research. In this sense, this study aims to develop and validate a mobile application that supports nurses in the decision-making process with regard to topical treatment of DFU.

Method

This is a methodological study approved by the Research Ethics Committee of the Health Sciences Center of the Federal University of Espírito Santo, (UFES) protocol number 66019217.5.0000.5060. In line with Resolution No. 466/2012 of the National Health Council, the regulations for the protection of participants in scientific research involving human beings were followed. The subjects were informed about the objective of the study and about the signing of the Informed Consent Term.

All steps of the study were developed in partnership between the Graduate Program in Nursing and the Laboratory and Observatory of Project Ontologies (LOOP), linked to the Department of Industrial Design, Arts Center, UFES. In addition, the ABNT norm ISO/TR 16982:2014, called "ergonomics of human-system interaction – usability methods that support user-centered projects" supported the development of the app. The development was organized in iterative design cycles that comprised teaching, research and extension actions linked to the LOOP.

The application called DFUAPP was developed using the Android operating system, as it is free and enables wide distribution through Google Play. The images used were extracted from a publication, with authorization from the author.[26]

The study was carried out in four stages: definition of requirements and construction of the conceptual map of the application; generation of alternatives for implementation and prototyping; tests; and implementation.

In the first stage, it was decided that the theoretical framework would be based on evidence-based publications on the treatment of DFU, made available in 2015 and revisited in 2020, in the Cochrane Database of Systematic Reviews, International

Working Group Diabetic Foot and National Institute for Health and Care Excellence, with the objective of defining the requirements and constructing the conceptual map (CM) of the application. The literature review enabled the construction of the text on topical care of DFU. Based on this, the content of each screen and the tutorials were created.

An organizational matrix was created so that the team could start the development of the prototype. This tool enabled the creation of a graphic design that organizes and represents knowledge, the CM (Figure 1).[27]

In the second stage, the CM supported the LOOP team in the development of new steps for organizing the process into iteration cycles and in the generation of alternatives for the functionalities of the application, using the Nativescript software, with a view to adopting free and open technologies whenever possible. Functional prototypes (alpha, beta and pre-release) of the functionalities were included in the general structure of the UPDAPP in order to carry out real tests with potential users – nursing professionals.

For the development of the third stage, the ABNT norm ISO/IEC 25062:2011 was followed. It recommends a minimum sample of eight subjects.[28] The study involved a total of 18 participants, of which eight were evaluators from the LOOP team, making up the Group G1; and ten were nursing assistants who worked in primary and secondary care, had a minimum of two years of experience, and were directly associated with care of DF, making up the Group G2. All evaluators were selected at random. The evaluations occurred in October 2017.

The tests were carried out in two stages. At first, the application was inspected by the Group G1, using a technique carried out through a set of principles and guidelines – the heuristics. One way to characterize the usability of the systems is the heuristic evaluation (HE), which consists of: 1) Visibility of the system; 2) Match between system and the real world; 3) User control and freedom; 4) Consistency and standards; 5) Recognition rather than recall; 6) Flexibility and efficiency of use; 7) Aesthetic and minimalist design; 8) Error preven-
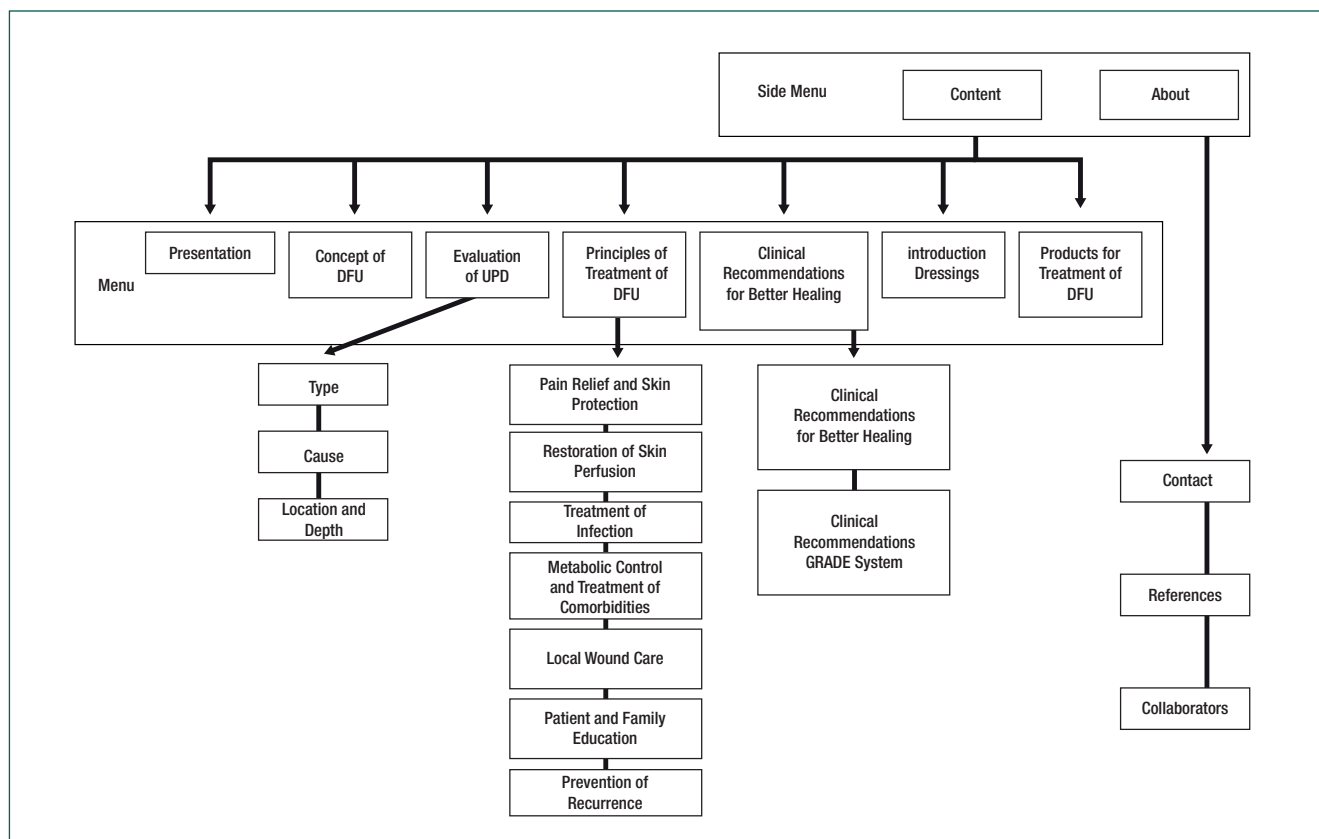
Figure 1. Conceptual Map of the application DFUAPP

tion; 9) Help users recognize, diagnose and recover from errors; 10) Help and documentation.[29]

Three other adapted and validated heuristics for usability in touchscreen phones were included: 1) Little human/device interaction; 2) Physical interaction and ergonomics; 3) Legibility and layout. The objective was to provide better interaction and an user-friendly interface.[30]

Combining the heuristics found, a set of customized principles and guidelines was proposed, resulting in a checklist for this HE.[31] The evaluators received this instrument to inspect the entire system and identify possible errors in the interface, based on the design guidelines.

Thus, each problem was recorded, including the number of evaluators who identified it, the place where it occurred and the degree of severity according to a scale divided in: 1) Cosmetic problem; 2) Minor problem; 3) Major problem; 4) Catastrophic problem. Data on violated heuristics and suggestions for possible corrections were also collected.[31]

In the second stage, which was aimed at finding usability problems experienced by the target audience, the application was individually evaluated and validated by the Group G2. Ten nurses aged between 28 and 50 years old, with experience in the treatment of DFU and in the use of smartphones were selected.

The evaluation occurred in two steps. In the first step, a script with five questions about topical care was distributed. The questions should be answered with the support of the content provided by the application. Therefore, the process of using the application and the user reactions were observed. The time, in minutes, that each professional needed to perform the tasks was also recorded.

The second step was the completion of a validated and adapted questionnaire. The questionnaire used a Likert scale with answers varying from one (strongly disagree) to five (strongly agree); the score of three indicated the evaluator was in doubt of whether they agreed or disagreed or did not feel

able to respond; scores equal to or greater than four were considered adequate.[32,33]

After the necessary corrections, with the application ready for upload on the internet, the fourth step – implementation – was carried out. This step consisted of making DFUAPP available on the UFES provider and on the Google Play store.

Results

The screens were organized in the following sequence: general information about the application, collaborators in its development, references used and contact information of the author. The home screen has the following options: Presentation, Concept of DFU, Evaluation of DFU, Principles of Treatment, Clinical Recommendations and Products for Treatment, References, Collaborators and Contact the Author.

Clicking on the option Presentation, the user will have access to the general information of the application. The option Concept of DFU will show the definition of the term and an illustrative image. In Evaluation of DFU, the nurse is instructed to follow a standardized and consistent strategy to assess the wound. There are some options to classify the wound according to Type, Cause, Location and Depth and presence of Signs of Infection. In Principles of Treatment, the seven principles of the treatment of DFU are available for consultation. These principles contribute to the healing of most lesions (Figure 2).

The screen of Clinical Recommendations for better healing provides recommendations based on the standardized classification system GRADE (*Grading of Recommendations Assessment, Development and Evaluation*), considering the quality of the evidence (classified into four levels that represent high, moderate, low and very low confidence), and the strength of the recommendation (expresses the emphasis of adoption or rejection of a certain conduct as strong or weak).[34]

Next, we have Products for Treatment, with three options: Introduction Dressings, Proper Dressing and Dressing Options. The Introduction Dressings screen highlights that dressings are a fundamental part of care. In Proper Dressing, the characteristics of an proper dressing and the dressing options indicated are described. Dressing Options presents the topical treatment recommended for wound management.

The usability evaluation carried out by the Group G1 resulted in the detection of eight major problems and two minor problems. The major problems encountered were: the user is forced to
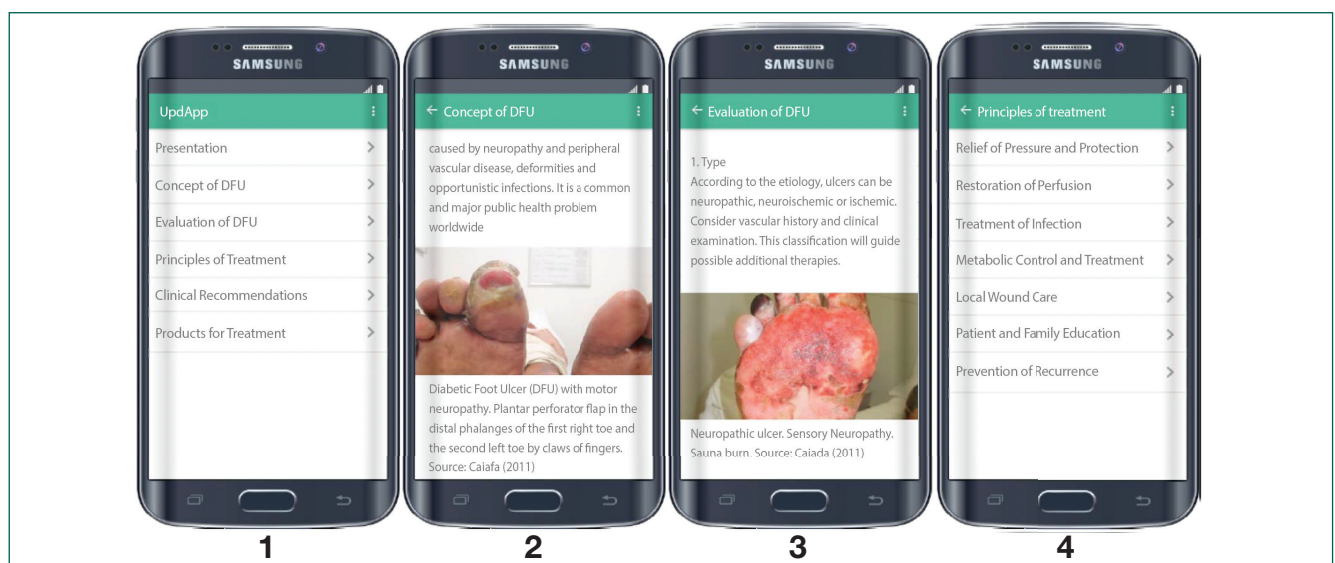

Figure 2. 1) Home Screen; 2) Concept of DFU; 3) Evaluation of DFU; 4) Principles of treatment;

return to the main menu using only the back button, so they may get tired of constantly repeating this action (six evaluators); content screens do not have navigation components, the number of pages, sections already seen or remaining screens for consultation are not informed (four evaluators); the section Products for Treatment did not have an adequate name, since its content included treatment techniques and options, and not only dressing options (one evaluator); the titles are long and do not fit on the screen, so the user cannot know for sure what is the item (three evaluators); there are no mechanisms for dynamic navigation, such as going from one screen to another with just one click (three evaluators); the user has to use the scroll bar in the content screens (one evaluator); in Dressing Options, the title is still Products for Treatment (an evaluator); and all submenu options lead to the beginning of the same page (two evaluators). As for minor problems, one evaluator considered that the back button did not inform where the user would be directed to and three evaluators suggested changing the title to For a Better Healing, to provide a better understand.

In the first stage of the evaluation and validation carried out by the Group G2, no user exceeded the time of ten minutes. In total, there were three mistakes in the execution of the activities proposed, all related to the difficulty in finding the answers to the questions. For example: the user accessed the option Principles of Treatment in the attempt to find the answer for an activity about the GRADE system, which would be found in the item Clinical Recommendations. In the second stage, mean values and standard deviation were obtained from the responses of the questionnaires, as shown in table 1. One participant was not considered because he did not answer two items.

The mean of the responses of users in the Group G2 ranged from 4.2 to 4.9. Thus, the application was considered adequate in all items evaluated. A second analysis was carried out with responses from different users to the same questions. These means ranged from 4 to 5. The standard deviation (SD) was calculated to identify

Table 1. Mean and standard deviation of responses from nursing professionals

Questions	Mean of answers	Standard Deviation
1. Mobile applications are easy to use (functionality)	4.5	0.70
2. The software is precise in the execution of its functions (functionality)	4.7	0.67
3. The software includes the main functions necessary to treat diabetic foot ulcers (functionality)	4.4	1.26
4. The software reacts properly when failures occur (reliability)	4	1.05
5. It is easy to understand the concept and application of the software (usability)	5	0
6. It is easy to learn how to use the software (usability)	5	0
7. The software provides help in a clear manner (usability)	4.5	0.52
8. The software tutorial is easy to understand (usability)	4.9	0.31
9. The execution time of the software is adequate (efficiency)	4.9	0.31
10. The resources available in the software are adequate. (efficiency)	4.7	0.48

the variability around the mean. The lowest SD found was 0.31 (no convergence) and the highest was 1.26 (largest divergence).

When asked if the application reacted properly in the event of failure, the responses of the Group G1 had higher variability than the responses of G2. Questions 5 to 10 showed lower variability, demonstrating that there were no difficulties in the use of the application.

Discussion

The Heuristic Evaluation and the tests performed with evaluators (G1) and users (G2) provided important information about the usability and validation of the DFUAPP and demonstrated that it is easy to use the app and to understand its concept and utilization, and that it provides help in a clear manner.

However, suggestions included the creation of a structured navigation scheme to provide the user's location (breadcrumbs); improvement of mobility in the screens of the system, with the implementation of fixed scroll bars, allowing that continuous text, images or any other element can be "scrolled", in addition to closing of links; and standardization of the sources of the images.

As usability is an important characteristic for the quality of any interactive product, especially on touchscreen devices, it must be considered when launching a product. Therefore, it can be a compet-

itive edge of the DFUAPP in a fast market, as is the case of these technologies.

The HE is based on the knowledge and experience of specialist software evaluators, who analyze the interface of a given system, identify possible problems and suggest solutions. It was demonstrated that the method is simple, lasts less than two hours and has a low cost. The importance of user participation is also emphasized. Therefore, the participation of nursing professionals was a priority.

Precision in the execution and inclusion of the functions necessary to treat DFU (functionality), adequate reaction when failures occur (reliability) and adequate execution time (efficiency) were demonstrated. These characteristics are included in the evaluation of the quality of an application that prioritizes the user experience. Other relevant aspects for the construction of digital resources are organization, interpretation and visualization, which must be attractive and favor reflection and re-elaboration of knowledge. Therefore, the amount of information included on each screen and its presentation must be accurate, simple and direct. Therefore, items such as font size and type, choice of colors and contrast between them were carefully selected.

No user exceeded the time of ten minutes, which is a positive point, as the use of an application under test should not exceed this time.[35]

The importance of developing this tool in a multidisciplinary context should be emphasized, as other professionals can gain interest in the creation of health technologies with integration of knowledge. In the setting of higher education in nursing, technology will provide countless opportunities, as it can be used by the student in the teaching-learning process, with the objective of building their own knowledge, and can assist the educator as a tool of interactive teaching and an alternative for fostering thinking and creation.

Regarding the mobile technology used, in general, users did not find any difficulties, as they are familiar with this type of device, and the obstacles identified were minimized or corrected. In all, the DFUAPP application brings an important contri-

bution to nursing, as it demystifies information about conduct and provides the necessary resources to assist in decision-making with regard to topical care of DFU. Above all, it can improve the scientific knowledge of the user and have a positive effect on their professional practices.

Among the limitations identified, the heuristic evaluation has very general questions for mobile devices, some of which cannot be applied to the DFUAPP. In addition, the application was developed only for Android. Another limitation was the impossibility of increasing the size of the images presented on the screens.

Conclusion

The objectives of this study were achieved, mainly regarding the development and validation of the proposed app. Given the reality of the use of technologies in teaching, especially in nursing, it is clear that the mobile tool to support decision-making with regard to topical care of DFU is a didactic and interactive proposal that is essential for the implementation and dissemination of evidence-based practice. The use of this approach in the provision of care can improve clinical judgment and favor the integration of knowledge, research and practice through the qualification and incorporation of a more clear and effective assistance, based on science.

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Collaborations

Colodetti R, Prado TN, Bringuente MEO and Bicudo SDS declare that they contributed to the design, analysis and interpretation of data, writing of the article, relevant critical review of the intellectual content and approval of the final version to be published.

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