Development of an application in the healthcare area using the Design Science Research methodology

Desenvolvimento de uma aplicação na área da saúde com metodologia Design Science Research

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ABSTRACT
Purpose: Pressure injuries are serious health problems and are considered to be one of the biggest challenges that health services face on a daily basis, especially nurses. In addition to the impact on institutions, such as increased treatment costs and length of stay, pressure injuries also have a major impact on patients' lives. Method: The method used was the Research Methodology in Design Sciences, this methodology is used to accurately describe the development of an innovation from the elaboration of the initial index to the communication of results. Results: The development of a mobile platform application that performs the appropriate classification of pressure injuries and has a support system for the correct choice of coverage, can provide safer and consequently quality health care. Conclusion: At the moment we live with the increase in people's longevity and consequently the increase in chronic diseases, this app can improve the quality of life of the population and also qualify health care, through correct information and easy accessibility and usability.

Keywords: portable electronic apps, mobile apps, pressure ulcers, technology, health care, health information system.

RESUMO
Objetivo: As lesões por pressão são graves problemas de saúde e são consideradas um dos maiores desafios que os serviços de saúde enfrentam diariamente, especialmente os enfermeiros. Além do impacto sobre as
instituições, como o aumento dos custos de tratamento e da duração da estada, as lesões por pressão também têm um impacto importante na vida dos pacientes. Método: O método usado foi a Metodologia de Pesquisa em Ciências do Design, esta metodologia é usada para descrever com precisão o desenvolvimento de uma inovação a partir da elaboração do índice inicial para a comunicação de resultados. Resultados: O desenvolvimento de uma aplicação de plataforma móvel que efetue a classificação adequada das lesões por pressão e disponha de um sistema de apoio para a escolha correta da cobertura, pode proporcionar uma assistência de saúde mais segura e, consequentemente, de qualidade. Conclusão: No momento em que vivemos com o aumento da longevidade das pessoas e, consequentemente, o aumento das doenças crônicas, este aplicativo pode melhorar a qualidade de vida da população e também qualificar os cuidados de saúde, através de informações corretas e fácil acessibilidade e usabilidade.

**Palavras-chave:** aplicativos eletrônicos portáteis, aplicativos móveis, úlceras de pressão, tecnologia, assistência médica, sistema de informação em saúde.

**1 INTRODUCTION**

The current demographic transition has shown an aging population and an increase in chronic diseases, which will demand in the coming years an increase in health care for this population and, consequently, the role of nurses who play a fundamental role in both primary and tertiary care. Currently, technological advances have contributed a lot to the quality of health services and nursing has gained prominence in this new sphere, which is information technology. Generally, nurses are known to act strongly in primary health systems and in maternal and child care, but there are several areas of knowledge that the nursing profession has worked with and with excellent results, for example, in the prediction of diseases and their complications, using Big Data and the use of smartphones and health apps that enable cardiac and respiratory monitoring, skin cancer detection, fitness trackers, sleep monitors, wearables, among countless other applications (app) \(^1,2,3,4\) In this sense, nursing as a dynamic profession seeks to incorporate new technologies into daily practice, always seeking efficiency in the health care of the population.

In the current health context, pressure injury (PI) is a growing problem in the level of primary, hospital and rehabilitation services\(^5\). PI is localized damage to the skin and/or underlying tissues, usually over a bony prominence that occurs
because of intense and / or prolonged pressure in combination with shear. The presence of comorbidities, as well as inadequate microclimate, nutrition and perfusion also contribute to the onset of PI. According to the Canadian Wound Care Association, the incidence rates of PI in general acute care services vary between 2.8% and 9.0%, and in long-term care services 3.6% to 50%; in home care, the incidences of PI vary from 4.5% to 6.3% ⁵⁻⁶. In the USA, approximately 2.5 million patients per year develop PI, and the cost of treatment is estimated between 9 and 11.5 billion dollars a year. In relation to mortality, 60 thousand patients die due to direct effects related to PI, thus, it is evident that PI are a risk to patient safety, due to the high power of iatrogenesis ⁷⁻⁸.

As of 2008, in the USA, the Centers for Medicare and Medicaid Services have stopped paying the additional costs arising from PI developed by patients during hospitalization, as, in addition to being an expensive treatment, such injuries can be avoided through good practices of nursing⁹. It is believed that health plans in Brazil will soon adopt the measures employed by Medicare and Medicaid and will no longer pay the additional costs arising from PI¹⁰, which will further burden hospital institutions. In this sense, the prevention of PI one of the major concerns of health services¹¹. Therefore, the nurse must seek prevention, evaluation and treatment strategies for the control and approach of these PI, with a view to promoting favorable conditions for good healing, avoiding the risk of complications. PI always trigger questions in the health area regarding the classification of the PI stage¹². This correct classification determines the choice of the appropriate dressing technique to be performed and the most appropriate coverage to be used, reducing the impacts of health care for this patient.

1.1 OBJECTIVE OF THE STUDY

Thus, the objective of this research was to develop an app for mobile devices that can assist in the classification of the stages of PI, as well as in the choice of the most appropriate coverage, contributing to a safe assistance. The research finds its justification in the researcher's personal experience as a nurse and programmer. This researcher is a nursing professor and works at a teaching hospital in the southern region of Brazil. Throughout his professional career, he
has always faced a lack of resolve in relation to PI at all levels of care, whether due to a lack of technical and professional resources or political reasons. With the growing change in health standards driven by aging, chronic non-communicable diseases and now also communicable diseases such as the Covid-19 example – with countless elderly patients affected and bedridden, realize the need to work with information technology, focused on for nursing problems related to PI.

1.2 EVIDENCE BEFORE THIS STUDY

For the elaboration of this application, it was necessary to carry out a systematic review, as recommended by the method used by Design Science Research (DSR). Thus, the protocol of this systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with (ID: CRD42018114137). The objective was to conduct a review of published studies on mobile apps and systematic research in app stores developed to identify and / or evaluate and / or treat and / or prevent PU in adults, and to evaluate the app based on the quality characteristics of the software. The research took place between the period from January 1, 2017, to November 15, 2018. Six studies were selected for qualitative analysis. One study developed a prototype of a seat pressure mapping system using a mat that transmits data to a smartphone app in real time, another proposed smartphone software for wound tracking, and one study developed an algorithm to determine the size of the wound in relative and absolute terms and analyzing the color of the PI image, but none had the PI stage classification interface. Some studies had objectives aimed at the compliance of users’ data and PI treatment recommendations. Only one study has similarities with the study presented here, however, it does not present the interface for indicating coverages and has not been tested in real patients with different anatomical areas. In the present review, it was identified that the studies on app still need to be evaluated using software quality characteristics.
2 METHOD

2.1 DESIGN SCIENCE RESEARCH METHOD OF RESEARCH

Research carried out in healthcare uses several methodologies, but none of them has managed to technically, and with methodological rigor, develop an app. The development that presents a structured method with a theoretical basis to give the app a scientific value is found in the engineering area. In this sense, the present study employed the DSR method of research\textsuperscript{21,22,23,24}.

2.2 DESIGN SCIENCE RESEARCH STAGES

The DSR is a simple and practical methodology for conducting cutting-edge scientific research\textsuperscript{20,21,22}, providing comprehensive guidance on how to conduct research in any area of knowledge (Table 1).

<table>
<thead>
<tr>
<th>Steps</th>
<th>Application in research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Problem identification</td>
<td>Formalized research question, contextualizing the LP and mobile technologies used in health care.</td>
</tr>
<tr>
<td>2 Awareness of the problem</td>
<td>Use of the recommendation adopted worldwide for LP, established by the National Pressure Ulcer Advisory Panel (NPUAP) and studies of the types of coverings to be recommended for each stage of PI.</td>
</tr>
<tr>
<td>3 Systematic literature review</td>
<td>Search for material already published to prove the innovation and originality of the current research. The PICO of the research was prepared, after the registration of the Systematic Review was carried out in PROSPERO, the selection of articles in the databases was carried out, the PRISMA flowchart was prepared, data extraction of the included articles was carried out, and qualitative analysis was performed.</td>
</tr>
<tr>
<td>4 Identification of artifacts and problem class configurations</td>
<td>Understanding of the problems to be addressed in the research. Classification of PI stages; Proper use of covers for PI; Contribute to safe care for patients with PI.</td>
</tr>
<tr>
<td>5 Proposition of artifacts to solve the specific problem</td>
<td>The proposition is: To develop an app for mobile devices that can assist in the classification of the stages of PI, as well as in the choice of the most adequate coverage, contributing to a safe assistance to the patient with PI.</td>
</tr>
<tr>
<td>6 Selected artifact project</td>
<td>Systems Development Life Cycle was used to prepare the app script. The technical support for the graphic images was extracted from the NPUAP website, which hosts the images for actions involving education without gaining value. To obtain PI images, the project was registered with the Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul (PUC / RS) with CAEE 54732516.4.0000.5336, a Free and Informed Consent Term was applied to the patient or their guardian. the research objectives and participants' rights and an image usage term. The images were all collected at the medical and surgical clinic (adults and the elderly) in a hospital in southern Brazil, which also allowed the research to be carried out.</td>
</tr>
</tbody>
</table>
**Steps** | **Application in research**
---|---
7 Artifact development | For the elaboration of the app development technology based on JavaScript and Web programming languages was used, using Ionic, Angular and TypeScript. The algorithm was developed based on the support vector machine algorithm for image processing and classification (after capture). The classification was made using the S band (color) of the image in the color format Hue, Saturation, Value (HSV).
8 Evaluation of the artifact | The evaluation of the app was analytical, experimental and of structural and functional thesis. The analytical phase occurred during the elaboration of the application, when the best performance for the image processing was sought. The experimental phase, on the other hand, took place at the hospital, in the medical and surgical clinic unit, where the classification of pressure lesions with patients was tested. The evaluation phase of structural and functional testing occurred by sending the application link to a selected group of evaluators to handle the app and, afterwards, to respond to a form structured in accordance with ISO / IEC 25010: 2011, through a Likert Scale. The structural question was evaluated by teachers and computer professionals, while the functional question was carried out by specialists in the area of PI. (Nurses, Doctors and Physiotherapists).
9 Explanation of learning | The use of DSR is an innovation for the health area. The objective, which was to develop an app for mobile devices that can assist in the classification of the stages of PI, as well as in the choice of the most adequate coverage, contributing to a safe assistance to the patient with PI, was successfully achieved;
10 Conclusion | Experimentation with a new scientific DSR methodology in the health area. Evaluation of the app in real conditions and with real patients is another major contribution of this research. Need to incorporate Artificial Neural Networks and thermographic image, in order to improve the processing of results.
11 Generalization for a class of problems | The app can handle the needs raised by the class of problems, where it correctly identifies the PI stage and later offers a list of coverages that can be used according to each stage. All these actions contribute to safe and quality care for the patient.
12 Communication of results | National Institute of Industrial Property – Brazil under the Process Nº: BR512020000311-7. The app will be distributed free of charge in specialized stores

Source: Author data.

### 3 RESULTS

#### 3.1 STRUCTURE OF THE APP LEPRESS

The logical structure of the app called “LEPRESS – support in the identification of PI and use of coverings”, is described below, Figure 1.
3.2 APP INFORMATION

According to figure 1, LEPRESS presents a presentation screen and a tutorial to facilitate its use. Interface 1 presents the textual classifications of the PI with their corresponding graphic images. In interface 2 there is an image gallery that can be used if the user needs more information to perform the classification. In interface 3, the image is captured for comparison with the existing images in the app database. Interface 4 offers the possibility of consulting, at any time, information about the appropriate coverage for each stage of injury. Table 2 shows the sequence of the LEPRESS interfaces.
Table 2 – Initial demonstration of the app's interfaces

App information

This screen presents users with access to the app's tutorial, with important information that must be adopted for the app to function effectively. Once the tutorial has been read, the next step is the "ACCESS" command, which will take you to the next interface.

Interface 1
Description of stage 1 of PI according to the NPUAP

Interface 2
Shows the image of the PI stage 1.
App information

Interface 3
Image capture (take photo).

Interface 4
Coverage suggestions.

Source: Author data.

After the presentation of the initial screen, the technical description of the PI stages follows, as well as their corresponding graphic image (Interface 1) according to the NPUAP\(^25\). If the user remains in doubt regarding the classification of the injury, he can use the resource of the image gallery app “galeria de imagens” (Interface 2), which will enable him to compare the PI that the patient presents with an image bank, so that, improve the correct identification of the lesion. However, if neither the graphical demonstration of the PI stages (Interface 1) nor the image gallery (Interface 2) are enough to assist the user in identifying the PI, he can use an app feature that is capture image/“capturar imagem” (Interface 3).

Once this tool of the app is used, the user can photograph an PI and the app will relate that captured image to the image bank and return the PI that most closely matches the photograph as a classification possibility. Another app interface directs to the covers (Interface 4) to be used in PI. The objective is to
ensure patient safety in relation to care assistance in injuries with the proper use of the cover. The presentation of the app screens with the operating steps are presented in a supplementary document.

3.3 STRUCTURAL AND FUNCTIONAL TESTING PHASE

Finally, the structural and functional testing phase was carried out. This verification occurred by sending the application link through Google Forms to a selected group of evaluators to handle the app and, afterwards, to answer a structured form with questions related to ISO / IEC 25010: 2011, through a Scale of Likert (0 completely disagree, 5 completely agree). Table 3 shows a comparison of the functional and structural tests.

<table>
<thead>
<tr>
<th>Rated aspect</th>
<th>Average functional evaluation (0-5)</th>
<th>Average of structural evaluation (0-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality</td>
<td>4.49</td>
<td>3.21</td>
</tr>
<tr>
<td>Reliability</td>
<td>4.03</td>
<td>3.33</td>
</tr>
<tr>
<td>Usability</td>
<td>4.67</td>
<td>4.17</td>
</tr>
<tr>
<td>Efficiency</td>
<td>4.44</td>
<td>3.96</td>
</tr>
<tr>
<td>Manutenibilidade</td>
<td>-</td>
<td>3.13</td>
</tr>
<tr>
<td>Portability</td>
<td>-</td>
<td>3.61</td>
</tr>
</tbody>
</table>

Source: Author data.

4 DISCUSSION

4.1 TESTS PERFORMED AND APP PERFORMANCE EVALUATION

For the evaluation of the app, analytical, experimental, and structural and functional thesis analyzes were used. The analytical phase occurred during the elaboration of the app, when the main objective was the best performance for image processing using two image comparison techniques, KNN and SVM.

The experimental phase took place at the hospital, where the classification of PI was tested with the patients. The app has been tested several times and after each evaluation step improvements have been increased; these improvements are summarized in Table 4 below.
<table>
<thead>
<tr>
<th>Steps</th>
<th>Tests performed</th>
<th>Result of App performance</th>
<th>Evaluation</th>
<th>Improvement</th>
</tr>
</thead>
</table>
| 1     | Analytical Evaluation  
At hospital using KNN and SVM techniques. | Un satisfactory: Identified that some factors could change the expected result of the app. | SVM showed a greater tendency to success than KNN. | - When capturing the image, pay attention to the lighting and also the sharpness of the image.  
- Increase the image bank so that the algorithms have more possibilities for comparison. |
| 2     | Experimental Evaluation 1  
Held at hospital. Using KNN and SVM techniques. And increasing the image bank. | Un satisfactory: Neither KNN nor SVM were able to correctly classify the images. | Retrogressivity in the processing of images with the increase of the database. | - Determination of only one classifier of the algorithm, the SVM. |
| 3     | Experimental Evaluation 2  
Held at hospital, using only the SVM. | Un satisfactory: Improvement in results but maintains the incorrect classification. | Stagnation in image processing. | - Maintain a distance of, at most, 15 cm between the cell phone camera and the PI.  
- And use the image selection tool to better determine the area of the lesion. |
| 4     | Experimental Evaluation 3  
Held at hospital. With PI camera approach and image selection. | Satisfactory: It resulted positively in the PI classification. | Evolution in terms of image processing. | - Preparation of a tutorial with the main suggestions for using the App.  
- Incorporation of lighting for cavity PI. |
| 5     | Experimental Evaluation 4  
Held at hospital. Using camera (flash) for cavitory PI. | Satisfactory: Positive result with the inclusion of lighting. | Evolution in terms of image processing. | - The recommendation to use the (flash) camera will be incorporated into the tutorial. |
| 6     | Functional test  
Performed with health users.  
Structural testing  
Performed with users of information technology. | The access link to the application was sent to the evaluators (which was downloaded on the evaluators’ cell phones) and the questionnaire link prepared in Google Forms. | - Some of the suggestions sent:  
- Use of artificial neural networks.  
- Inclusion of other evaluation elements.  
- Improvement of the image selection technique.  
- Improve the design of the application and its interaction with the user. |

Source: Author data.

The structural question of the application evaluated by professionals in computer technology, while the functional evaluation was carried out by
specialists in the health area. The definition of the number of evaluators is determined by ISO / IEC 25010: 2011\textsuperscript{26}. The items maintainability and portability were not evaluated by health professionals, as a specific knowledge of programming is required. Analytical and experimental evaluations demonstrate the seriousness of the research proposal.

The great acceptance of “LEPRESS” by health professionals, especially nursing, represents the innovation of the app for the health area. Assisting professionals both in their practical and educational activities, and mainly contributing to patient safety in relation to PI. The evaluation of computer professionals, on the other hand, demonstrated the need to structure a different evaluation for them, offering them the open source and not just the app link. However, all placements are fundamental to improving the app.

However, due to the infinity of variables in relation to the type of fabric and its color grading, reaching the exact precision in all interactions is the objective to be pursued by artificial intelligence. Other authors such as\textsuperscript{5,14,15,16,17,18,30} also found this same need for improvement.

However, the main difference between LEPRESS and other applications is that this app was developed through DRS, which consolidated the scientific rigor in its development and the tests carried out with the application were carried out with real situations and real patients.\textsuperscript{20,21,31}

4.2 INNOVATIONS OF THE LEPRESS APPLICATION

Being a technology developed by a nurse, having been developed through a new methodology in health, the evaluation of real patients and in real environmental conditions (many app are validated in prepared environments or with fictitious patients, where it is not possible to determine the accuracy of the results)\textsuperscript{13}, be an application aimed at health professionals, and not just for a category, have tools that make it an instrument of learning and permanent update, be developed for the Android and iOS operating systems, allows the image selection for the classification of PI stages, thus optimizing the final result, offering a list of coverages to be used in the treatment and prevention of PI, contributes to a safer and more qualified health care for PI carriers.
4.3 LIMITATIONS

The limitations are related to the language issue, difficulty in adapting the brightness, to the user to maintain the appropriate distance of a maximum of 15 cm when capturing the image and also to select the appropriate lesion to generate the classification in the app, without other structures such as a sheet, bed among others.

4.4 FOR FUTURE WORK

Increase the image bank and determine other evaluation elements that can improve the classification of PI, include Artificial Neural Networks and thermal images for the recognition of the image pattern, increase the interaction of the app with the user, improve the application with regard to the interface design.

5 CONCLUSION

The innovation of this study is found in the elaboration of the app, because it was supported by a robust methodology, but little used in the health area, which is DSR, which presents a rigorous method of elaborating innovations. The study followed all the quality requirements for software development recommended by ISO / IEC 25010: 2011. In addition to all important requirements, the application validation took place in real environments with real patients, necessary for the regulation of digital health products, validating their effectiveness.

The developed app was built within all software security standards. It can be used by both health professionals and students, it has dynamic interfaces that lead to the central objective, which is the correct classification of PI and indication of the best coverage to be used. It is a tool for decision-making, especially for nurses, subsidizing quality, and safe health care in relation to PI. Overcoming social, financial, and geographical barriers.
AUTHOR STATEMENT

Participation was on a voluntary and consent was signed and obtained.

Summary points

<table>
<thead>
<tr>
<th>Know</th>
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<tbody>
<tr>
<td>● Mobile apps are important health assessment tools</td>
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<tr>
<td>● Several free and paid mobile app for identification, evaluation,</td>
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<tr>
<td>treatment and/or prevention of pressure injuries are available in</td>
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<tr>
<td>the current market</td>
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<table>
<thead>
<tr>
<th>Unknow</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Research points out problems related to the functionality, design,</td>
</tr>
<tr>
<td>security, and veracity of the application's information.</td>
</tr>
<tr>
<td>● Studies are currently in the early stages of application development or improvement and, therefore, still need to be evaluated for different characteristics of software quality.</td>
</tr>
<tr>
<td>● Currently, the prescription of an application for the identification, evaluation, treatment and/or prevention of pressure injuries in adults is limited.</td>
</tr>
<tr>
<td>● Need for a quick search guide to indicate specific coverage for PI</td>
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</tbody>
</table>

CONTRIBUTORS

JK, developed the planning of the algorithm, collected the images, elaborated the study design, as well as applied the tests, made the analysis, data interpretation and writing of the manuscript. BC, LK and LD, guided the preparation of the study design, contributed to the analysis and interpretation of data, in addition to writing the critical review of the manuscript for important intellectual content. MB contributed to the analysis and interpretation of data and writing and critical review of the manuscript.
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