Cadernos Brasileiros de Terapia Ocupacional
Brazilian Journal of Occupational Therapy

ISSN 2526-8910

Original Article

Development and assessment of the e-Seating app as a tool for prescribing wheelchairs and postural support devices: a qualitative study

Desenvolvimento e avaliação do aplicativo e-Seating como ferramenta de apoio à prescrição de cadeira de rodas e dispositivos de adequação postural: estudo qualitativo

Adriana Klein[a], Marcelo Archanjo[a], Rodrigo Suigh[a], Roseli de Deus Lopes[a]

[a]Universidade de São Paulo – USP, São Paulo, SP, Brasil.

How to cite: Klein, A., Archanjo, M., Suigh, R., & Lopes, R. D. (2025). Development and assessment of the e-Seating app as a tool for prescribing wheelchairs and postural support devices: a qualitative study. *Cadernos Brasileiros de Terapia Ocupacional*, *33*(spe1), e3788. https://doi.org/10.1590/2526-8910.ctoAO397737882

Abstract

Introduction: e-Seating is a mobile application developed to assist rehabilitation professionals in decision-making during the prescription of wheelchairs and postural support devices (WPSD). The app provides a structured assessment protocol, aligns with the stages of the prescription process, integrates relevant information, and generates technical reports. **Objective:** To describe the development and evaluation process of the e-Seating application. **Method:** This qualitative, exploratory, and descriptive study was conducted in three phases, involving 91 participants, including occupational therapists, physical therapists, physiatrists, technicians, wheelchair users, and technology specialists. In phase 1, challenges related to WPSD assessment and prescription were identified, informing the development of the initial prototype. In phase 2, the app was tested and refined based on feedback collected through four iterative versions. In phase 3, technology experts assessed the app's usability. Data collection methods included semi-structured interviews, focus groups, and heuristic evaluations. Data analysis followed a qualitative approach. **Results:** Phase 1 revealed a lack of systematization in WPSD assessment and prescription, communication gaps between professionals and technicians, and limited user participation. In phase 2, feedback from rehabilitation professionals contributed to improvements in each app version. In phase 3, usability testing informed refinements to the app's technical and functional features. **Conclusion:** The study led to the development of a structured framework for WPSD assessment and prescription, offering comprehensive support throughout the prescription process.

Keywords: Wheelchair, Assistive Technology, Mobility Assessment, Occupational Therapy, Seating, Postural Support.

Received on May 27, 2024; 1st Revision on June 26, 2024; Accepted on Dec. 11, 2024.

Resumo

Introdução: e-Seating é um aplicativo desenvolvido para apoiar os profissionais de reabilitação na tomada de decisão no processo de prescrição de cadeiras de rodas e dispositivos de adequação postural (CRDAP). Oferece um roteiro sistematizado de avaliação, acompanha as etapas da prescrição, integra informações e gera relatórios técnicos. **Objetivo:** Apresentar o processo de desenvolvimento e avaliação do aplicativo e-Seating. **Método:** Trata-se de um estudo qualitativo, de caráter exploratório e descritivo, conduzido em três fases, com a participação de 91 indivíduos (terapeutas ocupacionais, fisioterapeutas, fisiatras, técnicos, usuários de cadeiras de rodas e especialistas em tecnologia). Na fase 1, foram identificados os desafios relacionados à avaliação e prescrição de CRDAP que subsidiaram o desenvolvimento do protótipo inicial. Na Fase 2, o e-Seating foi testado e aprimorado a partir dos feedbacks recebidos em quatro versões. Por fim, na fase 3, especialistas em tecnologia avaliaram a usabilidade do aplicativo. A coleta de dados foi realizada por meio de entrevistas semiestruturadas, grupos focais e avaliação heurística. A análise dos dados seguiu abordagem qualitativa. **Resultados:** Na fase 1, identificou-se a ausência de sistematização nos processos de avaliação e prescrição de CRDAP, dificuldades na comunicação entre profissionais e técnicos e participação limitada dos usuários. Na Fase 2, os profissionais de reabilitação contribuíram com sugestões que aprimoraram cada versão do aplicativo. Na Fase 3, os testes de usabilidade possibilitaram o refinamento dos requisitos técnicos e funcionais da ferramenta. **Conclusão:** Este estudo resultou na proposição de um roteiro para avaliação e prescrição de CRDAP, promovendo suporte na jornada de prescrição.

Palavras-chave: Cadeira de Rodas, Tecnologia Assistiva, Avaliação da Mobilidade, Terapia Ocupacional, Sistema de Posicionamento, Suporte Postural.

Introduction

The World Health Organization (WHO) estimates that between 10 and 15% of the world population has some type of disability and that 10% of them need a wheelchair (World Health Organization, 2011). In developing countries, wheelchairs are often not fitted according to their user's body features and only less than 5% of those who need this equipment have a model fit to their condition (Jhpiego Corporation, 2015; Cruz et al., 2016; Caro & Cruz, 2020).

Several wheelchair users need additional postural support devices (PSD) (Cook & Polgar, 2015; Pontes et al., 2021; Hosking, 2024). Regardless of the type of PSD, there is evidence that appropriate evaluation methods can promote better choices and outcomes for patients (International Organization for Standardization, 2006; Khasnabis & Mines, 2013; International Society of Wheelchair Professionals, 2016). The WPSD prescription is part of a complex intervention which is usually performed by physiotherapists (PT) and occupational therapists (OT) (Hastings et al., 2003; Campos, 2013). Some studies show the importance of expertise in the WPSD prescription process and some assessment scales can assist practitioners in their decision-making (Kenny & Gowran, 2014; Aissaoui et al., 2001, Hatta et al., 2007, Toro et al 2017).

Our study highlights a singular contribution to be added to the assessments available since it is not focused on the outcomes, such as functioning, user skills or satisfaction

with the technology; it rather focuses on establishing a framework with features to prescribe the technology to the user and considers their participation in this process (Kirby & Doucette, 2019).

A review of the literature gives evidence to support the need of our study to provide a framework for the process of prescription, to standardize it and to organize the documentation of practice. Our study aims to present the research process of development and usability of the e-Seating prototype, a mHealth App developed to support the process of assessment and prescription of WPSD for OTs and PTs.

Methods

Ethics

This study was approved by the ethics and research committee Institutional Review Board of the Universidade de São Paulo, Brazil (protocol number 53929516.6.0000.0065). All the participants signed a consent form to participate in this research. The data was stored on the study researcher's external hard drive and will be preserved for five years.

Study Design

This study has a qualitative approach, consisting of three sequential stages of development and evaluation. An iterative process consisted in consulting/user testing (using open interviews at all stages), system (re)design and software development. Figure 1 shows all the stages and participants of our study. All questionnaires used in this study are available on Supplementary Material (Klein, 2020).

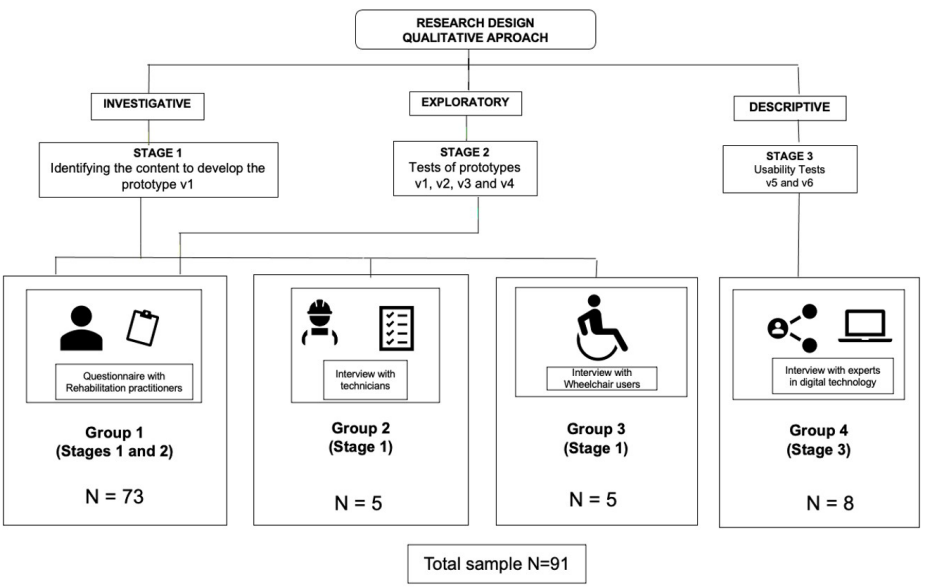

Figure 1. Qualitative research design. These three stages are described as follows concerning their participants, instruments, data collection and data analysis.

STAGE 1 - Prototype development v1

This stage aimed to identify the clinical practice features and the terminology used in the prescription of WPSD by rehabilitation practitioners, specialized technicians and user's needs. All stage 1 interview structure questions were developed based on a literature review and on AT abandonment studies, clinical practice challenges related to WPSD prescription (Frost et al., 2012; Lange & Minkel, 2017). The three questionnaires were previously validated by a commission of specialists in the field. The study methodology used qualitative techniques (Murphy et al., 1998; Mays & Pope, 2000).

All the content or discourse of the answers was explored to develop the prototype (v1) of the App based on the real needs of the rehabilitation settings. The App was developed in Android Studio® with Kotlin® language and used SQLite® to implement an internal database. The remote database service is provided by back4app® (Klein & Lopes, 2018).

Recruitment stage 1

A convenience sample of twenty-four participants (n=24) was invited to join Stage 1. The inclusion criteria for each participant and the instruments for data collection are described as follows and are available in Supplementary Material.

1) Practitioners: fourteen practitioners (n=14) (OTs, PTs and physiatrists): have a minimum of twenty-four months of clinical practice of WPSD, work experience in a range of settings (public and private) of different workplaces in the State of Sao Paulo, Brazil. The form themes comprised evaluation features, such as procedures, instruments, tools, and terminology adopted for WPSD prescription. For data collection, the principal author contacted the professionals by telephone and, after they signed an online agreement, the researcher sent the link to the participants by e-mail.

2) Specialized technicians: using the 'snow ball technique', five participants (n=5) who were technicians working in orthopedic settings were recruited, with a minimum of twelve months of practical experience in WPSD, and work experience in different settings of rehabilitation (public, private or self-employed). A semi-structured interview consisted of questions related to the themes: comprehension of the prescriptions, communication with the rehabilitation team, and the participation of users in the process of experimenting the WPSD prescribed. The interviews were conducted at the workplace.

3) WPSD Users: five participants (n=5) were included: aged eight or over; being literate and a user of WPSD for at least six months. A semi-structured interview consisted of questions related to the themes: evaluation process for WPSD, perception of the user about their participation in the process of prescription, the practitioners involved, and follow-up services of the WPSD. The participants were invited to the interviews through social media. These interviews were conducted by the principal author in the participant's home. All the interviews were recorded using an iPhone 6® by Apple Inc.

Data analysis stage 1

All the interviews were categorized. For practitioners, data were organized into categories such as instruments and tools used by practitioners, methods of assessment, terminology adopted, strategies to monitor the client and difficulties faced in clinical practice.

For the specialized technicians, the analysis aimed to identify their comprehension about WPSD prescription, communication with users and their families and also with the practitioners.

For WPSD users, data were analyzed according to the information in their report about the evaluation process, prescription, satisfaction with WPSD and follow-up.

At this stage, we adopted Lefevre's analysis of the content, which gathers information from the different respondents to summarize all the content in a collective discourse (Lefevre & Lefevre, 2010).

The qualitative analyses of the participant's discourse were performed, but the discourse of the practitioners was mostly used to define the terminology to formulate the flow diagram for v1 of the e-Seating App (Creswell & Clark, 2017).

STAGE 2 - Prototypes Versions Test 1 to 4 (v1, v2, v3, v4)

The second stage aimed at improving the overall functioning of the app and consisted in developing, testing and evaluating the prototype versions 1, 2, 3 and 4. The instruments and data collection are described in the sequence order of their application:

Description of Test v1

Six practitioners (OTs, PTs and physiatrists) were invited for this stage. The criteria were that the subjects had worked with WPSD for a minimum of twelve months and worked in different places. The goal was to present the first version(v1) of the App to them, for exploring it. v1 was presented individually to the participants using a Tablet Samsung Galaxy® Note model SM-P601 - version Android 5.1.1. The participants answered the open question, based on the design thinking method (McLaughlin et al., 2019): "What do you think of this App?". The main researcher took note of the suggestions. The answers were also recorded using an iPhone 11® by Apple Inc. Data from this exploratory question were used for improving v2.

Description of Test v2

To test v2, a convenience sample of ten participants (n=10) was invited based on the inclusion criteria of at least twelve months of WPSD prescription experience. The e-seating App was presented by the main author of this research to all the participants simultaneously using a 300 x 228 Data Show Projector HD with the App Vysor® - Android control on PC. All the participants were asked to complete a questionnaire following the demonstration of each item of the e-Seating App.

A Health Care Professionals Questionnaire was developed using a five-rating Likert Scale where 1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree and 5: Strongly agree, for the issues: suitability in clinical practice; content about the wheelchair; variety of

PSD, backrest, head restraint, trunk support, upper limb and lower restraints models; safety system and tables/ supports (Supplementary Material).

The participants also scored the feasibility of the PDF report assessment produced by the App and the interaction between the user and the practitioner. It was possible for the participants to give feedback on all the questions and suggestions to improve the App for the next prototype, v3. This test was used as a reference to the agile prototyping method of software development (Srivastava et al., 2017).

Description of Test v3

v3 was applied to thirty-nine rehabilitation practitioners (n=39) from one of the hospitals in Sao Paulo, Brazil. The inclusion criteria were that the subject be an OT or PT, with or without experience in WPSD.

The procedures were exactly the same as those adopted for v2 (including the questionnaire applied). The feedback given by the participants was used for the next prototype, v4 (Srivastava et al., 2017).

Description of Test v4

v4 was tested with a small sample of four rehabilitation practitioners (n=4). The inclusion criteria was to have a minimum twenty-four-month experience in WPSD prescription. We aimed to compare if both ways of data gathering (printed form or app) were considered effective by the practitioners.

The participants tested v4 of the App in a context of focus group technique (Vicsek, 2007). Each participant met the researcher at the University where the research was being conducted. In a special room, they received a link to download the e-Seating App to their own mobile phones.

All the participants received a case study with the full information about a patient who needed a WPSD prescription. They received instructions on how to apply the assessment to the case study. These participants were then divided randomly into two pairs (2-2); one pair started to use the app and the other used a printed sheet with the same content as the app. The time to complete the assessment was recorded. After this, both groups changed their roles, i.e. the one who performed the assessment with the app turned to the printed sheet and so on for the other group.

When they had completed both methods, the main researcher asked the pairs to discuss both ways of performing the prescription for 25 minutes, and after this, all four participants discussed outcomes together for a further 45 minutes. These discussions were recorded and transcribed by a research assistant.

Data analysis Stage 2

This stage comprised a quantitative and qualitative approach by the descriptive data from the questionnaires, organized in the Microsoft Excel Program®, to identify the frequency and intensity of answers. The notes were organized in Tables with the main suggestions reported by the participants for each prototype (Srivastava et al., 2017).

STAGE 3 - Prototypes Usability Test Versions 5 and 6

v5 and v6 were tested by eight technology experts (TEs) (computer programmers, engineers and UX designers) in two tests (test 1 and test 2). The goal was to find gaps and technological problems using the Nielsen Heuristic Assessment method (Nielsen, 2012). Each participant tested the prototypes using a Samsung Galaxy ®Note tablet - Android version 5.1 - 2014 edition. They were guided through the performed four predefined tasks: 1) registering a new patient, 2) prescribing a wheelchair, 3) prescribing PSD and 4) exporting the final report document to their own email and then answering a 10-question form (Supplementary Material). The notes were reviewed and the programmers implemented the suggested changes in v6. Test 2 was performed with the same evaluation method as in test 1. All the TE tests comments were recorded by the main author of this research during the test and after these procedures, the final v7 was concluded.

Data analysis Stage 3

The answers given by the TE were organized into tables. Each of the 10 questions of the interview script was classified according to the level of usability problems, ranging from 0 to 4 (0: unimportant; 1: an aesthetic problem; 2: a simple problem; 3: a serious problem; 4: a catastrophic problem). All the qualitative suggestions were transcribed and analyzed for the final adjustments of the App.

Finally, the e-Seating App followed these development steps and the system architecture represents the WPSD prescription flow in Figure 2.

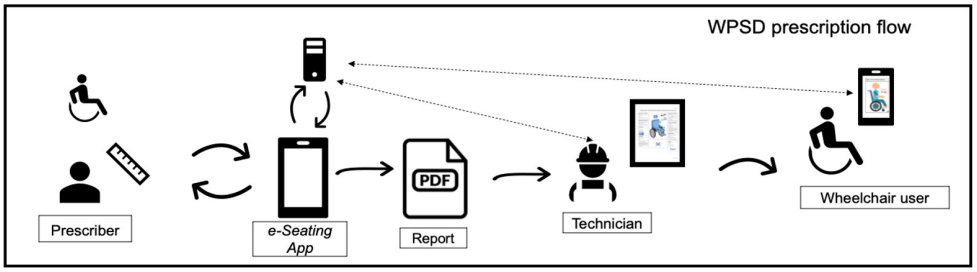

Figure 2. Architecture for WPSD prescription by the e-Seating App. The prescriber evaluates the patient and adds the data in the App. The system generates a PDF document with the illustrated prescription and detailed metrics. The technician interprets the prescription and performs the customization of the mobility device.

Results

STAGE 1 - Gathering information for developing v1

In Stage 1, the frequency of PSD types mentioned and the terminology adopted by the participants are described in Table 1, and the fourteen practitioners were interviewed, according to Table 2.

Table 1. Terminology and Postural Support Devices (PSD) cited by the rehabilitation practitioners (n=14).

Device category	Number of PSD cited	Terminology used	n	(%)
Seat	n= 10	hard and flat support	9	64%
		anatomical	9	64%
		plan	8	57%
		different densities	6	42%
		with cushion space insertion	4	28%
		modular	4	28%
		custom molded	3	21%
		digitized	3	21%
		canvas or tarpaulin	2	7%
Backrest	n=14	hard surface	9	64%
		hard plan surface	8	57%
		anatomical	7	50%
		carved	6	42%
		digitized	5	35%
		with lateral support	5	35%
		arched	4	28%
		wedge	4	28%
		different backrest heights	4	28%
		modular backrest	4	28%
		tarpaulin	3	21%
		with regulated straps	3	21%
		custom molded	2	14%
		with lumbar support	2	14%
Trunk supports	n= 13	with a two-point support	7	50%
		adjustable	6	42%
		fixed/rigid	5	35%
		curved	4	28%
		with a three-point support	4	28%
		anatomical	3	21%
		custom molded	3	21%
		modular	2	14%
		plan	2	14%
		retractable	2	14%
		in one point	2	14%
Head restraints	n=13	adjustable	6	42%
		removable	6	42%
		occipital support	6	42%
		forehead stabilizer	6	42%
		lateral support	5	35%
		plan	5	35%
		with angulation	4	28%
		modular	4	28%
		fixed	4	28%
		curved	2	14%
		rigid/hard	2	14%
		anatomical	2	14%
Upper limbs support	n= 6	cushioned	7	50%
		tray	7	50%
		adjustable height	6	42%
		removable	3	21%
		manufacturer's originals	2	14%
Lower limbs support	n= 7	box	8	57%
		wedge	6	42%
		“swingaway”	6	42%
		footplates	5	35%
		tray	4	28%
		hangers	3	21%
		cushioned	2	14%

Table 1. Continued…

Device category	Number of PSD cited	Terminology used	n	(%)
Safety System	n=6	pelvic belt	13	92%
		shirt belt (torso)	8	57%
		chest belt	8	57%
		diagonal	3	21%
		a four-point support	2	14%
		modular	.2	14%
Tables and supports	n=6	customized table	10	71%
		with angulation	6	42%
		tray	4	28%
		acrylic	3	21%
		wooden	2	14%
		with edges around	2	14%

In stage 1, the main perceptions self-reported by specialized technicians regarding their professional practice were: a) difficulties in understanding the terminology described in the prescription by the rehabilitation practitioners, b) doubts about PSD measures suggested in the prescription, c) insufficient communication with the prescriber, and d) they recommended a standardization of the terminology in the App to help them better understand the prescriptions.

The third group interviewed comprised five wheelchair users. Three of them self-reported feeling pain and discomfort initially when they had the PSD in their wheelchairs. They had a follow-up after six months of use. Four participants admitted that they had found their own solutions for problems related to WPSD because they believed it was probably the easiest way to save time. All the users reported that they would like to change their current PSD.

The most frequent terminology and devices reported by the participants were then selected to create a framework fostering the development of the first version of prototype v1.

STAGE 2 - testing prototypes of v1, v2, v3 and v4.

Table 2 summarizes the main results of four prototypes of v1, v2, v3 and v4.

Table 2. Participants (n=59) and their recommendations for the prototype version 1, 2, 3 and 4.

V*	N*	Participant's Description	Results	Examples of changes
V1	6	v1 was tested by a group of prescribers composed by two physiatrists, two PTs and two OTs. The average professional experience in WPSD prescription was 10.1 years (ranging from 3 to 20 years).	All the participants considered the prototype version 1 as a tool with potential to improve the process of prescription. They indicated the need to add: a) user's metrics b) images to facilitate the choice of the devices and, c) extra information about the device feature. All the suggestions were implemented to create the prototype version 2, including PSD images drawn in Adobe flash CS6 and Adobe Photoshop CC were included to generate the wheelchair design with the PSD prescribed.	Inclusion of 70 images (wheelchair types and postural support devices); a classification of the spine levels and pelvic girdle positions were added. We increased data related to the wheelchair records.
V2	10	v2 was tested by nine OTs and one physiotherapist. All had experience of at least 2	The Likert scale scores of the eight categories analyzed showed that all app items had content and	Improved data security of the prescriber; increased data entry about anthropometric measurements of the

Table 2. Continued…

V*	N*	Participant's Description	Results	Examples of changes
		years with WPSD prescription.	presentation with high levels of agreement scored 5 as "strongly agree". Only the items backrest, trunk supports and tables/brackets received score 4 or "agree". These low scores were because: a) it was not clear if there was an option for a modular backrest; b) they found it difficult to see the image of the device when positioned in the wheelchair and c) the item tables/brackets had few choices to mark. All the recommendations were considered for the next prototype.	patient; implementation of the interactive anatomical body image; increased wheelchair specifications; inclusion of metrics for some postural support devices
V3	39	v3 was tested by OTs; 66.6% had at least 2-year experience in WPSD prescription, 7.8% reported little experience and 25.6%, no experience.	The Likert Scale lower percentage of disagreements among participants scored 3 (neutral) for: backrest (2.6%), trunk support (6%); tables/brackets (5.2%), seat (2.6%). Concerning these disagreements, participants pointed more options of manufactured devices. They thought the pictures of trunk support were not very clear to detect its qualities in terms of metrics or size. For tables/brackets, they suggested the option of customization. In the section of cushions, they recommended adding more options of manufactured seats available commercially.	inclusion of more detailed information about postural support devices options to support unexperienced prescribers; inclusion of date, month and year of the prescriptions; improvement in control buttons
V4	4	v4 was tested by four OTs in a focus group. They had at least 2-year experience in WPSD prescription.	Participants suggested: 1) adding an option for anamnesis; 2) including the picture of a "body" to record places of deformities in the spine; 3) anthropometric measurements easy to be seen while performing the prescription; 4) making available the progress of the app assessment, i.e., indicating the progression of its completion; 5) improving the possibility of combining devices, for example, to prescribe 3 types of seat belts; 6) adding a box to inform the density of the foam; 7) allow checking the entire prescription prior to exporting the final PDF document.	inclusion of a descriptive section for anamnesis and for the patient's medical records; a space to upload images of the patient; inclusion of goniometric measurements for angles and joints; availability of the patient's summary form; interaction with the database of the international classification of diseases (ICD); implementation of the database to start the artificial intelligence tests of the system.

Caption (*)= version of the prototype/ (N)= sample

STAGE 3 - Usability of the e-Seating App by TE

The results of stage 3 are shown in Figure 3. In test 1, two experts pointed out two catastrophic problems related to "feedback". Major problems could be identified for "simple dialogue", "consistency", "error messages" and "error prevention". For Test 2, catastrophic problems can be observed in the items "user memory", "error prevention"

and "help and documentation". However, major problems were reported for "feedback", "clearly marked exits", "error messages and prevention" and "help and documentation". From this process, we improved the "combox" configurations; adequacy of the "radio-buttons"; limitation of numerical data; uniform font size; interface adjustments and increased notifications for the user.

Based on the results of tests 1 and 2, the final v7(final) of the App improved in the following aspects: smartness, increasing the dialog and feedback with the user (practitioner). The usability tests of the system showed that some items needed to be improved (user memory, help with error prevention and data storage). These were recognized as critical points related to the interaction of the system with the user. In addition, this final stage results in improving database storage; adequacy of flow diagram; increase the number of feedbacks to users of the App and improvement of resources: Create, Read, Update and Delete (CRUD) (Carvalho & Mello, 2011).

For test 2, all the suggestions made after test 1 were implemented, and then prototype v6 was reapplied by two (n=2) TEs in usability; an information systems engineer and a software engineering operative. The results demonstrated that feedback, user language, shortcuts, and consistency functionality improved, while aspects regarding user memory, error prevention, and help documentation worsened. Figure 3 represents a histogram with comparative results between the usability test for tests 1 and 2.

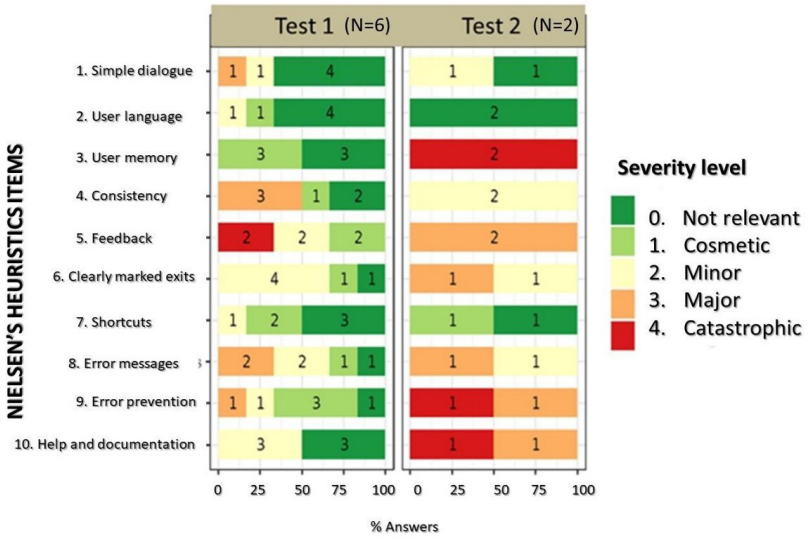

Figure 3. Comparative results of usability between test 1(n=6) and test 2 (n=2).

Finally, the app was developed, and there is a demo video of the final version of the e-Seating (Youtube, 2024).

Discussion

Our study presented the three stages of development and usability of the e-Seating App.

In Stage 1, our findings showed that the practitioners had continuous education and clinical practice, which are considered essential elements in several studies of WPSD prescription (Campos, 2013; Toro et al., 2017; Routhier et al., 2019). Regardless of the experience, those practitioners did not seem to have standard procedures, as we observed that they reported using different tools and assessments; this suggested the need of Guidelines to address the fundamental requirements for best practices in AT services for seating & positioning.

Fostering a standardized terminology is a key issue for communication among practitioners, technicians and users. In our research, the technicians complained about clarity in the prescriptions made by the practitioners in terms of terminology and metrics. They also reported the divergence of prescriptions which were often opposed to the desires or expectations of users and their families; a fact corroborated by the significant technology abandonment (Mortenson et al., 2007; Cherubini & Melchiorri, 2012; Cruz et al., 2016; Fung et al., 2017).

The lack of standardization concerning identification of PSD is discussed in several studies (Handa & Hirose, 2011; Furui et al., 2016). The ISO 16840 standards attempt to establish a uniform terminology between the wheelchair seating industry and the terminology adopted by the prescribers; some studies propose integrating this information to facilitate the prescription of PSD (International Organization for Standardization, 2006; Waugh & Crane, 2013; International Organization for Standardization, 2014).

The uniform terminology provided by the research on e-Seating development was an important step in clarifying the language used in the prescription stage (Pearlman et al., 2006; Larsson Ranada & Lidström, 2019).

We expect these features of the e-Seating App can increase communication between practitioners and users once there is evidence that prescribers may not consider a client's choices when prescribing mobility devices and/or after the product is delivered (Mortenson et al., 2007; Gowran et al., 2014; McClammer et al., 2024). Our qualitative results, based on users' dissatisfaction, showed that their participation is critical when choosing the assistive devices.

Studies conducted in Canada demonstrate the importance of wheelchair users' participation using mobile technology. The first one aimed to know the places to which a community of individuals with disabilities goes using their mobility devices; the barriers and facilitators they faced and features of accessibility of the environment (Routhier et al., 2019). Specifically, data about places were gathered using the global positioning system and diaries. These methods allowed the researchers to identify problems and solutions for mobility device users to participate in their communities. The other study found that a program of Physical Activities named Smartphone Peer Physical Activity Counseling for Manual Wheelchair Users had benefits, such as reducing the burden on health care, and compensating for barriers such as transportation and costs (Best et al., 2017).

At Stage 2, all prescribers' main suggestions related to making the app easier to understand, for example, using images for describing the device and the number of other options available. At the end of this stage, we found that v4 had the complete content to be used as an assessment and prescription of WPSD, thereby replacing the use of printed forms and offering a faster technological prescription (Oderud et al., 2006).

Nonetheless, only at the final Stage 3 was the app tested with technology experts to add more "feedback" to prescribers and to demonstrate greater data storage security, an important ethical detail which may impact the decision to use mHealth in clinical practice. The results from this stage corroborate our study in identifying the need to find ways to evaluate health Apps in terms of data quality, privacy and security (Stoyanov et al., 2015).

In our app system, feedback from the prescribers seems to suggest that greater assertiveness is needed in the final prescription because its algorithm accounts for the incidence of the devices prescribed according to each diagnosis. Experiments have shown that the machine learning model developed for specific populations is effective for better scientific evidence in the medical field (Pande et al., 2016; Liu, 2018).

Finally, our app presents a smart and sequential assessment model, with illustrations of wheelchair and postural support devices, and a suggestive intelligence component that can give practitioners feedback when they choose a specific device. In spite of its features, the app did not fill the gap in training professionals to work with WPSD and there are several studies supporting the impact of professional training services on the good practices of prescriptions (Oderud et al., 2006; Bray et al., 2014; Fung et al., 2017; Bazant et al., 2017; Pontes et al., 2021).

Our study presents several limitations, such as the only language available at the moment being Brazilian Portuguese. There is also a need to test the App database to maximize its artificial intelligence; for example, when the practitioner completes the measurements, the app could automatically suggest possible commercial wheelchair availability. Future studies testing the app with practitioners in the course of their work could lead to new features and improvements to give e-Seating more usability (Klein et al., 2023).

Conclusion

Our study defined a uniform terminology; identified and recommended a framework for prescription based on tripartite considerations: on the practitioners, technicians and WPSD users; and documented a method to create a mHealth which can have reproducibility in the international community with interests in AT assessment, using technology; a decidedly new trend in the era of the fourth industrial revolution.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. Special thanks are due to undergraduate internship students and to and to John Lenon Couto and Phd Sandra Mara Meireles.

References

Aissaoui, R., Lacoste, M., & Dansereau, J. (2001). Analysis of sliding and pressure distribution during a repositioning of persons in a simulator chair. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *9*(2), 215-224. http://doi.org/10.1109/7333.928581.

Bazant, E. S., Himelfarb Hurwitz, E. J., Onguti, B. N., Williams, E. K., Noon, J. H., Xavier, C. A., Garcia, F. D., Gichangi, A., Gabbow, M., Musakhi, P., Kirby, R. L. (2017). Wheelchair services and use outcomes: a cross-sectional survey in Kenya and the Philippines. *African Journal of Disability*, *6*(1), 1648.

Best, K. L., Routhier, F., Sweet, S. N., Arbour-Nicitopoulos, K. P., Borisoff, J. F., Noreau, L., & Martin Ginis, K. A. (2017). The Smartphone Peer Physical Activity Counseling (SPPAC) program for manual wheelchair users: protocol of a pilot randomized controlled trial. *JMIR Research Protocols*, *6*(4), e69. http://doi.org/10.2196/resprot.7280.

Bray, N., Noyes, J., Edwards, R. T., & Harris, N. (2014). Wheelchair interventions, services and provision for disabled children: a mixed-method systematic review and conceptual framework. *BMC Health Services Research*, *14*(1), 309. http://doi.org/10.1186/1472-6963-14-309.

Campos, M. A. A. D. (2013). Cadeira de rodas e acessórios para adequação postural na paralisia cerebral: uma análise documental. *Cadernos de Terapia Ocupacional da UFSCar*, *21*(1), 43-49. http://doi.org/10.4322/cto.2013.007.

Caro, C. C., & Cruz, D. M. C. (2020). A mobilidade funcional com cadeiras de rodas em sujeitos com lesão medular. *Cadernos Brasileiros de Terapia Ocupacional*, *28*(4), 1133-1150. http://doi.org/10.4322/2526-8910.ctoAO1984.

Carvalho, B. V., & Mello, C. H. P. (2011). Scrum agile product development method-literature review, analysis and classification. *Product: Management & Development*, *9*(1), 39-49. http://doi.org/10.4322/pmd.2011.005.

Cherubini, M., & Melchiorri, G. (2012). Descriptive study about congruence in wheelchair prescription. *European Journal of Physical and Rehabilitation Medicine*, *48*(2), 217-222.

Cook, A. M., & Polgar, J. M. (2015). Seating systems as extrinsic enablers for assistive technology. In A. M. Cook & J. M. Polgar (Eds.), *Assistive technologies: principles and practice* (pp. 2-15). St. Louis: Elsevier.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research.* Thousand Oaks: SAGE Publications.

Cruz, D. M., Emmel, M. G., Manzini, M. G., & Braga Mendes, P. V. (2016). Assistive technology accessibility and abandonment: challenges for occupational therapists. *The Open Journal of Occupational Therapy*, *4*(1), 1-9. http://doi.org/10.15453/2168-6408.1166.

Frost, S., Mines, K., Noon, J., Scheffler, E., & Stoeckle, R. J. (2012). *Wheelchair service training package: basic level.* Geneva: WHO. Retrieved in 2024, May 27, from https://www.who.int/publications/i/item/9789241503471

Fung, K. H., Rushton, P. W., Gartz, R., Goldberg, M., Toro, M. L., Seymour, N., & Pearlman, J. (2017). Wheelchair service provision education in academia. *African Journal of Disability*, *6*, 1-8. http://doi.org/10.4102/ajod.v6i0.340.

Furui, T., Handa, T., Fujino, F., Nishinohara, T., Yamada, H., Fujihiira, Y., Oka, K., Nomura, M., & Kameoka, C. (2016). Benefit of "rysis": a wheelchair seat posture measurement based on ISO 16840-1. *Journal of Osaka Kawasaki Rehabilitation University*, *10*, 59-72.

Gowran, R. J., McKay, E. A., & O'Regan, B. (2014). Sustainable solutions for wheelchair and seating assistive technology provision: presenting a cosmopolitan narrative with rich pictures. *Technology and Disability*, *26*(2-3), 137-152. http://doi.org/10.3233/TAD-140408.

Handa, T., & Hirose, H. (2011). Development and evaluation of seated postural measurement software enabling application of the ISO 16840-1 standard in a clinical setting. *Assistive Technology Research Series*, *28*, 16-26. .

Hastings, J. D., Fanucchi, E. R., & Burns, S. P. (2003). Wheelchair configuration and postural alignment in persons with spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, *84*(4), 528-534. http://doi.org/10.1053/apmr.2003.50036.

Hatta, T., Nishimura, S., Inoue, K., Yamanaka, M., Maki, M., Kobayashi, N., Kishigami, H., & Sato, M. (2007). Evaluating the relationships between the postural adaptation of patients with profound

cerebral palsy and the configuration of the Seating Buggy's seating support surface. *Journal of Physiological Anthropology*, *26*(2), 217-224. http://doi.org/10.2114/jpa2.26.217.

Hosking, J. (2024). Impact of wheelchair seating systems on scoliosis progression for children with neurologic and neuromuscular disorders: a retrospective study of custom-contoured wheelchair seating and modular wheelchair seating. *Archives of Physical Medicine and Rehabilitation*, *105*(10), 1921-1929. http://doi.org/10.1016/j.apmr.2024.06.007.

International Organization for Standardization – ISO. (2006). *ISO 16840: wheelchair seating, section 1 - vocabulary, reference axis convention and measures for body posture and postural support surfaces*. Retrieved in 2024, May 27, from https://www.iso.org/obp/ui/en/#iso:std:iso:16840:-1:ed-1:v1:en

International Organization for Standardization - ISO. (2014). *ISO 16840: wheelchair seating, section 3 - determination of static, impact and repetitive load strengths for postural support devices*. Retrieved in 2024, May 27, from https://www.iso.org/obp/ui/en/#iso:std:iso:16840:-3:ed-3:v2:en

International Society of Wheelchair Professionals (2016). Retrieved in 2024, May 27, from https://iswp.org/

Jhpiego Corporation. (2015). *Phase one desk review: research study of wheelchair and wheelchair services provision in low-resource settings*. Retrieved in 2024, May 27, from https://www.jhpiego.org/about/annual-reports/

Kenny, S., & Gowran, R. J. (2014). Outcome measures for wheelchair and seating provision: a critical appraisal. *British Journal of Occupational Therapy*, *77*(2), 67-77. http://doi.org/10.4276/030802214X13916969447119.

Khasnabis, C., & Mines, K. (2013). *Wheelchair service training package: intermediate level.* Geneva: WHO. Retrieved in 2024, May 27, from https://www.who.int/publications/i/item/9789241505765

Kirby, R. L., & Doucette, S. P. (2019). Relationships between wheelchair services received and wheelchair user outcomes in less-resourced settings: a cross-sectional survey in Kenya and the Philippines. *Archives of Physical Medicine and Rehabilitation*, *100*(9), 1648-1654.e9. http://doi.org/10.1016/j.apmr.2019.02.002.

Klein, A. N. (2020). *Instruments of data collection for the development and usability of the eSeating App: a tool for wheelchair and postural support devices prescription.* Retrieved in 2024, May 27, from https://github.com/eseating/EasySeating/releases/tag/files

Klein, A. N., & Lopes, R. D. (2018). App for the seating devices prescription process. In *Annals of proceedings of Rehabilitation Engineering and Assistive Technology of North America - RESNA Annual Conference*. Retrieved in 2024, May 27, from https://www.resna.org/sites/default/files/conference/2018/wheelchair_seating/Klein.html

Klein, A. N., Gradim, L. C. C., Santana, A. L. M., Moreira, A. L. C. S., Ficheman, I. K., & Lopes, R. D. (2023). e-Seating - aplicativo para apoiar o processo de avaliação e prescrição de cadeira de rodas e dispositivos de adequação postural: avaliação da experiência do usuário. *Acta Fisiátrica*, *30*(4), 251-259. http://doi.org/10.11606/issn.2317-0190.v30i4a211806.

Lange, M. L., & Minkel, J. (2017). *Seating and wheeled mobility: a clinical resource guide*. London: Routledge.

Larsson Ranada, Å., & Lidström, H. (2019). Satisfaction with assistive technology device in relation to the service delivery process: a systematic review. *Assistive Technology*, *31*(2), 82-97. http://doi.org/10.1080/10400435.2017.1367737.

Lefevre, F., & Lefevre, A. M. (2010). *Pesquisa de representação social: um enfoque qualiquantitativo.* Brasília: Líber Livro Editora.

Liu, L. (2018). Occupational therapy in the Fourth Industrial Revolution. *Canadian Journal of Occupational Therapy*, *85*(4), 272-283. http://doi.org/10.1177/0008417418815179.

Mays, N., & Pope, C. (2000). Qualitative research in health care. Assessing quality in qualitative research. *BMJ (Clinical Research Ed.)*, *320*(7226), 50-52. http://doi.org/10.1136/bmj.320.7226.50.

McClammer, C., Choma, E. A., Schein, R. M., Schmeler, M. R., Pramana, G., Gliniak, J., & Morrow, C. (2024). Telerehabilitation for new wheelchair evaluations: a retrospective study of patient

characteristics. *International Journal of Telerehabilitation*, *16*(1), 1-9. http://doi.org/10.5195/ijt.2024.6630.

McLaughlin, J. E., Wolcott, M. D., Hubbard, D., Umstead, K., & Rider, T. R. (2019). A qualitative review of the design thinking framework in health professions education. *BMC Medical Education*, *19*(1), 98. http://doi.org/10.1186/s12909-019-1528-8.

Mortenson, W. B., Miller, W. C., & Miller-Pogar, J. (2007). Measuring wheelchair intervention outcomes: development of the wheelchair outcome measure. *Disability and Rehabilitation. Assistive Technology*, *2*(5), 275-285. http://doi.org/10.1080/17483100701475863.

Murphy, E., Dingwall, R., Greatbatch, D., Parker, S., & Watson, P. (1998). Qualitative research methods in health technology assessment: a review of the literature. *Health Technology Assessment*, *2*(16), 3-274. http://doi.org/10.3310/hta2160.

Nielsen, J. (2012). *How many test users in a usability study?* Retrieved in 2024, May 27, from https://www.nngroup.com/articles/how-many-test-users/

Oderud, T., Jensen, J. S., Lyimo, J. E., Munish, A., & Shunda, P. (2006). User satisfaction survey: an assessment study on wheelchairs in Tanzania. In *Report of a Consensus Conference on Wheelchairs for Developing Countries* (pp. 112-117). Geneva: WHO.

Pande, A., Mohapatra, P., Nicorici, A., & Han, J. J. (2016). Machine learning to improve energy expenditure estimation in children with disabilities: a pilot study in duchenne muscular dystrophy. *JMIR Rehabilitation and Assistive Technologies*, *3*(2), e7. http://doi.org/10.2196/rehab.4340.

Pearlman, J., Cooper, R. A., Zipfel, E., Cooper, R., & McCartney, M. (2006). Towards the development of an effective technology transfer model of wheelchairs to developing countries. *Disability and Rehabilitation. Assistive Technology*, *1*(1-2), 103-110. http://doi.org/10.1080/09638280500167563.

Pontes, F. V., de Miranda Luzo, M. C., da Silva, T. D., & Lancman, S. (2021). Seating and positioning system in wheelchairs of people with disabilities: a retrospective study. *Disability and Rehabilitation. Assistive Technology*, *16*(5), 550-555. http://doi.org/10.1080/17483107.2019.1684580.

Routhier, F., Mortenson, W. B., Demers, L., Mahmood, A., Chaudhury, H., Martin Ginis, K. A., & Miller, W. C. (2019). Mobility and participation of people with disabilities using mobility assistive technologies: protocol for a mixed-methods study. *JMIR Research Protocols*, *8*(4), e12089. http://doi.org/10.2196/12089.

Srivastava, A., Bhardwaj, S., & Saraswat, S. (2017). SCRUM model for agile methodology. In *International Conference on Computing, Communication and Automation* (pp. 864-869). Dehradun: Tula Institute.

Stoyanov, S. R., Hides, L., Kavanagh, D. J., Zelenko, O., Tjondronegoro, D., & Mani, M. (2015). Mobile app rating scale: a new tool for assessing the quality of health mobile apps. *JMIR mHealth and uHealth*, *3*(1), e27. http://doi.org/10.2196/mhealth.3422.

Toro, M. L., Bird, E., Oyster, M., Worobey, L., Lain, M., Bucior, S., Cooper, R. A., & Pearlman, J. (2017). Development of a wheelchair maintenance training programme and questionnaire for clinicians and wheelchair users. *Disability and Rehabilitation. Assistive Technology*, *12*(8), 843-851. http://doi.org/10.1080/17483107.2016.1277792.

Vicsek, L. (2007). A scheme for analyzing the results of focus groups. *International Journal of Qualitative Methods*, *6*(4), 20-34. http://doi.org/10.1177/160940690700600402.

Waugh, K., & Crane, B. (2013). *A clinical application guide to standardized wheelchair seating measures of the body and seating support surfaces.* Denver: University of Colorado. Retrieved in 2024, May 27, from https://www.ncart.us/uploads/userfiles/files/documents/GuidetoSeatingMeasuresRevisedEdition_November2013-compressed.pdf

World Health Organization – WHO. World Bank. (2011). *World report on disability 2011.* Geneva. Retrieved in 2024, May 27, from https://www.who.int/teams/noncommunicable-diseases/sensory-functions-disability-and-rehabilitation/world-report-on-disability

Youtube. (2024). *e-Seating Demo Video*. Retrieved in 2024, May 27, from https://www.youtube.com/watch?v=J35goxImByI

Author's Contributions

Adriana Klein, Marcelo Archanjo, Rodrigo Suigh and Roseli de Deus Lopes were responsible for conceiving the article. All authors approved the final version of the text.

Data Availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Funding Source

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

Corresponding author

Adriana Klein
e-mail: adinaklein23@gmail.com

Section editor

Prof. Dr. Daniel Marinho Cezar da Cruz

Supplementary Material

Supplementary material accompanies this paper.

Supplementary Material S1. Questionnaires.

This material is available as part of the online article from https://doi.org/10.1590/2526-8910.ctoAO397737882