REVISTA DE ENFERMAGEM REFERÊNCIA
homepage: https://rr.esenfc.pt/rr/
ISSNe: 2182.2883

RESEARCH ARTICLE (ORIGINAL)

Functionality and learning of a post-infarction rehabilitation device: The perspective of rehabilitation nurses

Funcionalidade e aprendizagem de um dispositivo de reabilitação para doentes pós-enfarte: Perspetiva de enfermeiros de reabilitação

Funcionalidad y aprendizaje de un dispositivo de rehabilitación para pacientes que han sufrido un infarto: Perspectiva de los enfermeros de rehabilitación

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Abstract

Background: Cardiovascular diseases are one of the leading causes of death and disability in Portugal. The development of rehabilitation devices is crucial for the promotion of functional recovery.
Objectives: To describe the two Ablefit prototypes in terms of functionality and learning for post-infarction patients.
Methodology: Qualitative research using focus groups. A convenience was composed of nurse specialists in rehabilitation.
Results: The study included 16 participants. The prototypes are distinct in functionality: the beta allows for greater resistance variation and progressive exercise programs. The biofeedback feature allows adapting the program to the user and facilitates returning home. The cycloergometer for the lower limbs included in the alpha is a significant advantage and should be improved.
Conclusion: The alpha prototype has fewer functional characteristics and lower ease of use than the beta, limiting the variety of exercise resistance and being incapable of monitoring physiological parameters. The biofeedback feature should be explored in future prototypes.

Keywords: rehabilitation nursing; myocardial infarction; cardiac rehabilitation; technological development and innovation projects

Resumo

Enquadramento: A patologia cardiovascular constitui uma das principais causas de morte e incapacidade em Portugal. Para a promoção da recuperação funcional da pessoa, o desenvolvimento de dispositivos de reabilitação é uma prioridade importante.
Objetivos: Descrever dois protótipos do *Ablefit* a nível da funcionalidade e aprendizagem para doentes pós-enfarte.
Metodologia: Investigação qualitativa com recurso a grupos focais. Foram recrutados enfermeiros especialistas em reabilitação por amostragem de conveniência.
Resultados: Foram incluídos 16 participantes no estudo. Os protótipos são funcionalmente distintos, possibilitando o *beta* maior variação de resistência e introdução de progressão a nível do programa de exercícios. A função de *biofeedback* introduzida posteriormente permite adaptação do programa e facilita o regresso a casa. A cicloergometria para membros inferiores incluída no *alfa* é uma vantagem significativa e deverá ser melhorada.
Conclusão: O protótipo *alfa* apresenta menos características funcionais e facilidade de aprendizagem que o *beta*, sendo limitativo na modulação da resistência dos exercícios, bem como na incapacidade de monitorizar os parâmetros fisiológicos. Recomenda-se explorar a funcionalidade de *biofeedback* em futuros protótipos.

Palavras-chave: enfermagem em reabilitação; infarto do miocárdio; reabilitação cardíaca; projetos de desenvolvimento tecnológico e inovação

Resumen

Marco contextual: La patología cardiovascular es una de las principales causas de muerte y discapacidad en Portugal. Para promover la recuperación funcional de la persona, el desarrollo de dispositivos de rehabilitación es una prioridad importante.
Objetivos: Describir dos prototipos del *Ablefit* sobre la funcionalidad y el aprendizaje para pacientes que han sufrido un infarto.
Metodología: Investigación cualitativa mediante grupos de discusión. Los enfermeros especializados en rehabilitación fueron seleccionados por muestreo de conveniencia.
Resultados: Se incluyeron dieciséis participantes en el estudio. Los prototipos son funcionalmente diferentes, lo que permite a *beta* tener una mayor variación de resistencia e introducir la progresión en el programa de ejercicios. La función de *biofeedback* introducida posteriormente permite la adaptación del programa y facilita el regreso a casa. La cicloergometría para los miembros inferiores incluida en *alfa* es una ventaja significativa y debe mejorarse.
Conclusión: El prototipo *alfa* tiene menos características funcionales y facilidad de aprendizaje que el *beta*, y es limitativo en la modulación de la resistencia a los ejercicios, así como en la incapacidad de monitorizar parámetros fisiológicos. Se recomienda explorar la funcionalidad de *biofeedback* en futuros prototipos.

Palabras clave: enfermería en rehabilitación; infarto del miocardio; rehabilitación cardiaca; proyectos de desarrollo tecnológico e innovación

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Received: 25.02.21
Accepted: 27.07.21

How to cite this article: Bernardes, R. A., Parreira, P. M., Salgueiro-Oliveira, A., & Cruz, A. G. (2022). Functionality and learning of a post-infarction rehabilitation device: The perspective of rehabilitation nurses. *Revista de Enfermagem Referência*, *6*(1), e21032. https://doi.org/10.12707/RV21032

Introduction

According to the Directorate-General of Health (DGS), circulatory system diseases account for about 44% of deaths in Portugal (DGS, 2017). In particular, acute myocardial infarction (MI) is a pathology with a mortality rate between 17% and 45% in patients admitted to hospitals and is the cause of several functional limitations. Cardiac rehabilitation (CR) in the form of cardiac rehabilitation programs (CRP) is essential for the treatment of cardiovascular diseases to promote greater autonomy and functional capacity. In this sense, and to make health care more effective, as well as to fight against the effects of bed resting and/or inactivity, recent innovations in the health area can improve the quality of care, making nursing more capable and proficient in the use of new technologies (Brysiewicz et al., 2015). In rehabilitation, there has been an increase in the development of support devices that improve physical activity, although many have huge limitations with unsatisfactory effectiveness (Qian & Bi, 2014).

The device in question is Ablefit, which is attached to the bed feet or headboard, allowing active/passive mobilizations of the upper and lower limbs while in bed. Currently, there are two functionally different prototypes. The alpha has important portability features, like easy assemblage and storage. It consists of a simple system of pulleys, allowing for several exercises to be performed at the upper limp level. For the lower limbs, a cycloergometer can be used. The beta prototype can provide real-time biofeedback and quantify the strength, time, and intensity of the exercises by sending the data to an associated computer. It includes elastic bands with different resistances, favoring the progression of the exercise program. The cycloergometer was not included in the design of this prototype.

Given that there is a significant decrease in functional status and quality of life in the first phase of CRP, this research aims to describe the two Ablefit prototypes in terms of functionality and learning for post-infarction patients undergoing the first phase of a CRP, also taking into account the perspective of rehabilitation nurses.

Background

The American Heart Association indicates that the prevalence of cardiovascular diseases, particularly acute MI, stroke, and hypertension, in adults over 20 years of age is around 48% (Virani et al., 2020). In Portugal, circulatory system diseases constitute about 44% of the total causes of death (DGS, 2017). Acute MI is the cardiac pathology with the highest number of hospitalizations after ischemic stroke and heart failure – about 11500 per year – with a favorable evolution in the number of deaths over the years – currently with an average of 849 deaths/year.

Clinically, acute MI can be defined as a syndrome resulting from structural and functional disorder in the myocardium, with rapidly developing signs and symptoms, impairing ventricular filling and blood ejection (Zakeri & Cowie, 2018).

The initial assessment of the rehabilitation nurse from a perspective of prevention of complications should focus on the patient's tolerance to activity and knowledge about mobility before the disease (Potter & Perry, 2018). Thus, in inpatient settings, the assessment of mobility should encompass the patient's coordination and static and dynamic balance, especially when the patient is already able to walk. Seeking to anticipate the patient's inclusion in a CRP, rehabilitation nurses should also, as soon as possible, assess the patient's ability to perform the activities of daily living and the suitability to participate in an exercise program (Potter & Perry, 2018).

The first phase of CR – the hospital phase – corresponds to the hospital stay period and has been shortened over time, mainly because of the increased frequency of percutaneous coronary interventions and also to reduce the damage associated with prolonged rest (Ordem dos Enfermeiros, 2020). The use of medical device-assisted interventions has contributed to this, and their application shows important results in the functional motor recovery of these patients. For bedridden patients with reduced muscle strength in prolonged institutionalization, some conventional rehabilitation programs, such as progressive walking or transfer and resistance training, can be too demanding. The literature reports a 90% dropout rate for this type of rehabilitation program (Brown et al., 2006). Thus, the design of more effective and motivating interventions for the person should be widely considered in rehabilitation nursing practice, mainly through the use of devices that facilitate the person's work, making functional readaptation processes more attractive.

Research question

How do rehabilitation nurses characterize the alpha and beta prototypes of Ablefit in terms of functionality and learning?

Methodology

A qualitative, observational study was carried out using focus groups. Rehabilitation nurses were recruited through the non-probabilistic snowball sampling method. A convenience sample was obtained.

The following inclusion criteria were considered: nurses with at least a Postgraduate Specialization in Rehabilitation Nursing; clinical experience of at least 3 years as generalist care nurses or rehabilitation nurses. Exclusion criteria were: generalist care nurses; previous contact with the device under study (theoretical, due to knowledge of the underlying concept, or practical, due to previous experimentation). Participants considered eligible to be part of the study received all the necessary information to sign the informed consent, which clearly described the purpose of the study, the procedures inherent to the research, and the voluntary nature of participation. Privacy and confidentiality were maintained by using

identification codes in the transcripts corresponding to each participant.
Before contacting the participants, the research team recorded two videos of how each of the Ablefit prototypes works. This device was specifically designed for the rehabilitation of bedridden patients. The alpha prototype integrates a set of removable, versatile, and customizable components, with pulleys that allow controlled mobilizations of the upper limbs, using a single elastic band but without resistance quantification, and a cycloergometer for the lower limbs. The beta prototype is similar to the previous one but with a more rigid structure, in which the pulleys and cycloergometer were replaced by elastic bands with several resistances. A biofeedback system was incorporated, which characterizes the movements made by the person (time, strength, intensity).
The two videos were later edited with a voice-over to describe the actions demonstrated by the video, which facilitated understanding. They were combined into one, with an average duration of 6 minutes. Participants were invited via email, which included consent. Recruitment took place between May and June 2020.
After a positive response and sending the signed consent, an individual email was again sent with a Doodle for the participant to indicate availability for one of three focus groups held in July 2020.
The sessions took place via Zoom and were recorded for later transcription with the permission of those involved. After a brief presentation, the video mentioned above was shown, and then a Google Forms link was sent through Zoom Chat to fill out the sociodemographic questionnaire. The moderators, who had previously studied the script and remained the same throughout the research, guided the discussion with open questions, promoting the participation of all and avoiding eventual "deviations" from the topic, according to the script prepared by the research team. Each session lasted 1 hour on average. Authorization was requested from the Ethics Committee of the Health Sciences Research Unit: Nursing (UICISA: E), and a favorable opinion was obtained (P671-05/2020). Statistical analysis and data processing were performed using the Statistical Package for the Social Sciences (SPSS v25), and content analysis used the ATLAS.ti v7 program, taking into account the assumptions presented by Bardin (2016).

Results

Three focus groups were conducted, the first with 5 nurses, the second with 6 nurses, and the third with 5 nurses, totaling 16 participants (Table 1). Of these, 68.8% (11) were male, with a mean age of 31.38 years (SD = 7.63). Regarding academic training, besides the specialty in Rehabilitation Nursing, 25% (4) had a postgraduate degree, 31.3% (5) a master's degree, 18.8% (3) a doctoral degree, and 6.3% (1) a postdoctoral degree. The majority (75%; 12) worked in public hospital institutions, and the remaining 25% (4) worked in higher education, namely in nursing schools. Of those who worked in public hospital institutions, the units/services varied: intensive medicine 12.5% (2), gastroenterology 6.3% (1), pediatrics 6.3% (1), medical oncology 12.5% (2), internal medicine 25% (4), physical and rehabilitation medicine 6.3% (1) and cardiothoracic surgery 6.3% (1). Regarding the length of professional practice as a nurse, 56.3% (9) had more than 20 years of experience. As rehabilitation specialists, the majority, 37.5% (6), had been practicing between 11 and 20 years.

Table 1

Sample characterization

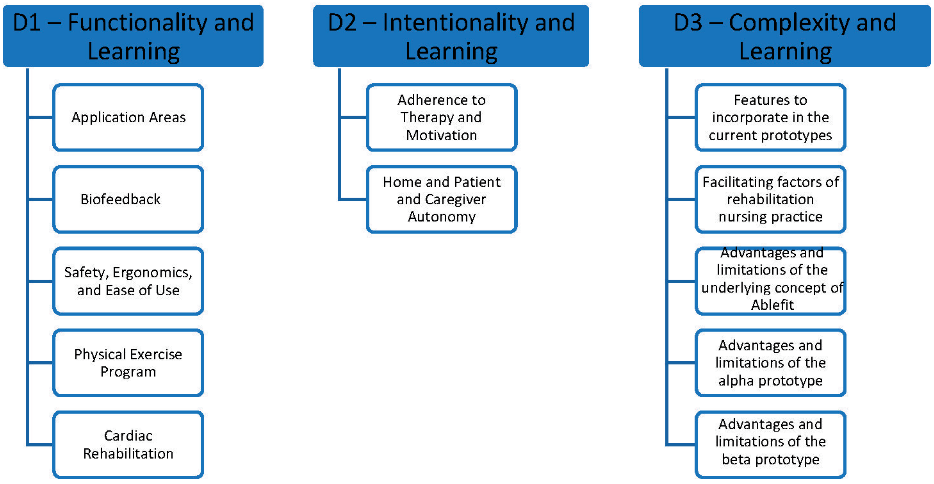
		N	%	*M*	*SD*
Gender	Male	11	69		
	Female	5	31		
	Total	16	100		
Age (years)				31.38	7.63
Academic education	Bachelor's	3	19		
	Post-graduation	4	25		
	Master's	5	31		
	PhD	3	19		
	Post-doc	1	6		
	Total	16	100		
Place of Work	Public Hospital Institution	12	75		
	Higher education	4	25		
	Total	16	100		
Unit/Service	Intensive Medicine	2	13		
	Nursing School	4	25		
	Gastroenterology	1	6		
	Pediatrics	1	6		
	Medical Oncology	2	13		
	Internal Medicine	4	25		
	Physical and Rehabilitation Medicine	1	6		
	Cardiothoracic Surgery	1	6		
	Total	16	100		
For how long have you been working in this unit/service?	≤ 5 years	4	25		
	6–10 years	2	13		
	11–20 years	6	37		
	≥ 20 years	4	25		
	Total	16	100		
Length of professional practice as a nurse	6–10 years	1	6,3		
	11–20	6	38		
	≥ 20 years	9	56		
	Total	16	100		
Length of professional practice as a rehabilitation nurse	≤ 5 years	5	31		
	6–10 years	3	19		
	11–20 years	6	38		
	≥ 20 years	2	12		
	Total	16	100		

Note. M = mean; *SD* = standard deviation

A total of 12 categories emerged from the focus groups. After being related to the empirical results, they generated three major dimensions: Functionality and learning (D1); Intentionality and learning (D2); and Complexity and learning (D3; Figure 1). The first dimension, the object of study in this article, concerns the device's applicability in various contexts, its use, and the type of functionality it allows.

Figure 1

Relation between the analysis categories of the focus groups and the dimensions created



The first dimension comprises the categories *application areas*, *biofeedback*, *safety*, *ergonomics*, *and ease of use*, *physical exercise program*, and *cardiac rehabilitation*.

With regard to the application areas, in general, all participants mentioned that both prototypes studied had a much broader application than cardiac rehabilitation and that it should be developed taking this perspective into account: "In all wards. Whether in medicine, neurosurgery, all of them" (I1.2); "in my opinion, it adapts to the most diverse issues . . . it seems to me that this brings about almost an inner world of capabilities . . . Meaning, if well analyzed and detailed, this is transversal to most of what we want to do in terms of rehabilitation" (I2.1).

Regarding the biofeedback feature of the beta prototype, most participants considered that it should be directed not only at the professional but also at the patient: "Yes, but I think that [patient biofeedback] would be important" (I1. 2); "Not only monitoring by the rehabilitation nurse . . . but also by the patient" (I1.5); "[parameter feedback] for the patient" (I1.6); "it would be interesting if the person doing the exercise, in this case, the patient, could have some feedback at the moment" (I2.1); "I think that the patient needs stimulation and feedback" (I2.5).

Regarding the advantages of the biofeedback incorporated into the system, the nurses identified that it allows for an easier interaction with the patient and the potential caregiver: "And this remote telemonitoring, by the professional, using the informal caregiver as a partner" (I1.3). In addition, real-time visualization allows observing the person's evolution and treatment effectiveness: "It is important to have these parameters . . . so that we can assess and present our evolution" (I1.5); "important for us to monitor the patients' health gains" (I1.1). Regarding which parameters should be assessed during physical exercise, there was a consensus among nurses, who often mentioned the inclusion of vital signs: "besides heart rate, blood pressure, saturation" (P1.1); "I would include the vital signs, especially heart rate" (I1.5); "Heart rate and respiratory rate" (I1.3); "Saturation, too" (I1.6); "Saturation, yes" (I1. 2); "Target heart rate . . . and respiratory rate" (I2.6); "Respiratory rate" (I2.1); "Saturation . . . Then, vital signs . . . for sure, cardiac monitoring would be essential" (I2.2); "We could program for the heart rate, blood pressure" (I2.4); "Oxygen intake" (I3.3); "Blood pressure and heart rate" (I3.5); "Include cardiac monitoring, include saturation and blood pressure" (I3.4).

In addition to the vital signs mentioned above, other parameters relevant to the cardiac area were suggested, such as effort: "A simple instrument is the Borg scale, in which patients can assess their subjective perception of effort. There is the modified Borg scale, which can be quite important for patients to monitor their own effort" (I1.1); "effort rate" (I2.4).

Some nurses reported that biofeedback should use positive stimuli in real time, which are shown to the patient himself/herself: "I think monitoring the evolution and providing feedback is important . . . with a smiling emoji or a pensive emoji or an emoji that represents that more effort is needed" (I1.3).

The incorporation of telemedicine into the device as a way to inform the professional, the patient, and the caregiver was also highlighted: "but telemedicine is necessary" (I1.2).

It is interesting to note that, in addition to the most usual parameters, some nurses identified some that are not so frequent, but that would be important in this context,

such as "joint range of movement" (I2.5) and "chest expansion, lung expansion" (I2.2).
On the topic of safety and ergonomics, a frequent concern emerged with hand and foot supports: "A Velcro boot would be crucial, or something else to promote hygiene, considering the use from different patients " (I1.3); "some kind of Velcro gloves to give more stability . . . and a shoe also with Velcro" (I1.1); "instead of that thing you had for the hands, something more adapted" (I1.2). Regarding safety, reports highlight the device's stabilization on the bed, which was pointed out as a disadvantage of both prototypes: "They presented prototype two with two aluminum bars. Carbon would be lighter" (I1.3); "I think the alpha was a little wobbly and not very stable" (I1.5); "I would reconsider or improve the stabilization process of one and the other" (I1.6). Suggestions were made to enhance safety and comfort for the person: "Is there a way for this to limit loads?" (I1.2), "And create a safety profile or level" (I1.6).
Another important theme among the focus groups was using the device to implement an exercise program. Participants stated that "the difficulty lies in the exercise prescription" (I1.6) because "there are several parameters" (I1.2). The exercise plan prescribed in post-stroke patients, besides monitoring these parameters, should be progressive - "the exercises must be progressive" (I1.5); "the patient would feel these progressive gains" (I1.1). More specifically, they would have to start "eventually with a short period - 5 to 10 minutes - in the first few days. Then we would be able to get into the aerobic part" (I1.1). The role of health education was also highlighted: "We have to play a vital role in teaching physical exercise . . . we have to educate the patient about contraindications" (I1.1).
In the alpha prototype, by not allowing to alter the difficulty in the elastic bands and cycloergometer, movements are "made with a constant resistance, which promotes, in my experience, performing the exercises below the anaerobic threshold" (I2.2). In fact, in the beta prototype, it is not always possible to work in an aerobic context, which may result in disadvantages for the cardiac patient: "I believe that it is an advantage [to work in an aerobic situation] for a patient with acute myocardial infarction, in phase I . . . With the elastic bands, from the start, there will be an increase in resistance at the end of the movement . . . forcing the person to apply greater tension than at the beginning of the movement itself" (I2.2). Despite this, the elastic band may help the patient with their difficulty initiating the movement: "I think the tension of the elastic band is a plus. Why? Usually, patients have difficulty initiating the movement, which is when the elastic band makes less force" (I2.5).
Regarding CR, the participants emphasized that in post-myocardial infarction patients, it is necessary to pay special attention to the intensity and progression of the exercises: "In phase I of cardiac rehabilitation . . . we have to pay attention to the intensity of the exercise" (I1.5); "consider very closely what the resistance of the first elastic band is" (I1.3). It is also essential to adequately monitor these patients, especially during physical exercise: "most of the services that treat phase 1 cardiac rehabilitation require patients to be monitored" (I2.2); "These patients do not exercise without proper monitoring" (I3.4).

Discussion

This study aimed to describe the two Ablefit prototypes on functionality and learning for post-stroke patients undergoing the first phase of a CRP, also taking into account the perspective of Rehabilitation Nurses.
The frequent lack of adherence to CRP encourages the development of alternative approaches, with new forms of active monitoring and surveillance for these patients (Mampuya, 2012).
Although both prototypes were developed to allow for exercise in bedridden patients, this study focused on cardiac patients, considering them as a vulnerable population, particularly in maintaining functional capacity. Indeed, according to Lara et al. (2017), the use of technology is a promising method in RC and should be explored.
The technology developed should be a catalyst for exercise plans incorporated in CRP and support professional practice. According to Claes et al. (2017), exercise-based CR – an objective of the Ablefit project – favors recovery after an episode of cardiovascular disease, with a 15% to 31% reduction in associated mortality.
One of the significant disadvantages of the alpha prototype is that it cannot alter exercise resistance intuitively and easily, unlike beta, which intuitively allows changing elastic bands and enriching the exercise program with different intensities. The literature agrees that it is crucial to design progressive exercise plans to improve a person's functional capacity (Mytinger et al., 2020). Particularly in the case of the cardiac patient undergoing a CRP, the inclusion of exercise with progressive loads has a multiplier effect on functional capacity (Mytinger et al., 2020). Although there is concern that the patient is acutely ill and bedridden and therefore at greater risk when subjected to periods of more or less intense exercise, Zengin et al. (2020) concluded, in an observational study of 100 patients diagnosed with STEMI, that 8 weeks of cardiac rehabilitation produced no significant effect on heart rate (HR) variability, which favors its application.
The use of elastic bands has brought numerous advantages to the plans prescribed with the aim of increasing functional capacity and muscle strength. According to a recent systematic literature review (Lopes et al., 2019), although the effects of using elastic bands in resistance training are similar to the impact of using conventional devices, elastic bands may be more advantageous in terms of the lower acquisition cost, ease of use, and flexibility as to where it can be used. Many focus group participants showed concern about the exercise dynamics generated by elastic bands, mainly because they can lose effectiveness at the end of the movement, influencing the potential of eccentric exercises. In this regard, and according to Suchomel et al. (2019), eccentric muscle actions involve stretching muscle tissue against an external force, as opposed to isometric and concentric actions. According

to these authors, eccentric movements, when compared to the others, have specific muscle responses, including higher force production capacity and lower metabolic cost, which corroborates the concern of the participants to maintain the effectiveness of the exercises with the use of elastic bands.
Participants' most commonly mentioned parameters were vital signs, namely blood pressure, which follows that proposed by Jarvis & Saman (2017), who studied the effects of hypertension and concluded that it produces both hypertrophy and myocardial dysfunction. In phase I of CR, where it is essential to tailor exercise to the person, as indicated by the rehabilitation nurses in the focus groups, biofeedback is a relevant procedure. For Giggins et al. (2013), providing biofeedback to patients and clinicians can have beneficial therapeutic effects, as it allows users to gain control of some physiological processes. Particularly in post-acute MI patients who are more vulnerable and have a lower tolerance to exertion, HR seems to be a determinant, as shown by the results of this study. Nurses were mainly concerned with establishing safety levels.
Regarding the individualization of CRP, applying functional tests seems to be necessary. The participants insisted on including the Borg scale in both prototypes, which is in line with the literature that states that this scale should be used to monitor the subjective intensity perceived by the patient (Mytinger et al., 2020). In addition to the operationalization of the biofeedback parameters, the nurses who participated in the focus groups mentioned the possibility of introducing virtual reality into the device under development. This constitutes an added concern for greater accuracy in controlling physiological variables, which is in line with Chau et al. (2019), who recommend that the development of this type of device focuses primarily on unique functionalities or favors wearable technology.
Some limitations of the study are the inclusion of few cardiac nurses, which may have limited or decreased the variety of suggestions. On the other hand, the fact that the nurses did not practice on the working prototypes may have contributed to a less rich perception. For future research, we propose a more detailed exploration of parameterization with biofeedback in the development of the Ablefit device or other similar devices.

Conclusion

Medical devices developed by nurses are crucial to facilitate recovery and response patterns, allowing the patient to feel connected and involved in his/her own recovery process. The adaptation and customization of this type of device require identifying the strengths and limitations, which will improve future prototypes to be developed, particularly in terms of functionality and learning. In this sense, this study allowed observing that the alpha prototype, compared to the beta prototype, does not allow varying the resistance intuitively and easily, thus making it difficult to use. On the other hand, the beta prototype using elastic bands is advantageous for the intended objectives, facilitating the learning process. Also, biofeedback is an essential function for CR, increasing the functionality provided by the beta prototype, which is a clear limitation of the alpha prototype. On the other hand, both prototypes should improve the hand and foot supports as a safety measure. It can be concluded that both prototypes are functional, thus achieving their purpose, with the beta prototype being more intuitive and promoting faster learning. Furthermore, Ablefit and similar devices are a plus to the practice of rehabilitation nurses, allowing them to design more effective intervention plans in which the person can actively participate.

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Writing – analysis and editing: Bernardes, R. A., Parreira, P. M.

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