Facilitating digital access: Development of an economically viable assistive device to assist people with upper limb dysfunction in the use of smartphones

https://doi.org/10.56238/sevened2024.006-029

Emilly Oliveira Sales[1], Flávio Roberto Pereira Tavares[2], Mário Ferreira Prist[3], Milena do Socorro Pereira Paula[4] and Jorge Lopes Rodrigues Junior[5]

ABSTRACT

Physical disability is the total or partial modification of one or more parts of the human body and directly interferes with physical function. This alteration consists of an impairment in the systems responsible for the body's mobility, which can make the individual depend on the help of other people to perform some activities, directly interfering with their subjective satisfaction. Thus, providing autonomy, within its potentialities, can favor the subject's self-esteem and well-being. Therefore, this research aims to develop a low-cost assistive device to improve the access and usability of smartphones by patients with physical dysfunction, being a qualitative study of a descriptive nature. The device was developed at the Assistive Technology Laboratory of the State University of Pará and its manufacture was divided into six phases. The adapted adaptation offers individuals with upper limb dysfunction a resource that aims at functionality, resistance and economic viability, assisting in the use of the smartphone and facilitating digital access. The importance of considering low-cost materials for the development of assistive devices is evidenced, with a view to democratizing access to assistive technology and resources to facilitate the performance of important activities and occupations.

Keywords: Occupational Therapy, Assistive Technology, Person with Physical Disabilities, Low Cost Technology.

[1] Occupational Therapy student at the University of the State of Pará (UEPA).
[2] Occupational Therapy student at Pará State University (UEPA).
[3] Occupational Therapy student at Pará State University (UEPA).
[4] Occupational Therapy student at Pará State University (UEPA).
[5] PhD in Tropical Diseases from the Federal University of Pará (UFPA).

INTRODUCTION

Occupational Therapy is a health profession defined by the *American Occupational Therapy Association* (AOTA) as the therapeutic use of occupations of daily living, whose objective is to reinforce or enable the participation of people, groups or populations through its services, which are intended for the training, rehabilitation and promotion of the health and well-being of clients with needs, related or not to disability (Gomes; Teixeira; Ribeiro, 2021).

Occupations, also described as a specific client's personalized and meaningful involvement in events of daily life, are a vital part of human development and acquired experience. Therefore, being satisfactorily engaged in important, self-identified life roles promotes the acquisition of a sense of self-efficacy and self-esteem, which can be threatened whenever a person presents with a health disorder, injury, or illness that results in a physical disability (Gomes; Teixeira; Ribeiro, 2021; Trombly; Radomski, 2013).

Physical disability, in turn, is the total or partial modification of one or more parts of the human body and directly interferes with physical function. This alteration consists of an impairment in the systems responsible for the body's mobility, which are the muscular system, the osteoarticular system, and the nervous system. Injuries or pathologies that affect these systems cause physical limitations that can have different degrees and severity (Ministry of Health, 2014). In addition, disability generates inability to perform activities according to the standard expected for human beings, since it compromises structure or function at the psychological, physiological or anatomical level (Brasil, 1999).

Physical disability, being a mobility impairment, can make the person depend on the help of other people to perform some activities, which directly interferes with their subjective satisfaction. Thus, providing autonomy, within its potentialities, can favor the subject's self-esteem and well-being (Oliveira; Paraná, 2021).

Occupational Therapy is based on the belief that meaningful activity (occupation) prevents or mediates dysfunction of physical or psychological origin, so its services include the acquisition and preservation of occupational identity for clients who have or are at risk of developing a disease, injury, dysfunction, condition, disability, disability, limitation in activity, or restriction of participation. Treatment may focus on changing the person's deficient capacities and abilities, guidance on compensatory measures to perform activities and tasks, or changing the physical and social environment, in addition to the use of assistive technology (Gomes; Teixeira; Ribeiro, 2021; Trombly; Radomski, 2013).

Assistive Technology is an interdisciplinary area of knowledge that encompasses products, resources, methodologies, strategies, practices and services that aim to promote functionality, related to the activity and participation of people with disabilities, disabilities or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusionthrough the improvement of communication, mobility and environmental control, as well as learning and work skills (Brasil, 2009; Bersch, 2017).

The Federal Council of Physical Therapy and Occupational Therapy (COFFITO), through Resolution No. 458 of 2015, defines that it is the responsibility of the occupational therapist to prescribe, guide, execute and develop products, resources, methodologies, strategies, practices and services of Assistive Technology within the scope of the training of Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs), aiming to improve the occupational performance of individuals in their daily lives. favoring their physical and mental health, quality of life and social participation (Brasil, 2015).

It is also important to emphasize that rehabilitation is a health process that provides a better quality of life, helping individuals with established disabilities to achieve and maintain higher levels of physical, mental and social functioning. The rehabilitation process emphasizes training in the use of specialized equipment or techniques to promote independence rather than remedying or correcting underlying deficits (Radomski; Trombly, 2013).

The occupational therapy professional, then, plays a key role in the rehabilitation process of individuals facing health challenges, assessing their particular needs and developing personalized treatment plans. Following this model, occupational therapists establish objectives, goals, and intervention strategies to restore the patient's maximum performance in their occupational roles (Pedretti, 2005).

It is in this context, therefore, that this article proposes to present the processes of development and functional analysis of an assistive device for individuals with physical disabilities, to assist in the performance of activities that make up the leisure occupation, in addition to corroborating the certification of the importance of the use of assistive technology by the Occupational Therapy professional.

OBJECTIVES

GENERAL OBJECTIVE

To develop a low-cost assistive device to improve the access and usability of smartphones by patients with physical dysfunction.

SPECIFIC OBJECTIVES

- Describe in detail the production process of an assistive device.
- Underline the importance of considering low-cost materials for the development of devices, aiming to democratize access to assistive technology.

METHOD

This article is a qualitative descriptive one, which seeks to report the step-by-step development of an assistive device that can assist in the autonomy and independence of people with disabilities in their leisure-related activities : namely, the use of the *smartphone*.

The device was made at the Assistive Technology Laboratory (LABTA), located at the State University of Pará (UEPA), from materials such as Polyvinyl Chloride (PVC), Ethylene Vinyl Acetate (EVA), self-adhesive velcros, marker pen, scissors, rivets, contact glue, scissors, mechanical pencil, A3 paper, as well as equipment such as a thermal blower, bench drill and sander and jigsaw. In addition, the Rodrigues technique was used, in which a segment of tubular PVC is opened and modified, through heat, into a plate with a smooth surface (Rodrigues Junior, 2012).

In summary, the preparation was divided into 6 phases: removal of anthropometric measurements, design of the device, PVC cutting and molding, thermomolding, coupling and velcro and EVA lining. These steps will be further described below.

It should also be noted that, in the case of a pilot experiment, all the tests performed for its development were applied to one of the researchers, therefore, it did not require the appreciation of the Research Ethics Committee.

RESULTS

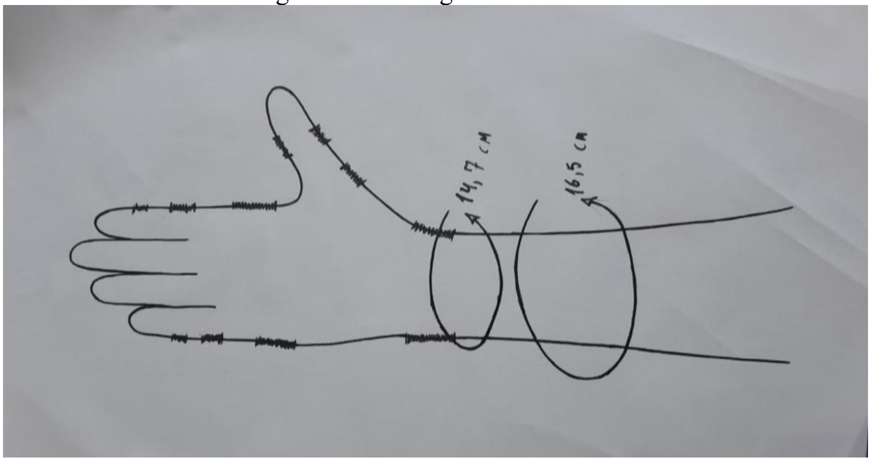
The manufacture of this device added several procedures and actions, requiring scientific knowledge and knowledge of the materials used, their properties and those resulting from the transformation processes to which they were submitted.

Its development and respective stages of production will be described in the following topics, divided for better systematization.

ANTHROPOMETRIC MEASUREMENTS:

Taking accurate measurements of the upper limb involved the use of flexible tape measures to measure the length, circumference, and width of various parts of the limb, including the forearm, wrist, hand, and fingers. These measurements were accurately recorded in order to ensure that the orthosis was manufactured according to the exact dimensions of the subject. In addition, for greater reliability with anthropometric measurements, a drawing of the hand was performed (**Figure 1**), for which it was necessary to position the limb in pronation on an A3 sheet of paper. Then, the alignment of the hand and the drawing of the contour from the apex of the third finger to the proximal third of the forearm followed, finally, delimiting its articular points to provide relief in them.

Figure 1: 2D design of the device.

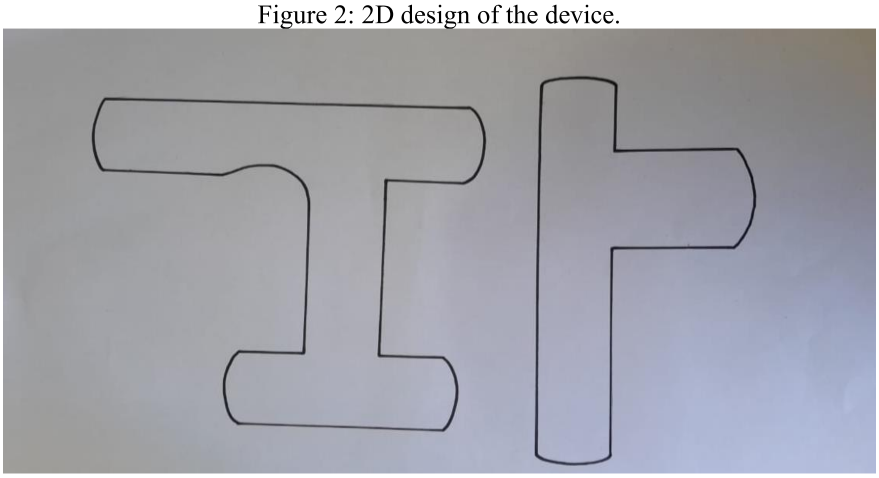


Source: Authors ' Archives

DEVICE DESIGN

Based on the measurements taken, the creative process of developing the design of the device unfolded, considering the desired function. At this time, the objective was to ensure maximum comfort, combined with practicality of use. With the aid of a mechanical pencil, the idea was transcribed into a two-dimensional model, represented on an A3 sheet of paper (**Figure 2**)

Figure 2: 2D design of the device.

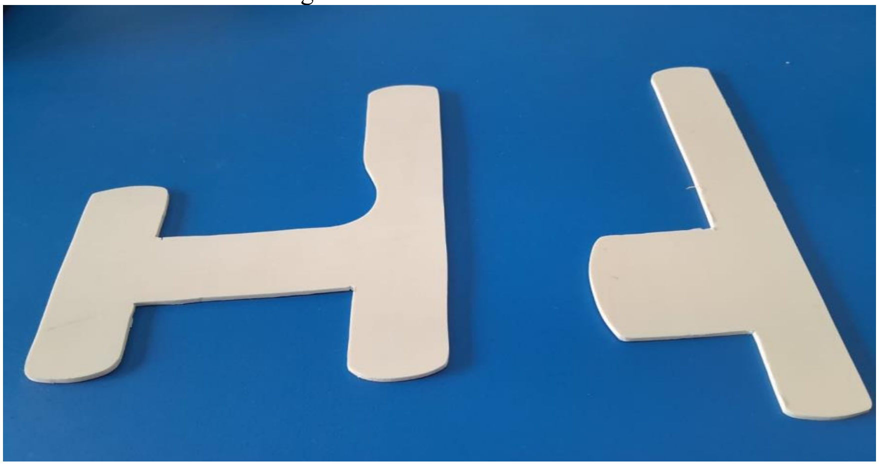


Source: Authors' archives.

PVC MOLD CUTOUT

At this stage, the design was transferred to a 150mm flat PVC board measuring 60x40cm. To cut the sheet, a jigsaw was used, responsible for contouring the limits of the design made on the piece, fixed on a surface by clamps. After that, the ends of the piece were sanded in a bench sander, resulting in a better finish (**Figure 3**).

Figure 3: Cut-out PVC sheets.



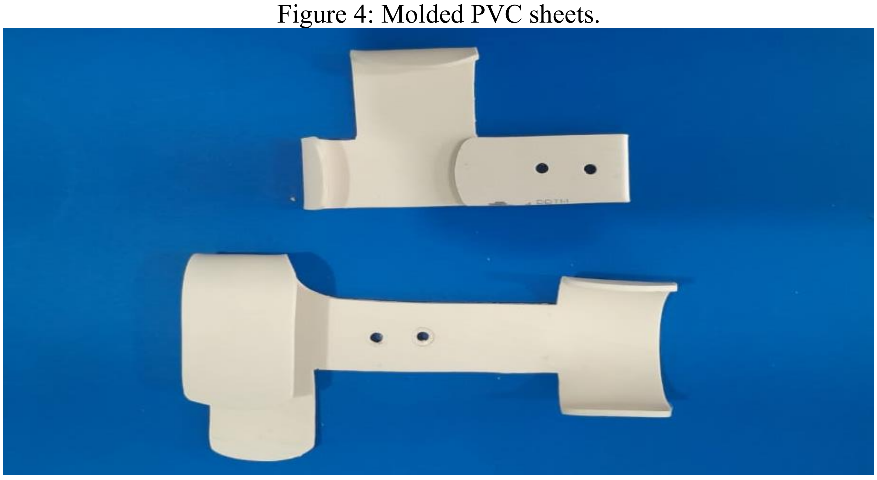
Source: Authors' archives.

THERMOCASTING

The main characteristic of the thermoplastic material is the ability to be repeatedly subjected to the heating process, changing from a solid state to a viscous liquid, and when cooling, returning to a solid state (BRASIL, 2014). Thus, for the molding of the part, the PVC sheet was subjected to heating at a temperature of 100° C, in order to make it malleable and easy plastic deforming, and pressure was applied so that it remained conformed until it cooled, according to the intended shape (**Figure 4**).

It is valid to state that the modeling process was facilitated by the capacity of reversible physical transformation of the chosen material.

Figure 4: Molded PVC sheets.

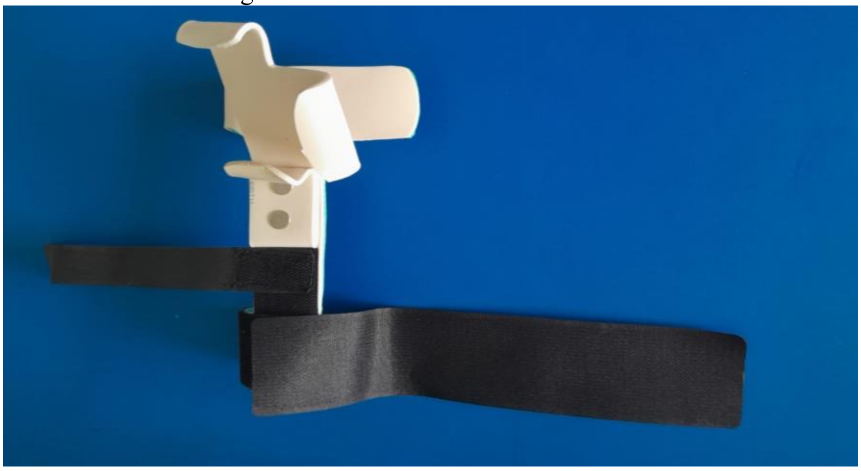


Source: Authors' archives.

COUPLING AND VELCRO

This was followed by the adjustments and addition of the components, the first being the coupling holes of the two PVC pieces, which were joined with two size five rivets. The next step was to fix the self-adhesive rough Velcro on the external areas of the device, while the soft Velcro was positioned facing the internal area, hugging the forearm in the medial third and wrist, allowing adjustment of size, pressure and contributing to comfort (**Figure 5**)

Figure 5: Device with velcro and rivets.



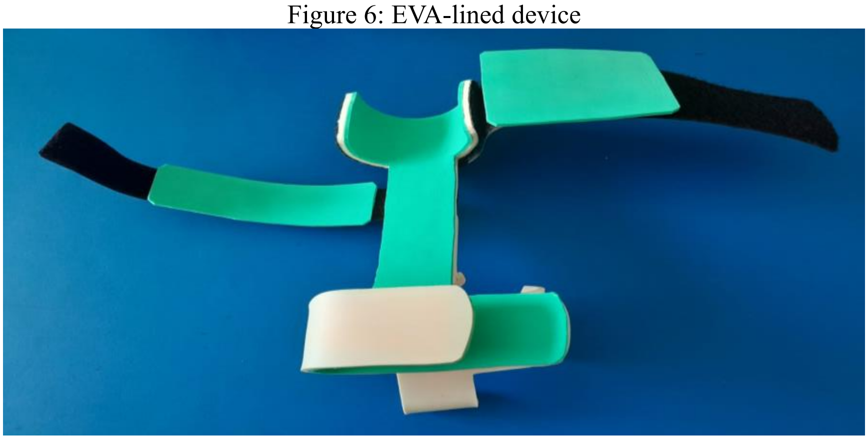
Source: Authors' archives.

EVA LINING

The fodder of the device was carried out using the mold made on paper as a reference for the demarcations in the EVA, with the use of a marker pen. One centimeter of margin was left between the drawing and the cutout to prevent errors in the gluing process. After cutting out the EVA, it was sanded on one of its sides, as well as the inside of the device where the material would be glued, in order to create small cracks that served as an anchor for the glue, ensuring the fixation of the EVA and the durability of the device.

This technique is in agreement with the Ministry of Health (2014) when it says that the use of EVA as an internal lining of orthoses and adaptations promotes the interface between comfort and protection, also allowing safe contact with the skin due to its toxicity (**figure 6**)

Figure 6: EVA-lined device



Source: Authors' archives.

DISCUSSION

For the device, we thought of an adaptation of the hand to the cell phone holder, indicated for individuals with possible loss of muscle strength in the upper limb, reduction of active movement or presence of wrist, hand and finger flexor patterns.

Considering the wide possibility of use of current *smartphones,* due to their continuous development of new functions and services (such as *instant messaging apps* , geolocation, public transport access, social networks, games, distance education, among others), the assistive device was designed with the objective of reducing limitations of use and assisting its handling by people with disabilities. ensuring a higher quality of life, independence, inclusion and social participation.

To this end, the manufacture of the device, composed of two main pieces of PVC, began. The first piece is designed for the insertion of the user's wrist and hand, being coated with EVA for added comfort.

EVA is a copolymer produced from the monomer of vinyl acetate and ethylene, and can assume different characteristics and densities. The traditional application of EVA is in the form of foam, which is achieved from expansion and crosslinking agents, as well as fillers and catalysts (Brasil, 2014).

As for the second piece, it is responsible for connecting the device, presenting an angle of 30° in relation to the first piece and 70° in relation to the support point, directing the screen to the user's face.

It is important to highlight that the use of force and the shape of the grip influence the performance of manual activities and the functionality of using objects with the hands (Paschoarelli *et al*., 2010). Therefore, as the device was developed for people with physical dysfunctions of the upper limb and who are unable to grasp, it makes it possible to support the *smartphone* in the device itself, since it has a coupler that allows the object to be fixed in the hand during its use.

In addition, the device has two adjustable Velcro loops for fixing the arm, aligning the forearm, hand and fingers, allowing their stabilization, preventing the device from sliding or falling during use and favoring the reduction of flexor or extensor patterns, harmful to the body.

It is also necessary to consider that, in the human body, there is a lever system that interferes with movement. The lever is a rigid part that can rotate on a fixed or mobile axis and, in the human body, the bone performs this role, having the function of converting a linear force into a rotational torque (Silva, 2015).

In the development of the device, these concepts were used as the basis for the arrangement and distance between the lever arm, the articular shaft and the power arm, thus allowing to take advantage of the mechanical advantage of the levers to avoid harmful pressure points. This is in line with what Silva (2020) states regarding hand support, which occurs by transferring weight by increasing the support surface of the forearm, using the seesaw balance principle, changing the size of the lever arm for compensation and maintenance of balance.

Another point to highlight is the inclusion of assistive technology in the principles of Universal Design, which is justified by the premise that, in order to achieve functional design for all people, it is necessary to use universal reference measures as a basis. Based on these measures, the necessary adaptations to allow the use of the product by people in different conditions will be made using these same universal measures. This approach ensures that design is accessible and useful to a broad spectrum of users, promoting inclusion and equal access to assistive technologies (Marins, 2011).

In view of this, the docking system for *smartphone* devices was designed taking into account the principles of Universal Design, aiming to maximize its applicability to various people. This means that the design has been designed to be accessible and functional for as many users as possible, regardless of their specific abilities or needs, since, by following these principles, the coupling system promotes inclusivity and accessibility, contributing to a broader and more satisfying user experience for all.

Another important factor is the choice of material for the manufacture of a product, which for Pereira (2017) is essential, as it is what determines a large part of its quality, enables correct functioning, comfort, among other factors depending on the type of product. To choose the right way, some factors need to be taken into account, such as mechanical resistance, functionality, performance, among others, which guarantee the length of the customer's demands.

Low-temperature thermoplastics, such as Ezeform, are an efficient and practical choice in making upper limb orthoses due to their ability to be molded directly onto the patient's body. With a low melting point, these materials allow for a streamlined and fast manufacturing process, resulting in orthotics that fit precisely and comfortably. In addition, the fast cooling and hardening time of thermoplastics ensures practicality in the manufacturing process (Silva, 2013).

PVC has similar characteristics, but has its wide versatility attributed to its ability to adapt to a variety of molding processes. This material can be subjected to different techniques, such as injection, extrusion, calendering, flattening, among others. This processing flexibility allows for the creation of a wide range of products and applications (Silva, 2013).

Both thermoplastics, Ezeform, and PVC have advantageous characteristics in the manufacture of orthoses for upper limbs. While low-temperature thermoplastics stand out for their ability to mold directly onto the patient's body, resulting in precise and comfortable orthotics with a simplified and fast manufacturing process, PVC offers a wide versatility due to its ability to adapt to various molding processes.

A PVC pipe with 6 meters and 150 millimeters in diameter, when submitted to the Rodrigues technique, can take the form of a plate with dimensions of 60 cm x 47 cm x 2.5 mm thick, being ready for molding assistive devices. Using this method, a 6-meter PVC pipe with a price ranging from R$ 133.00 to R$ 214.00 can be converted into 10 plates for the construction of devices. The Ezeform, on the other hand, in its smaller plates 31.4 cm x 46 cm x 1.6 mm, has a price that can vary between 194.00 R$ to 205.00 R$.

In addition, when evaluating the cost-benefit of the materials mentioned, it is possible to make some considerations. PVC pipe offers an economically viable alternative costing approximately between 6.85% and 10.44% of the cost of Ezeform, depending on the exact prices. This means that PVC is about 9 to 15 times cheaper than Ezeform. On the other hand, although Ezeform has a higher cost, its dimensions are already suitable for use, which can save time and effort in the transformation of the material. That is, the choice between materials depends on the specific needs of the project, considering not only the cost but also the time and practicality involved in preparing the material for use in assistive devices.

Thus, in situations where resources are limited, PVC emerges as a practical and affordable alternative for the manufacture of assistive devices. With up to 15 times less cost compared to Ezeform, PVC offers a cost-effective solution that can be essential for organizations and individuals with tight budgets and while it requires an additional transformation process, the potential to convert one PVC pipe into multiple usable boards demonstrates its versatility and adaptability. Therefore, PVC not only represents a financially viable option, but also stands out as a pragmatic choice to maximize available resources and promote accessibility to assistive technology to disadvantaged populations.

CONCLUSION

In view of the analysis presented, we conclude that the development of a low-cost assistive device to improve the access and usability of *smartphones* by patients with physical dysfunction is, in addition to being feasible, crucial to promote the inclusion and autonomy of these individuals. The application of Occupational Therapy combined with Assistive Technology offers a holistic and patient-centered approach, seeking not only to mitigate the limitations imposed by physical disability, but also to promote meaningful engagement in activities of daily living.

The device offers individuals with upper limb dysfunction a resource that aims at functionality, endurance and economic viability, aiding in the use of the *smartphone* and facilitating digital access, so valued in the modern world. The importance of considering low-cost materials for the development of assistive devices is evidenced, with a view to democratizing access to assistive technology and resources to facilitate the performance of important activities and occupations.

When selecting materials, in environments with limited financial resources, it is essential to prioritize the financial aspect, evaluating the cost in relation to the quality and effectiveness of the device. In this scenario, PVC proves to be an economical and efficient choice, enabling the maximization of available resources and access to assistive technology for those who need it most. Thus, investing in the development and dissemination of low-cost assistive devices represents a significant step towards inclusion and improving the quality of life of people with physical disabilities.

Finally, the need for the development of research in this area is highlighted, since this article addressed only a part within the great field of Assistive Technology, describing the manufacture of a specific device and the use of alternative materials.

REFERENCES

1. Brasil. COFFITO. Conselho Federal de Fisioterapia e Terapia Ocupacional. (2015, 20 de novembro). Resolução n. 458 de 20 de novembro de 2015. Dispõe sobre o uso da Tecnologia Assistiva pelo terapeuta ocupacional e dá outras providências. Brasília: Diário Oficial da União. Disponível em: https://www.coffito.gov.br/nsite/?p=3221. Acesso em: 18 abr. 2024.

2. Brasil. (1999, 20 de dezembro). Decreto n° 3298, de 20 de Dezembro de 1999. Regulamenta a Lei n° 7.853, de 24 de outubro de 1989, dispõe sobre a Política Nacional para a Integração da Pessoa Portadora de Deficiência, consolida as normas de proteção, e dá outras providências. Brasília, DF. Disponível em: https://www.planalto.gov.br/ccivil_03/decreto/d3298.htm. Acesso em: 23 de abril de 2024.

3. Brasil, Ministério da Saúde. (2009). Técnico em órteses e próteses. Secretaria de Gestão do Trabalho e da Educação na Saúde. Departamento de Gestão do Trabalho na Saúde. Brasília.

4. Bersch, R. (2017). Introdução à tecnologia assistiva. Porto Alegre: CEDI. Disponível em: http://inf.ufes.br/~zegonc/material/Comp_Sociedade/ZEGONC_Tecnologias_Assistivas_Livro_Introducao_TA.pdf. Acesso em: 18 abr. 2024.

5. Comitê de Ajudas Técnicas. (2009). Tecnologia assistiva. Brasil: CORDE. Disponível em: https://www.mpes.mp.br/Arquivos/Anexos/385c40f5-66aa-42a6-beef-eb7621350f95.pdf. Acesso em: 18 abr. 2024.

6. Gomes, D., Teixeira, L., & Ribeiro, J. (2021). Enquadramento da Prática da Terapia Ocupacional: Domínio & Processo 4ª Edição. Versão Portuguesa de Occupational Therapy Practice Framework: Domain and Process 4th Edition (AOTA - 2020). Politécnico de LeiriaDepartamento de Gestão do Trabalho na Saúde; Brasília: Ministério da Saúde.

7. Marins, S. C. F. (2011). Design universal, acessibilidade e tecnologia assistiva: a formação profissional do terapeuta ocupacional na perspectiva da equidade. Tese de Doutorado. Programa de Pós Graduação em Educação Especial, Universidade Federal de São Carlos. Disponível em: https://repositorio.ufscar.br/bitstream/handle/ufscar/2875/3438.pdf?sequence=1. Acesso em: 25 abril 2024.

8. Oliveira, T. K. P., & Paraná, C. M. de O. B. (2021). Deficiência Física Adquirida e Aspectos Psicológicos: Uma Revisão Integrativa da Literatura. *Revista Psicologia e Saúde*, 13(2), 97–110. Disponível em: https://pssa.ucdb.br/pssa/article/view/1212. Acesso em: 23 de abril de 2024.

9. Paschoarelli, L. C., Campos, L. F., Silva, D. C., Menin, M., & Silva, J. C. P. (2010). Correlação entre forças de preensão humana: aspectos do design ergonômico. *Revista Ação Ergonômica, 5*(3), 8-13. Disponível em: https://revistaacaoergonomica.org/article/627d5d52a95395082a598192. Acesso em: 25 de Abril de 2024.

10. Pedretti, L. W. (2005). *Terapia Ocupacional - Capacidades Práticas para as Disfunções Físicas*. Editora Roca.

11. Rodrigues Júnior, J. L. (2012). Órteses de baixo custo. In: Cruz, Daniel. Órteses para membros superiores. In: CRUZ, Daniel. *Terapia Ocupacional na reabilitação pós Acidente Vascular Encefálico: atividades de vida diária e interdisciplinaridade*. São Paulo: Santos.

12. Trombly, C. A., & Radomski, M. V. (2013). *Terapia Ocupacional para Disfunções Físicas*. 6.ed. São Paulo: Santos Editora.

13. Pereira, A. R. S., et al. (2017). Órtese de punho: materiais e ficha técnica. *Revista Engenharia em Ação UniToledo, 2*(2). Disponível em: http://www.ojs.toledo.br/index.php/engenharias/article/view/2790. Acesso em: 24 abril 2024.

14. Da Silva, I. O., et al. (2020). Confecção de um dispositivo ortótico dinâmico de baixo custo para indivíduos com sequelas medulares de C6 e C7: nova forma de assistência no desempenho das atividades de vida diária. *Revista de Terapia Ocupacional da Universidade de São Paulo, 31*(1-3), 38-45. Disponível em: https://www.revistas.usp.br/rto/article/view/169699. Acesso em: 23 abril 2024.

15. Silva, V. R. (2015). *Cinesiologia e biomecânica*. Rio de Janeiro: SESES. Disponível em: https://www.academia.edu/download/61807732/kupdf.net_livro-completo-cinesiologia-e-biomecanica20200116-69331-10phbx0.pdf. Acesso em: 23 abril 2024.

16. Silva, L. G. D. (2013). Órteses em PVC para membro superior: utilização por terapeutas ocupacionais brasileiros, propriedades físicomecânicas e de toxicidade e desempenhos funcionais e mioelétrico. Disponível em: https://repositorio.ufscar.br/handle/ufscar/6876. Acesso em: 23 abril 2024.