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Benefits of the application of exoskeletons in hand rehabilitation

Beneficios de la aplicación de exoesqueletos en la rehabilitación de la mano

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Abstract

The hand is a complex anatomical and biomechanical functional component, indispensable for performing Activities of Daily Living and which has two primary functions: grasping and touching. Injuries in this anatomical region constitute between 6.6% and 28.6% of the injuries of the musculoskeletal system, being young male patients between 21 and 30 years of age the most affected and the most predominant injuries were fractures, contusions and sprains. Exoskeletons are mechanical and electrical devices with very specific applications in the field of rehabilitation; they contribute to the substitution or potentiation of basic functions of a body segment, thus, exoskeletons become useful to facilitate simple motor activities. The present study sought to determine the benefits of the application of exoskeletons for hand rehabilitation through a literature review of various databases. It was possible to identify that more than half of the articles included in the research describe a benefit in the rehabilitation processes, although there is a lack of quantitative data and anatomical foundations, it is determined a positive factor to include exoskeletons in the rehabilitation practice.

Exoskeletons, Rehabilitation, Hand, Disability

Resumen

La mano es un componente anatómico y biomecánico complejo funcional, indispensable para realizar las Actividades de la Vida Diaria y la cual tiene dos funciones primordiales: la prensión y el tacto. Las lesiones en esta región anatómica constituyen entre el 6,6 y el 28,6% de las lesiones del sistema musculoesquelético, siendo los pacientes hombres jóvenes entre 21 y 30 años de edad los más afectados y las lesiones más predominantes fueron fracturas, contusiones y esguinces. Los exoesqueletos son dispositivos mecánicos y eléctricos con aplicaciones muy específicas en la rama de la rehabilitación, coadyuvan a la sustitución o potencialización de funciones básicas de un segmento corporal, de este modo, los exoesqueletos llegan a ser útiles para facilitar actividades motoras simples. El presente trabajo buscó determinar los beneficios de la aplicación de los exoesqueletos para la rehabilitación de mano mediante una revisión bibliográfica de diversas bases de datos. Se logró identificar que más de la mitad de los artículos incluidos en la investigación, describen existir un beneficio en los procesos de rehabilitación, aunque se carece de datos cuantitativos, y fundamentos anatómicos, se determina un factor positivo incluir a los exoesqueletos en la práctica rehabilitadora.

Exoesqueletos, Rehabilitación, Mano, Discapacidad

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Introduction

The hand is a complex anatomical and biomechanical functional component, indispensable for performing Activities of Daily Living (ADL) and which has two primary functions: grasping and touching. The biomechanical characterization of the grip involves the determination of the different kinematic and dynamic variables that affect its different phases: transport, grip formation and manipulation, as well as their relationship with the anthropometric characteristics of the subject and the object (Vázquez, Díaz, Lázaro, & Guamán, 2021). On the other hand, injuries in this anatomical region constitute between 6.6 and 28.6% of injuries to the musculoskeletal system, with young male patients between 21 and 30 years of age being the most affected (Arroyo & Quinzaños, 2022). Students and housewives account for almost half of the population treated for hand and wrist injuries (Arroyo & Quinzaños, 2022). The most predominant injuries were fractures, contusions, and sprains. In addition to requiring timely specialized treatment to avoid complications and permanent disability (Arroyo & Quinzaños, 2022). The success of hand rehabilitation after impairments depends on timing, intensity, repetition, and frequency, as well as task-specific training. Considering the continuing limitations imposed on therapist-led rehabilitation and the need for better outcomes, robot-assisted rehabilitation has been explored (Haghshenas-Jaryani, Patterson, Bugnariu & Wijesundara, 2020).

Anatomically the hand is part of the upper limb; composed of twenty-seven bones divided into three groups: the carpus made up of 8 bones, the metacarpus of 5 bones and 14 phalanges (Ferrin, et al., 2021) as well as the musculature, tendons, ligaments, nerves and blood vessels (Rodriguez et al., 2020) in carpometacarpal, metacarpophalangeal and interphalangeal joints. Based on the normal anatomy of the hand, the development of technologies has been sought for the efficient development of the mechanical processes of the segment, which contribute to the reduction of injuries and rehabilitation, through devices such as exoskeletons, understood as rigid external structures that incorporate actuators that allow controlled and precise movements as well as sensors that provide movement information related to angle, speed and acceleration (Broche & Torres, 2020).

Can also be defined as devices that dress the human being or a part of his body, with very specific purposes and applications, such as support or enhancement of functionality in subjects that require it. In a very general way it can be said that an exoskeleton is a frame that allows or facilitates the movement of its wearer, it can be made of different materials and are divided into electrical or active and mechanical or passive (Zubizarreta, 2021), the electrical ones have as main function to enhance the strength while the mechanical ones help mainly to redistribute the weight. Among the most common uses of exoskeletons, we can find several activities, such as physical training, military use, transport of heavy materials, rescue, functionality in patients with disabilities and rehabilitation. In the most advanced ones, they make it possible to capture the patient's muscular electrical activity (electromyographic signals) or electroencephalography (EEG), related to the intentionality of the movement (Broche & Torres, 2020). The use of an exoskeleton provides very specific advantages to its user such as: reduced exhaustion, reduced risk of injury, increased functionality and increased work productivity. Rehabilitation medicine is one of the fields with the greatest development in the use of exoskeletons, with the aim of helping in the recovery of lost functionality when possible, otherwise, it seeks to replace it (Zubizarreta, 2021). The designs of hand exoskeletons vary in weight, complexity and total cost, with a unidirectional and bidirectional mechanism, the first is based on the opening or closing of the hand, with active rehabilitation through pneumatic or electrical mechanisms where the patient performs voluntary movements during each activity and the second are passive actuators based on automatic motion control where the therapy is guided in its entirety by the device. Also standing out is the production of mixed exoskeletons that offer greater benefit in rehabilitation (Arias, 2021). In an attempt to provide the user with the full range of motion of the human hand, most of these devices have become bulky and complex and, because of this, are restricted to a single functional activity: opening the hand or pinching (Triolo & BuSha, 2022).

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Theoretical frame

Most of the articles reviewed refer to obtain a positive result for intervention processes and functionality, it is described as in the case of Arias (2021), that the users participating in the study presented some type of injury or it is difficult for them to place the exoskeleton. This suggests that more specific parameters should be established for the anthropometric measurement of the hand structures, in order to increase the benefit of exoskeletons in the rehabilitation area. In addition, it is found in the literature that exoskeletons have direct action in the decrease of local effort, decrease of biomechanical load, increase of cardiac and muscular activity of the antagonist groups. And although there is evidence that demonstrates the benefits, it is found that most research projects do not have quantitative data to validate their results. The present review has implications for the practice of neurological hand rehabilitation and physical therapy, which can be summarized in the following aspects: Towards the implementation of exoskeletons directed to the functionality of fine and gross gripper following trauma or neurological condition in which the role of the physical therapist has to be directed in providing knowledge about the physiology of the hand, the ergonomic requirements of exoskeletons as an approach to the complementation of what can be obtained with the conventional treatment of Physical Therapy and be included in rehabilitation programs. Since the patient's adaptation to exoskeletons may vary depending on the pathology or neurological condition, an individualized evaluation adapted to the patient's needs is required for the design of exoskeletons, which implies the personalization of therapy with the implementation of these devices.

Finally, several suggestions for future work and new hypotheses can be made, such as: long-term studies to measure the results and benefits of using exoskeletons in rehabilitation processes, sustainability evaluations with them, as well as their functional capacity, comparisons between exoskeleton designs with specific features and functions that give us standard implementations for each condition.

Methodology

For the present literature review, a search for articles was conducted in the following databases, Dialnet, Redalyc, PubMed, Google Scholar and Scielo. The following inclusion criteria were applied: published articles that their year of publication was from 2018 to date, included the keywords and descriptors: exoskeleton, rehabilitation, disability, benefits and hand. Randomized clinical trials, meta-analyses, case-controls, cohort studies, systematic reviews, and literature reviews were included in the search. Studies were excluded if their year of publication was less than 2018 and if they did not contemplate the keywords or were not complete or available.

Results

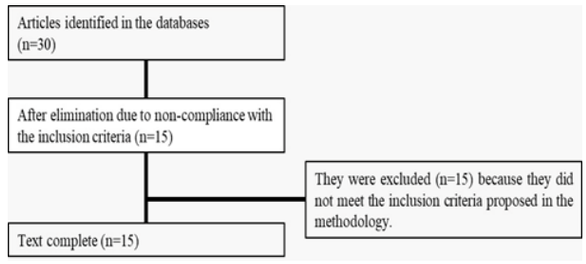

Figure 1 Analysis of articles
Source: Prepared by the authors

After the review of the analyzed literature, it is shown that 47% of the selected articles correspond to the design and development of an exoskeleton prototype for the hand or arm, 33% are experimental studies and the remaining 20% correspond to bibliographic reviews. Of the total of bibliographies, 93.3% of the investigations describe the benefits and functionality of exoskeletons in rehabilitation and the performance of manual activities. Only one article discards the benefits of the use of robots.

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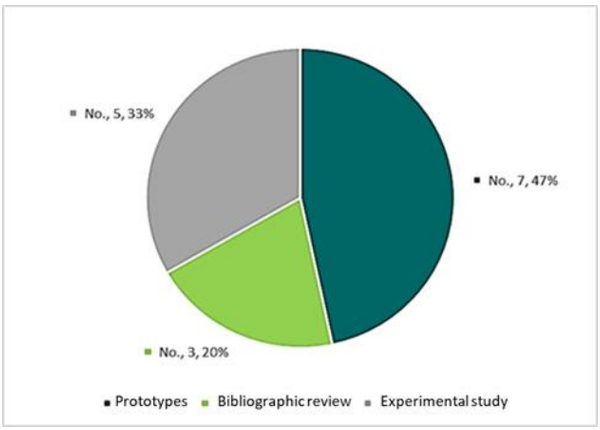

Graphic 1 Percentage of the number of studies analyzed
Source: Prepared by the authors

Conclusions

In this literature review regarding the benefits of exoskeletons in hand rehabilitation process and after the analysis of the analyzed information, a positive result was obtained in terms of applications, functionality, ergonomics and improvement in physical abilities of strength, precision in the fine and coarse gripper in which exoskeletons are presented as a promising implementation for hand rehabilitation in terms of mobility recovery. Estimation of different types of exoskeletons reveals their plurality in terms of design, features and functionalities.

Practice protocols and recommendations for exoskeleton performance require continuous estimation and individualized tailoring of protocols according to the disease to maximize application outcomes to exoskeleton performance and benefits. No articles have been found that more accurately analyze and evaluate application outcomes in patients with hand rehabilitation in the face of the variety of devices available, however, contributions have been initiated for ergonomic improvements focused on exoskeleton design and functionality.

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