Robotics and Gametherapy for Neurological Rehabilitation in Physiotherapy: A Systematic Literature Review

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Abstract

This systematic review analyzes the impacts, benefits, and challenges of using robotics and gametherapy for neurological rehabilitation in physiotherapy. The bibliographic survey was conducted on the CAPES journals portal, including full articles published between 2016 and 2025, focusing on upper limb neurological recovery. Twenty-five studies were selected, 16 on robotics and 9 on gametherapy, categorized according to the technologies utilized. The results showed functional gains in post-stroke patients, such as increased strength, range of motion, and gait, in addition to greater treatment engagement. Challenges related to costs, infrastructure, protocol standardization, and the need for long-term studies persist. It is concluded that robotics and gametherapy constitute innovative and complementary approaches, capable of enhancing the therapeutic quality of neurological rehabilitation.

Keywords

Robotics, Gametherapy, Neurological rehabilitation, Physiotherapy

1 Introduction

Neurological rehabilitation in physiotherapy constitutes a complex and multidimensional process, involving not only functional recovery but also the overcoming of physical, emotional, and social barriers [1]. Globally, it is estimated that more than 2.4 billion people could benefit from some form of rehabilitation, according to the World Health Organization [2], demonstrating the magnitude of the demand. Meanwhile, in Brazil, data from the National Household Sample Survey (PNAD) 2022 indicates that approximately 18.6 million individuals have some type of disability [3], reinforcing the need for effective public policies and clinical strategies. Among the main challenges reported are regional inequality in the supply of specialized services, the scarcity of technological and human resources [4], high costs, and a lack of patient motivation, factors that often result in premature treatment abandonment [5].

In this scenario, Information and Communication Technologies (ICTs) emerge as promising alternatives, allowing greater precision in data collection, treatment personalization, inclusion of people with physical limitations, and expansion of service reach through remote monitoring technologies [6]. Furthermore, they promote patient motivation and engagement, which are essential aspects for therapeutic adherence.

Among the technological approaches, gametherapy stands out, defined as the use of electronic games for therapeutic purposes [**b38**]. This strategy has demonstrated positive results by stimulating specific or global movements through reward systems and immediate feedback, promoting motivation, adherence to treatment, and the release of neurotransmitters associated with well-being, such as dopamine and endorphin [7]. Recent studies indicate that serious games and immersive virtual reality platforms can contribute to motor gains and greater patient participation.

Robotics applied to physiotherapy has stood out for its ability to offer high-intensity training, with precise control of movements and constant monitoring of clinical evolution. Robotic gait platforms, exoskeletons, and adaptive systems allow patients with motor disorders to perform exercises safely and effectively, enabling the early incorporation of functional movements, increasing the intensity and frequency of sessions, and enhancing autonomy during the rehabilitation process [8].

Given this overview, the main purpose of this article is to present a systematic review of the literature on robotics and gametherapy for neurological rehabilitation in physiotherapy, aiming to understand their impacts, benefits, and challenges, as well as to outline future perspectives for the area. Using the Coordination for the Improvement of Higher Education Personnel (CAPES) journal database, named CAPES Periodicals Portal, for the search, we selected 25 articles with proven efficacy in clinical trials, 16 focusing on robotics, and 9 on gametherapy. After in-depth analysis, we conclude that the application of robotics and gametherapy in neurological rehabilitation yields positive results: greater precision, motivation, engagement, practicality, and other functional improvements such as strength, speed, and progression in sessions. However, some

challenges persist related to costs, the need for specialized infrastructure, the scarcity of standardized protocols, and ethical and logistical barriers to conducting large-scale clinical studies.

2 Methodology

A systematic literature review allows mapping, critically evaluating, and integrating available results in a rigorous, transparent, and replicable manner. This review was conducted based on previously defined methodological protocols, ensuring rigor, transparency, and replicability. The research focuses on the use of robotics and gametherapy applied to neurological rehabilitation in physiotherapy, using the CAPES Periodicals Portal as the main database, recognized for the breadth and quality of its indexed publications.

The following inclusion criteria were established (Figure 1): (i) articles published between 2016 and 2025; (ii) studies specifically focused on neurological rehabilitation of upper limbs in physiotherapy; (iii) works available in full article format and (iv) research with consolidated results applicable to the clinical context. The exclusion criteria included: (i) studies without consolidated results and (ii) publications that did not present a full article format. The search was conducted using the keywords "gametherapy neurological rehabilitation in physiotherapy" and "robotics neurological rehabilitation in physiotherapy".

Figure 1: Acceptance and Exclusion Criteria for Article Selection

The selection process followed a structured roadmap, that included the stages of identification, screening, eligibility, and inclusion of studies. The articles were subsequently categorized into two main groups: robotics applied to rehabilitation and gametherapy applied to rehabilitation. For each study, aspects such as technologies used, clinical conditions addressed, objectives, methods, results, implementation challenges, technological potential, and year of publication were analyzed.

3 Results

This systematic review analyzed a total of 25 scientific articles available on the CAPES Periodicals Portal. Among these, 16 studies (64%)

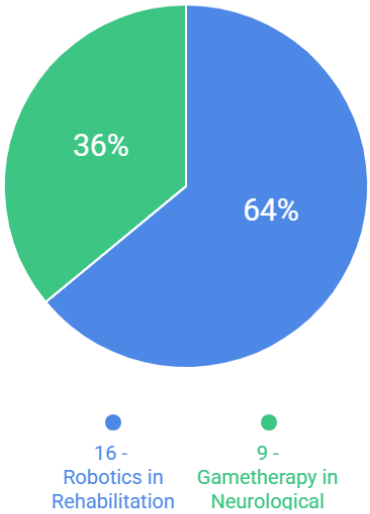

Figure 2: Distribution of Articles on Rehabilitation Approaches

addressed robotics applied to rehabilitation, while 9 studies (36%) (Figure 2) focused on gametherapy applied to neurological rehabilitation, indicating a greater prevalence of research centered on robotic technologies within the rehabilitation context. The distribution of studies in these two main categories reflects current trends in the adoption of advanced technological interventions aimed at improving functional recovery and therapeutic involvement in individuals with neurological impairments.

To enable a more structured and in-depth analysis, the selected articles were further organized through a thematic sub-classification within each category. Studies related to robotics applied to rehabilitation were grouped into 4 sub-categories: robotic gait platforms, exoskeletons and orthoses, assistive/adaptive robots, and multimodal integration systems. In parallel, studies addressing gametherapy applied to neurological rehabilitation were classified into 3 sub-categories: immersive virtual reality, conventional screen- or computer-based systems, and commercial platforms. These subcategories were established on the basis of the primary technological approach and therapeutic application described in each study and will be explained in detail in the following.

3.1 Robotics applied to rehabilitation

The 16 articles were grouped into four main subcategories:

- **Robotic Gait Platforms (5 articles):** Mechatronic systems that combine biomechanics and adaptive control, used for the intensive repetition of motor patterns and partial body weight support. The main challenges include high costs, the need for specialized maintenance, and the difficulty in reproducing the natural gait.
- **Exoskeletons and Orthoses (4 articles):** Wearable devices that assist movement and offer postural support. The reported obstacles involve clinical adaptation, complexity of algorithms, and durability of materials.

- **Assistive/Adaptive Robots (4 articles):** Systems that provide graded and adjustable assistance, applied in gait and upper limb training. Challenges include the need for specialized centers, inter-individual variability, and the risk of patient passivity.
- **Multimodal Integration (3 articles):** Combines different therapeutic modalities (sensors, virtual reality, electrical stimulation, brain-machine interfaces) in a single protocol or device. Used in adaptive assistance, immersive training, cortical neuromodulation, muscle and brain monitoring, and potentiation of neuroplasticity. The main obstacles are complex protocols, patient variability, and the need for specialized adaptive controls and laboratories.

3.2 Gametherapy Applied to Rehabilitation

The 9 articles were grouped into three subcategories:

- **Immersive Virtual Reality (5 articles):** Simulated three-dimensional environments using VR goggles and motion sensors, applied in gait and balance rehabilitation. It promotes engagement and is widely accepted by children and adolescents. Challenges include high cost, adverse symptoms — dizziness and nausea — and the need for professional training.
- **Conventional Screen/Computer (2 articles)**: Use of ordinary computers for serious games and non-immersive virtual reality. It is more accessible as it does not require VR goggles or advanced projection systems. Used to train gait and specific movements, monitor muscle effort, increase repetition, and boost motivation. It presents limitations in capturing fine movements and offers less immersion, scarcity of equipment, technical support, and professional training.
- **Commercial Platforms (2 articles):** Entertainment systems such as Xbox Kinect and Nintendo Wii, used to increase engagement, work with immediate visual feedback, without the need to create a device from scratch. The main obstacles are the lack of rehabilitation-specific games, difficulty in registering complex movements, and the need for adequate space, equipment, and professionals.

3.3 Main Observations

Following the collection and categorization of the relevant information, the data were systematically organized and synthesized into a clear and structured format, culminating in the development of Table 1. This comparative table was designed to facilitate the visualization and critical analysis of the information extracted from the 25 selected studies. By presenting the data in a consolidated manner, the table enables a more efficient comparison of the characteristics, methodologies, and outcomes reported in the literature, thereby allowing for the rapid identification of similarities and differences between robotics-based approaches and gametherapy strategies within the field of rehabilitation.

Among the conditions addressed, post-stroke and chronic stroke were the most prevalent, accounting for 10 of the 25 articles. Stroke

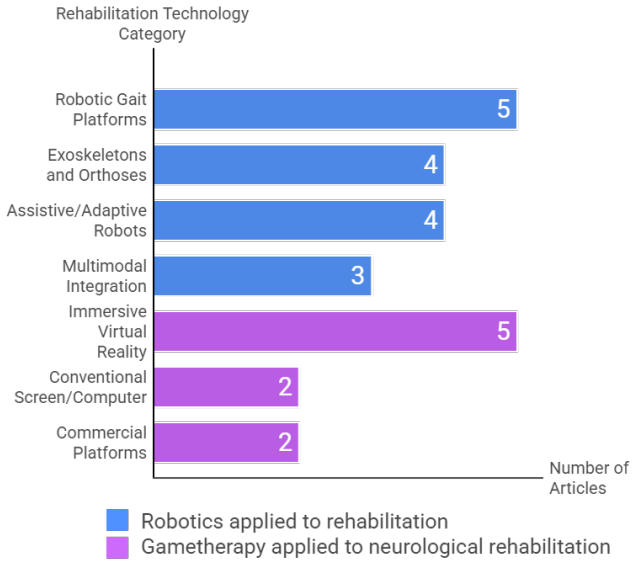

Figure 3: Distribution of Articles on Rehabilitation Approaches

(CVA) is one of the most prevalent and limiting neurological conditions in Brazil and worldwide. Most studies reported positive outcomes, including:

- **Functional improvements:** increased strength, range of motion, and gait.
- **Behavioral improvements:** greater engagement and adherence to treatment.

These results were evaluated through practical tests and metrics, such as in the robotics article [14], categorized as multimodal integration: robot-assisted gametherapy activities were carried out, like a virtual fishing game, where participants had to reach targets at the maximum voluntary arm extension. The robot provided arm weight support. 32% of the participants showed improvement in FMA-UE, half showed improvement in the ABILHAND scores superior to the MCID for each measure, and 82% showed improvements in the FMA-UE, ABILHAND, MAL-14, or SIS measures, surpassing the MCID values. In addition to functional improvements, there was greater patient engagement and motivation, verified through questionnaires and observations during the tests.

The robotics article [12], categorized as assistive/adaptive robots, investigates the use of an electromyography-based controller to prevent neglect behavior during robotic rehabilitation. The system adapts to the participant based on their EMG signal and other data. Based on the practical test, the Fugl-Meyer assessment, and other performance parameters, there were improvements in functional indices. It is concluded that robotics and EMG signal acquisition is a solution for the lack of effort during treatment, in addition to promoting functional improvements.

The gametherapy article [25], categorized as immersive virtual reality, analyzes the effects of VR therapy on the dynamic balance

Table 1: Comparative Table of Articles

Article	*Focus*	*Condition Addressed*	*Publication Year*
[8]	Assistive Adaptive Robots	Post-Stroke/Chronic Stroke	2019
[9]	Exoskeletons and Robotic Orthoses	Neurodegenerative Diseases	2022
[5]	Multimodal Integration	No specific focus	2021
[10]	Gait Training Platforms	Cerebral Palsy	2017
[11]	Exoskeletons and Robotic Orthoses	No specific focus	2023
[12]	Assistive Adaptive Robots	Post-Stroke/Chronic Stroke	2023
[13]	Exoskeletons and Robotic Orthoses	No specific focus	2020
[14]	Multimodal Integration	Post-Stroke/Chronic Stroke	2021
[15]	Gait Training Platforms	No specific focus	2024
[16]	Gait Training Platforms	Cerebral Palsy	2016
[17]	Gait Training Platforms	No specific focus	2017
[18]	Assistive Adaptive Robots	Post-Stroke/Chronic Stroke	2021
[19]	Assistive Adaptive Robots	Post-Stroke/Chronic Stroke	2021
[20]	Exoskeletons and Robotic Orthoses	No specific focus	2021
[21]	Gait Training Platforms	Cerebral Palsy	2023
[22]	Multimodal Integration	Post-Stroke/Chronic Stroke	2023
[23]	Commercial Platforms	Post-Stroke/Chronic Stroke	2016
[24]	Immersive Virtual Reality	Neurodegenerative Diseases	2021
[25]	Immersive Virtual Reality	Post-Stroke/Chronic Stroke	2019
[26]	Commercial Platforms	Down Syndrome	2020
[27]	Immersive Virtual Reality	Neurodegenerative Diseases	2024
[28]	Immersive Virtual Reality	Post-Stroke/Chronic Stroke	2019
[29]	Immersive Virtual Reality	Cerebral Palsy	2018
[30]	Conventional Screen/Computer	Cerebral Palsy	2024
[31]	Conventional Screen/Computer	Post-Stroke/Chronic Stroke	2022

of post-stroke individuals. The sessions were conducted using the Nintendo Wii® Fit Plus and Wii Sports ResortTM. At the end of the sessions, an improvement was observed according to the DGI instrument, which evaluates the dynamic balance of the individuals.

The gametherapy article [27], categorized as immersive virtual reality, evaluates the quality of life of patients with spinocerebellar ataxias. Based on the tests, there was an increase in SF-36 scores in the domains of functional capacity and vitality; evolution in the Berg Balance Scale scores, indicating greater stability; reduction in TUG time, suggesting improved agility and lower risk of falls; greater control in movements and better performance in virtual reality tasks; and a high rate of treatment adherence.

Based on the analysis of the four selected articles and their respective subcategorizations, it becomes evident that the integration of technological resources into the rehabilitation process offers significant benefits for both patients and healthcare professionals. These technologies contribute to more dynamic, engaging, and potentially more effective therapeutic interventions, while also supporting professionals in monitoring, evaluating, and adapting treatment strategies. In this context, technological solutions demonstrate considerable potential to become essential tools within modern rehabilitation practices. Nevertheless, despite these promising advantages, several challenges associated with the development, validation, and implementation of such technologies must be considered.

One of the primary challenges lies in the difficulty of implementing these solutions on a large scale. This limitation is often related to ethical regulations governing research involving human participants, as well as the restricted availability of hospitals, rehabilitation centers, and patients willing or eligible to participate in experimental studies. Furthermore, the viability and safety of these technological interventions require rigorous validation processes. As a result, experimental procedures must be conducted with a high degree of caution and methodological rigor to ensure that the proposed solutions do not pose risks to patients and that their therapeutic benefits are scientifically substantiated.

Another significant barrier concerns the high cost associated with the acquisition, development, and maintenance of technological resources, such as robotic systems, specialized hardware, and software platforms. In many healthcare environments this financial constraint can hinder the widespread adoption of innovative rehabilitation technologies. Additionally, the scarcity of technological infrastructure and specialized technical support may further limit the practical implementation of these solutions in real-world clinical settings.

It is also important to consider the potential risk of user complacency, which may arise when patients become overly accustomed to certain technological tools or when the novelty of the intervention diminishes over time. Such complacency can lead to reduced

engagement and motivation, potentially affecting adherence to therapeutic protocols and, consequently, the overall effectiveness of the rehabilitation process.

4 Conclusion

This study presents a systematic review on the use of robotics and gametherapy in neurological rehabilitation in physiotherapy, focusing on upper limb functional recovery. The analysis of 25 carefully selected articles shows that these technologies are proving capable of increasing the precision of treatments, enhancing patient engagement, and promoting relevant functional gains. The predominance of studies focusing on post-stroke patients reinforces the importance of these approaches in the face of one of the most prevalent and disabling neurological conditions globally.

The results highlight the advantages offered by robotics, such as refined movement control, high-intensity training, and real-time adaptation to the patients condition, while gametherapy stands out for motivational stimulation, broad movement practice, and immediate feedback. Together, these technologies boost motor gains, favor treatment adherence, and adapt to patient conditions. However, challenges persist: high costs, the need for specialized infrastructure, the scarcity of standardized protocols, and ethical and logistical barriers to conducting large-scale clinical trials.

Given this overview, we conclude that the integration between robotics and gametherapy represents a promising path for the evolution of neurological rehabilitation in physiotherapy. Nevertheless, gaps remain that should be explored in future research, such as conducting longitudinal studies with a larger number of participants, developing low-cost solutions, and creating standardized protocols that facilitate replication in different clinical contexts. Overcoming these challenges may democratize access to these technologies and elevate therapeutic quality, consolidating robotics and gametherapy as relevant tools in neurological rehabilitation.

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