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Original Article

Robotic Rehabilitation Devices in the Philippines: A Review of Recent Advancements

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Abstract

Background: *Rehabilitation robots are emerging technologies that address common challenges in conventional rehabilitation methods, such as labor-intensive, costly, and often yielding slow or suboptimal recovery outcomes. These robots have been gaining popularity in the Philippines due to their cost-effectiveness and improved therapeutic efficiency. The country has gradually begun adapting technology, with rehabilitation robots introduced as assistive devices for clinical practice such as electromyogram (EMG)-assisted devices, Functional Electrical Stimulation (FES), Robotic Exoskeleton Hand, and Robot Exoskeleton for the Upper Limb. However, there is limited to no existing literature exploring robotic rehabilitation device advancements in the Philippines.*

Methods: *Thus, this review examined the prototypes developed and the progress made in developing rehabilitation devices from 2010 to the present in the country.*

Results: *Findings indicate that the Philippines is becoming more receptive to rehabilitation robotics, as evidenced by increasing recognition of its relevance and the procurement of foreign-developed technologies. Nevertheless, its progress is limited by investment, insufficient academic programs, and the absence of regulatory frameworks.*

Conclusion: *Increased government support for research, infrastructure, and protocols alongside university integration of relevant courses and interdisciplinary research are needed to foster its advancement.*

Keywords

rehabilitation robots, Philippines, advancements, prototypes, adaptation

INTRODUCTION

The field of rehabilitation has evolved over the past decade, with advancements playing a significant role in improving patient outcomes. Robotic-based rehabilitation has gained attention for its potential to enhance recovery processes, particularly for individuals with upper and lower limb comorbidities. Worldwide, rehabilitation robots have been increasingly integrated into clinical settings. Rehabilitation robotics have the advantage of offering automated and precise therapeutic interventions that complement traditional rehabilitation methods (Bhardwaj et al., 2021). These advancements have been driven by growing research highlighting the cost-effectiveness, efficiency, and long-term benefits of robotic-assisted therapy compared to conventional manual therapy (Cano-de-la-Cuerda et al., 2024).

Global adoption of robotic rehabilitation has led to breakthroughs in stroke recovery, spinal cord injury rehabilitation, and other neuromuscular disorders (Chang et al., 2013). Research findings indicate that robotic rehabilitation is more efficient, less labor-intensive, and more cost-effective than conventional therapy (Lo et al., 2019). A study by Mohebbi (2020) suggests that robotic rehabilitation reduces the dependency on labor-intensive sessions while providing consistent and repetitive therapeutic exercises. Carpino et al. (2018) further demonstrated that robotic-assisted lower limb rehabilitation enables patients to regain mobility 2.45 times faster than conventional therapy while achieving higher average walking speeds. Additionally, the study revealed that wearable robotic rehabilitation devices are economically sustainable, with cost savings exceeding 150 euros per patient compared to traditional therapy. These benefits have encouraged many healthcare institutions to invest in robotic rehabilitation technologies as part of their standard treatment protocols.

Figure 1. *HAL being used in Ospital ng Maynila Medical Center (Turingan, 2021)*

In the Philippines, robotic rehabilitation is still nascent, with limited commercially developed devices available. Local hospitals such as the Ospital ng Maynila Medical Center have begun incorporating lower limb rehabilitation robots, specifically the Hybrid Assistive Limb (HAL) developed by Cyberdyne (Lungsod ng Maynila, 2021). These technologies originate from Japan rather than being domestically produced. Most locally developed rehabilitation robots remain in the prototype phase, with many not yet ready for commercialization. Consequently, traditional therapy remains the predominant rehabilitation method in Philippine healthcare institutions.

This paper aims to highlight the significance of adopting robotic-based rehabilitation in the Philippines to enhance patient recovery and contribute to the broader regional implementation of these technologies. It presents a comprehensive overview of various rehabilitation devices, including end-effector-based robots, which connect at a distal point without aligning joint axes with human joints, and exoskeleton-based robots, which feature multiple connection points with joint axes aligned to human anatomy (Lee et al., 2020). The paper explores recent advancements in Philippine rehabilitation technology, such as electromyogram (EMG)-assisted devices that utilize sensors to detect muscle movement (Galido et al., 2018). Notably, research has introduced hybrid solutions combining EMG with functional electrical stimulation (FES) to activate muscles through controlled electrical impulses (Al-Ayyad et al., 2023). Furthermore, this study examines ongoing developments in locally designed robotic rehabilitation devices, such as the Robotic Exoskeleton Hand (Ong & Bugtai, 2018) and the Robot Exoskeleton for the Upper Limb (Baniqued et al., 2018), developed under the AGAPAY Project (Philippine Council for Health Research and Development [PCHRD], 2021). By shedding light on these technological advancements, this paper underscores the importance of fostering growth in the robotic rehabilitation ecosystem in the Philippines. Expanding research and development in this field will improve patient rehabilitation outcomes and create more affordable alternatives, ultimately making advanced rehabilitative care accessible to a more significant population segment.

METHODS

Researchers consulted various sources, including published journals such as IEEE and in-market device websites such as Robocare and Philippine Government Websites, to create a list of robotic devices. The search focuses on articles published from September 2019 onward, using keywords such as "rehabilitation devices," "robotic rehabilitation," and "rehabilitation developments". Robotic devices being used in the Philippines or prototyped in the Philippines were included, while those currently unavailable in the country were excluded. The selected rehabilitation devices must specifically target either upper or lower limb impairments. An initial exploration identified ten (10) rehabilitation devices available on the global market; however, these were not accessible in the Philippines. Among these were technologies such as ReWalk, LOPES exoskeletons, KINARM, Burt, and other rehabilitation devices developed through international research initiatives. Following a more refined search process, five devices were ultimately selected. Of these, one is an internationally developed product currently in use within the Philippines, while the remaining four are derived from published research studies conducted within the country.

Rehabilitation Devices

Rehabilitation devices are also therapeutic devices used alone or with other active medical devices to support, modify, replace, or restore biological processes or structures to treat or alleviate a disease, injury, or disability (ASEAN Secretariat, 2015). ASEAN classifies these therapeutic devices as either low-risk (Class A) or low to moderate-risk (Class B) medical devices depending on factors such as their intended use, whether they are invasive, pose potential hazards, or present other risks to patient safety. Rehabilitation devices are further categorized into non-robotic and robotic types.

A non-robotic rehabilitation device is a non-programmable mechanical device that the therapist manually operates. This type of device often relies on the therapist's strength to perform manual rehabilitation techniques, such as moving the patient's limbs for passive joint movements (Iversen, 2012). In contrast, a robotic rehabilitation device is pre-programmed or programmable, capable of automatically performing rehabilitation techniques to improve the movement of a physically impaired individual (Giansanti, 2020). Unlike non-robotic devices, robotic rehabilitation devices offer automation in their functionality. Robotic rehabilitation devices represent a collaboration of interdisciplinary fields, combining expertise from healthcare professionals, technology developers, and engineers. These devices can be classified based on movement types, target joint rehabilitation, and other features. The applications of these devices range from sensors to soft robotics, active prosthetics, and orthoses. Regarding mechanical structure, rehabilitation devices are generally classified as end-effector-based or exoskeleton-type robots (Zhang et al., 2023).

End-effector-based Robots

End-effector-based robots are robots connected to the human body through a distal point. The robot joints do not match the human joints of the patient (Lee et al., 2020). One example of an end-effector-based robot is the Cardiovascular Rehabilitation Equipment or "CaRE" (Advincula et al., 2018). It is an automated aerobic exercise equipment focusing on cardiovascular rehabilitation with a monitoring system for automated adjustments.

CaRE is a stationary bike equipment where the patient will be strapped onto the foot for security. The patient will also be strapped on the arms with the blood pressure monitoring module. The user's fingers will also be strapped with an oximeter to monitor the blood oxygen levels/oxygen saturation and the user's beats per minute (BPM). Every second, parameters such as heart rate, oxygen saturation, elapsed time, cadence, and resistance level are measured and displayed on the user interface. On the other hand, the blood pressure is recorded and displayed every three minutes.

Additionally, the heart rate is tracked throughout the exercise. These will be reset once the reset button is clicked (Advincula et al., 2018). Lastly, the machine will automatically adjust to the patient's current conditions with these parameters. Depending on the parameters detected, different light colors will flash to indicate whether the user is too slow or too fast (Advincula et al., 2018).

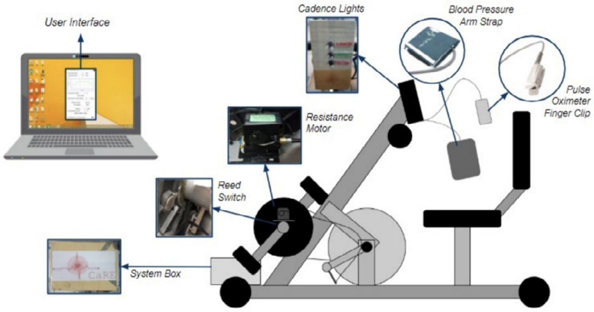

Figure 2. *CaRE system layout (Advincula et al., 2018)*

Exoskeleton-type Robots

Exoskeleton-type robots are robots that are connected and aligned to the human joints. There is a one-to-one relationship between the robot and the human joints. Additionally, these robots are usually programmed to guide the focused human joints and simultaneously assist activities and driven movements to increase the user's body strength and restore skeletal muscle memory (Siviy et al., 2022). In recent years, some of the exoskeleton-type robots developed in the Philippines are the 3-DOF Cable-Driven Robotic Ankle Rehabilitation Device (Saysay et al., 2021), the Bio-inspired Design of a Hand Exoskeleton for Rehabilitation (Galido et al., 2018), and the Robotic Exoskeleton of the Upper Limb with Biomimetics Application (Carag et al., 2015).

The 3-DOF Cable-Driven Robotic Ankle Rehabilitation Device is based on the commercial ankle foot brace. It allows a 3-axis rotation through the ankle-foot part of the device. Unlike the commercial ankle-foot brace, where the foot is tightly strapped with a fixed brace, the ankle-foot brace was cut out while maintaining the straps on the middle top of the foot to allow rotation. The device is actuated through the connected steel cables attached to the braces (Saysay et al., 2021).

The Bio-inspired Design of a Hand Exoskeleton for Rehabilitation focuses on developing a hand exoskeleton that mimics the movements of a human hand, which involves studying the biomechanics of the hand, the grasping movements, and the kinematics of the human hand (Ong & Bugtai, 2018). Since the device is intended for rehabilitation, it must offer sufficient DOF to enhance the user's movements and function safely within the intended environment.

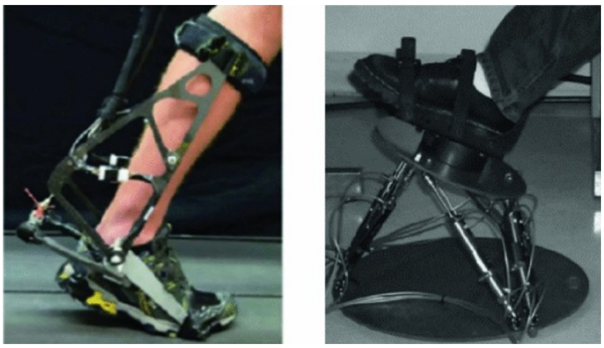

Figure 3. *3-DOF Cable-Driven Robotic Ankle Rehabilitation Device (Saysay et al., 2021)*

Philippine Rehabilitation Advancements

Some of the rehabilitation robots that have recently developed in the Philippines are electromyogram-assisted upper limb devices (Carag et al., 2015), robotic exoskeleton hand (Galido et al., 2018), and robotic exoskeleton for the upper limb (PCHRD, 2021).

Electromyogram-Assisted Devices

The electromyogram-assisted upper limb device was developed as an automated rehabilitation device for stroke patients' upper extremities. The device uses electromyogram (EMG) signals, temperatures, and pulse rates, incorporating passive activity, active-passive activity, and active activity in rehabilitation (Carag et al., 2015). The device guides the patient's movement with visual stimulus when in passive mode. While in active mode, the device needs force from the patients to move accordingly. Lastly, when the patient cannot reach the target motion or the EMG cannot detect any input force, the device will help in movement, which is the active-passive mode. The study by Galido et al. (2018) discusses their tests on readings and measurements through the device, resulting in minimal deviation in temperature and pulse rate readings compared to other commercially available devices.

EMG was also considered accurate in detecting the input force, especially during active-passive activities (Galido et al., 2018). EMG has also been used to develop rehabilitation devices for the lower extremities. A study by Borbajo et al. (2017) introduced a device incorporating EMG and functional electrical stimulation (FES) for leg rehabilitation. The idea is for the device to manipulate the muscles through electrical stimulation to perform movements such as ankle dorsiflexion, plantar flexion, and knee flexion. The EMG signals function as a sensor to determine the stimulation level caused by the FES. A flex sensor is also used to determine the type of movement executed by measuring angular displacements. The study discussed the potential of an EMG-FES system in leading to new methods and techniques in physical rehabilitation (Al-Ayyad et al., 2023).

Robotic Exoskeleton Hand

A paper by Ong and Bugtai (2018) introduces a device that uses a cable system designed to accommodate the flexion and extension of all five fingers. Cable guides were strategically placed so that the individual units provided by the cables could actuate effectively. The researchers were able to design a lightweight, low-profile prototype that can still supplement the flexion and extension movements of the hand and fingers. Testing the integration of cable wires into the exoskeleton was deemed successful in using flexion forces. The prototype provides the necessary forces regardless of the human hand complexity and maintains a simple mechanism (Baniqued et al., 2018).

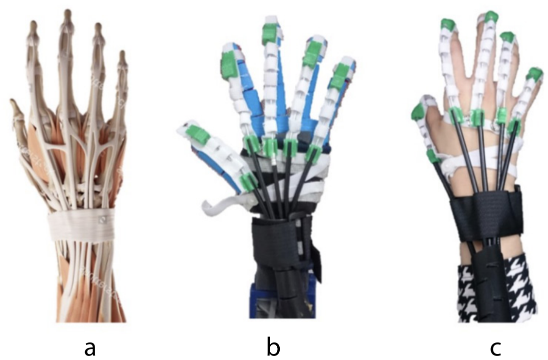

Figure 4. *Bioinspired design and prototype of a hand wearable device (a) Hand anatomical structure; (b) Prototype of exoskeleton tested in a mechanical hand; (c) Prototype of exoskeleton tested in an actual human hand (Baniqued et al., 2018)*

Robotic Exoskeleton for the Upper Limb

A 5-degree-of-freedom robotic exoskeleton device developed by Baniqued et al. (2018) is a rehabilitation device that utilizes linear actuators and other mechanisms to resemble the motion of the muscles of the upper limbs. The design of the robotic linkages was inspired by the natural morphology of cancellous and cortical bones and their ability to respond to mechanical stress. Each link was carefully designed to respond to stress without compromising weight. A biomimetic approach methodology was performed during the design process of the exoskeleton, and the study proved that the methodology promotes the biocompatibility and safety of the device (PCHRD, 2021). However, it should also be noted that the study recommends prioritizing user needs and requirements while doing this approach.

Most of these are prototypes and are not ready for commercialization; however, one robotic-based rehabilitation, the AGAPAY robotic exoskeleton, is already readily available for commercialization and seeks partnerships with distributors, manufacturers, and other relevant stakeholders (PCHRD, 2021).

Furthermore, the Global Cooperation on Assistive Technology (GATE) was highlighted during the World Health Organization's (WHO) meeting on rehabilitation in universal health coverage in Manila, Philippines, in August 2017. Assistive Technology (AT) is being pushed to coordinate rehabilitation across different levels of care within and beyond the health sector. The meeting emphasized cost as one of the significant barriers to integrating assistive technology in medical rehabilitation. Closing the gap between need and access was a significant goal of WHO. With this, a Priority Assistive Products list has been developed and presented at the World Health Embassy, discussing the importance of such assistive technology (WHO Regional Office for the Western Pacific, 2017).

Figure 5. *Prototype of the AGAPAY Robotic Exoskeleton (De La Salle University, 2021)*

Key Challenges in Robotic Rehabilitation Devices in the Philippines

Although the recent developments of Robotic Rehabilitation in the Philippines show high growth potential, which can provide high treatment access to patients from clinical and home settings, significant challenges are currently being faced by researchers and institutes that are passively slowing down progression. Emerging hurdles such as cost and accessibility have been the prominent issues within the fabrication of materials, access to resources, and affordability of implementing the production of these robotic devices. Aligning with the high costs, a lack of funding deviates the research and development of rehab devices to focusing more on innovation and product efficiency, and less financial support from both public and private sectors can result in a reduction of opportunities in technology development. In addition, governments and higher education institutions (HEIs) need to create strategies and a clear patent policy to support the impact of the resulting publications (Sukoco et al., 2023). Moreover, more roadblocks in the country need to be addressed, such as research and development availability and access, talent availability, production equipment and access, intellectual property (IP) policy, standards/certifications, culture mismatch, lack of knowledge or trust in the industry, weak linkages between industry and the academe and between government agencies on innovation ecosystem (Munsayac et al., 2023). Lastly, investing in a research culture inside institutions is a challenge, and building it would require rigorous assessment and evaluation as it is not just having a way to publish research but changing an entire environment (Olvido, 2020).

DISCUSSION

The table highlights the absence of Philippine-made rehabilitation robots in the market and the reliance on imported devices from countries like Japan. This unavailability may be attributed to the lack of FDA protocols for locally manufactured rehabilitation devices, leading to dependence on foreign FDA approvals, and is proof of the problems stated above.

Table. 1. *Comparison of the State of Research between Japan and the Philippines in Biomedical Rehabilitation Technology*

Device	Estimated Cost	Availability	Place Of Origin
Hybrid Assistive Limb Robot	$14,000 and $19,000	Ospital ng Maynila Medical Center	Japan
3-DOF Cable-Driven Robotic Ankle Rehabilitation Device	In Research Phase	Not in Market	Philippines
Bio-inspired Design of a Hand Exoskeleton for Rehabilitation	In Research Phase	Not in Market	Philippines
Robotic Exoskeleton of the Upper Limb with Biomimetics Application	In Research Phase	Not in Market	Philippines
AGAPAY: Robotic Exoskeleton for Upper Extremity Rehabilitation	In Research Phase	Not in Market	Philippines

Robotic rehabilitation is known for its capability to support and develop the productivity and effectiveness of therapists in facilitating rehabilitation exercises. The difference between rehabilitation robots and non-robotic devices is that rehabilitation robots are programmable or automated. In contrast, non-robotics are non-programmable mechanical devices requiring manual rehabilitation effort. Only a few prototypes have been developed and are continually developing in the Philippines.

In-depth analyses of the prototypes and further tests with human subjects are suggested to develop such devices further in the country. With the prototypes mentioned, it is also suggested that mathematical analyses are done for the concepts, such as the robotic exoskeletons, to be used in rehabilitation for the disabled and post-stroke patients (Baniqued et al., 2018; Ong & Bugtai, 2018). As the use of sensors such as the EMG and functional electrical stimulation (FES) is uncommon in Philippine practice, its integration is significant in developing other methods of rehabilitation to acquire enough data for a baseline study (Borbajo et al., 2017; Carag et al., 2015). The field of robotic rehabilitation is far from being perfected. However, current developments promise that our knowledge and resources will continue to grow (Zhang et al., 2023). In stroke rehabilitation, robot-assisted therapy currently works together with traditional rehabilitation therapy and cannot serve as a replacement yet (Mohebbi, 2020).

The development of these devices requires proper support and guidance, as it involves various aspects, including human factors and ergonomics for wearability design, ensuring the safety of the physical rehabilitation device about potential hazards and device failures, and considering design elements that impact performance (Song et al., 2023). A challenge for researchers and developers is making the device cost-effective and accessible. Integrating such technology will benefit stakeholders and those in underdeveloped countries where cheaper healthcare options are limited.

Although some cities have started investing in rehabilitation robots as part of their programs, the robots utilized are not locally produced but imported from foreign developers. While there is growing recognition of the need for robotic-assisted rehabilitation in the country, only a few organizations are willing to invest in research and development. Government agencies such as the Department of Science and Technology (DOST) and the Food and Drug Administration (FDA) must draft and implement protocols for Robotic Devices. Government agencies should also explore increasing the budget for internal research and creating more infrastructure and human capital instead of importing robotic devices from other countries due to high costs (Munsayac et al., 2023).

Lastly, only a few universities offer robotics as a college course, contributing to the country's underdevelopment in local robotics. With the rise of technology and the advancement of the Internet of Things (IoT), the Philippines should emphasize developing robotic rehabilitation devices. Investing in this area supports technological innovation and attracts investors, which can contribute to the country's economic growth (Munsayac et al., 2023). These innovative devices would benefit patients, physicians, therapists, and physiotherapists by enabling more efficient and ergonomic therapy sessions.

Moreover, integrating sensors and feedback systems in these devices would enhance the objectivity of therapy data and outcomes. To foster growth in rehabilitation robotics, universities should consider offering courses such as Biomedical Engineering and encourage multidisciplinary collaboration between engineering and medical departments.

CONCLUSION

As a closing point, the Philippines' complex interplay of challenges and opportunities serves as a microcosm of the broader dynamics observed. Innovations in rehabilitation robotics present a practical pathway for modernizing healthcare systems nationwide and enhancing the sustainable development of ASEAN and the Asia-Pacific. This study demonstrates that healthcare providers can improve recovery outcomes while reducing long-term costs by integrating advanced robotics with targeted patient care, such as remote monitoring systems, personalized therapy algorithms, and scalable rehabilitation devices. Additionally, it's crucial for government bodies should also take action on investing more in human capital, infrastructure, and funding, and universities should explore courses related to robotics and medicine following international trends and standards. These solutions strengthen healthcare infrastructure and contribute to sustainable development by fostering technological self-reliance and operational efficiency. Finally, the Philippines must initiate pilot programs focused on biomedical robotics research and begin drafting FDA policies to regulate their use, ensuring the country remains competitive with other ASEAN nations in this emerging field.

Author Contributions

Ompico: Conceptualization, Validation, Formal analysis, Writing – original draft; **Dela Vega:** Formal analysis, Writing – original draft; **Garcia:** Writing – original draft; **Ramos:** Writing – original draft; **Perez:** Writing – review & editing, Resources; **Reyes:** Writing – review & editing, Resources; **Banayo:** Project administration, Validation, Supervision, Writing – original draft; **Sy:** Validation, Funding acquisition, Project administration; **Roxas:** Validation; **Munsayac:** Project administration; **Bugtai:** Funding acquisition

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Ethical Approval

Not Applicable

Competing Interest

The authors declare no conflicts of interest.

Data Availability

Data will be made available by the corresponding author on request.

Declaration of Artifical Intelligence Use

In this work, the author(s) employed artificial intelligence (AI) tools and methodologies, including ChatGPT for paraphrasing assistance. While ChatGPT aided in this process, the author(s) ensured proper citation of paraphrased content where necessary. Ultimately, the author(s) evaluated and revised the generated content and take full responsibility for the final published work.

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