

ISSN 2523-6849

Volume 9, Issue 20 -- e2025920 January -- December - 2025

Journal of Physiotherapy and Medical Technology

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Journal of Physiotherapy and Medical Technology, Volume 9, Issue 20: e2025920 January – December 2025, is a Continuous publication - ECORFAN-Taiwan. Taipei. YongHe district, ZhongXin, Street 69. Postcode: 23445. WEB: www.ecorfan.org/taiwan, revista@ecorfan.org. Editor in Chief: Iglesias-Suarez, Fernando. MsC. ISSN: 2523-6849. Responsible for the last update of this issue of the ECORFAN Informatics Unit. Escamilla-Bouchán Imelda, Luna-Soto, Vladimir, updated December 30, 2025.

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In the first article we present, *Rehabilitation Glove RECOVGLOX* by Juárez-Santiago, Brenda, Ledesma-Urbe, Norma Alejandra, Ojeda-Hernandez, Mario Alberto and Barreto-Ocampo, Santiago, with adscription in Universidad Tecnológica de San Juan del Río, the next article we present, *Proposed prosthetic device for energy storage and return for the lower limbs* by Bedolla-Hernández, Jorge, Islas-Zistecatl, Rolando, Bedolla-Hernández, Marcos and Cruz-García, José Michael with adscription in Tecnológico Nacional de México / Instituto Tecnológico de Apizaco, the next article we present, *We are plastic* by Hernández-Rodríguez, María Guadalupe, Ortega-Chávez, Laura Antonia, Santos-Benítez, Lina Susana and García-González-Héctor, with adscription in Tecnológico Nacional de México/ Instituto Tecnológico de Chihuahua II, the last article we present, *Determination and evaluation of official tests on rosemary extract tablets [as a finished product]* by Orta-Martínez Felipe, Hernández-Salas, Claudia, Regalado-Barrera, José David and Reyes-Escobedo, Fuensanta del Rocío, with adscription in Universidad Autónoma de Zacatecas "Francisco García Salinas".















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Rehabilitation Glove RECOVGLOX

Guante para rehabilitación RECOVGLOX

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Classification:

Area: Engineering
 Field: Engineering
 Discipline: Systems engineer
 Subdiscipline: Computer Sciences

 <https://doi.org/10.35429/JP.2025.9.20.1.1.14>

History of the article:

Received: October 11, 2025
 Accepted: December 30, 2025



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Abstract

This article presents the design and implementation of RECOVGLOX, an IoT-based smart glove prototype designed to support the rehabilitation of hand motor functions. The glove integrates flexible sensors and a servo motor to track real-time hand movements such as finger flexion. The system enables data collection and monitoring through a mobile/web application powered by Firebase, providing therapists and patients with personalized rehabilitation insights. Agile development methodology [Scrum] was used throughout the design and validation process. Results demonstrate the glove's precision, usability, and potential to enhance therapy outcomes.

Resumen

Este artículo presenta el diseño e implementación de RECOVGLOX, un prototipo de guante inteligente basado en IoT orientado a apoyar la rehabilitación de funciones motrices de la mano. El guante integra sensores flexibles y un servomotor para registrar en tiempo real movimientos de flexión de dedos. El sistema permite la recolección y monitoreo de datos mediante una aplicación móvil/web respaldada por Firebase, brindando a terapeutas y pacientes una herramienta de rehabilitación personalizada. Se empleó la metodología ágil SCRUM durante el desarrollo y validación del prototipo. Los resultados demuestran precisión, usabilidad y potencial terapéutico.

RECOVGLOX		
OBJECTIVES	METHODOLOGY	CONTRIBUTION
IoT glove with sensors, servomotor, and gyroscope measures finger strength, wrist flexion, and rotation in real time. Monitors motor rehabilitation, assesses progress, and personalizes exercises. Data on digital platform.	Project developed with SCRUM, an agile methodology for dynamic environments. Continuous delivery through 2-3 week sprints, with feedback at the end to identify errors and successes, applied in the next sprint.	"RECOVGLOX": IoT glove for motor rehabilitation with real-time sensors. Enhances personalized therapies, efficiency, and quality of life. Promotes innovation, data analysis, patient autonomy, ergonomic and scalable design, professional training, and digital health advancements.

Rehabilitation – IoT – Sensorized glove

RECOVGLOX		
OBJETIVOS	METODOLOGÍA	CONTRIBUCIÓN
Guante IoT con sensores, servomotor y giroscopio mide fuerza de dedos, flexión y rotación de muñeca en tiempo real. Monitorea rehabilitación con motriz, evalúa progreso y personaliza ejercicios. Datos en plataforma digital.	Proyecto desarrollado con SCRUM, metodología ágil para entornos dinámicos. Entrega continua mediante sprints de 2-3 semanas, con retroalimentación al final para identificar errores y éxitos, aplicándola en el siguiente sprint.	"RECOVGLOX": Guante IoT para rehabilitación motriz con sensores en tiempo real. Mejora terapias personalizadas, eficiencia y calidad de vida. Fomenta innovación, análisis de datos, autonomía del paciente, diseño ergonómico y escalable, formación profesional y avances en salud digital.

Rehabilitación – IoT – Guante sensorizado

Area: Strengthening the scientific community

Citation: Juárez-Santiago, Brenda, Ledesma-Uribe, Norma Alejandra, Ojeda-Hernandez, Mario Alberto and Barreto-Ocampo, Santiago. [2025]. Rehabilitation Glove RECOVGLOX. Journal of Physiotherapy and Medical Technology. 9[20]1-14: e1920114.



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Peer review under the responsibility of the Scientific Committee MARVID® - in the contribution to the scientific, technological and innovation Peer Review Process through the training of Human Resources for the continuity in the Critical Analysis of International Research.



Introduction

Hand motor rehabilitation plays a crucial role in the treatment of patients with neuromotor impairments resulting from stroke, traumatic injuries, or neurodegenerative diseases. It is estimated that more than 80% of stroke survivors experience motor deficits in the upper limbs, significantly affecting their independence and quality of life [Langhorne, Bernhardt, & Kwakkel, 2011].

Effective therapy requires intensive repetition, immediate feedback, and continuous progress monitoring. However, traditional rehabilitation methods often require frequent in-person sessions, which can limit access due to economic, geographic, or logistical barriers.

In response to these limitations, the development of wearable technologies and the Internet of Things [IoT] has led to portable systems capable of capturing biomechanical data in real time. These devices enable remote monitoring and provide greater accessibility to personalized therapies [Coughlin, & Steward, 2016].

Among such technologies, sensorized gloves stand out for their ability to measure finger flexion, grip strength, and joint mobility. Recent innovations have incorporated flexible sensors, wireless communication, and cloud-based platforms, transforming how rehabilitation is delivered and monitored [Zhao, Ji, Wen, Li, Liang, & Jiang, 2021].

This article presents the design and development of RECOVGLOX, an intelligent IoT-based glove prototype designed to support hand motor rehabilitation. The glove integrates flexible sensors, embedded electronics, and a real-time data visualization platform to assist in therapy personalization. We hypothesize that RECOVGLOX can improve treatment adherence and effectiveness by providing continuous monitoring and immediate feedback in both clinical and home environments.

Furthermore, the RECOVGLOX project is aligned with the fundamental criteria established by Mexico's Higher Education Evaluation and Accreditation System [SEAES], particularly emphasizing Social Responsibility, Inclusion, and Social Innovation.

These principles ensure that the glove's development promotes equitable access to rehabilitation technologies and fosters sustainable improvements in the quality of life for people with motor disabilities.

Background

Motor rehabilitation of the hand has significantly evolved in recent decades, driven by the need to enhance functionality and independence in patients with neurological impairments. Traditionally, this type of rehabilitation has been performed through repetitive therapist-guided exercises in clinical settings, which often involves high costs and logistical constraints that may reduce treatment frequency and quality [Langhorne et al., 2011].

To address these limitations, the integration of digital technologies has enabled the development of assistive systems capable of objectively capturing biomechanical data. Wearable devices, particularly sensorized gloves, have become increasingly relevant by enabling the precise measurement of finger joint movement, grip strength, and motor coordination. These systems often incorporate flexible sensors, inertial measurement units, and embedded electronics to provide real-time feedback and support remote monitoring [Coughlin & Steward, 2016]. Recent advances in triboelectric nanogenerators and tribotronics have enabled innovative human-machine interfacing devices, which offer promising applications in wearable rehabilitation systems due to their high sensitivity and flexibility [Ding, Wang, Wu, Guo, & Wang, 2018]. Furthermore, the development of wearable devices focused on musical interaction has been recognized as an effective complementary tool for motor rehabilitation, significantly improving patient motivation and adherence to therapy [Márquez Crispancho, 2025].

In addition, the emergence of the Internet of Things [IoT] has transformed rehabilitation by allowing wireless data transmission to cloud platforms. This connectivity enables healthcare professionals to remotely monitor patient progress and tailor therapy based on performance metrics, which enhances continuity of care beyond clinical environments.

Recent research in human motion analysis, such as the biomechanical study of vertical jumping in children using motion capture and simulation modeling, has highlighted the potential of sensor-based systems to extract detailed movement patterns for clinical or developmental assessment [Zhao et al., 2021].

These methodologies can be adapted to hand rehabilitation scenarios by using wearable technologies like sensorized gloves to analyze joint dynamics during therapy.

In this context, the trend towards developing portable and accessible solutions has driven the creation of intelligent devices that combine low-cost technologies with real-time processing algorithms. This convergence allows not only for the recording of movement data but also for its immediate analysis and interpretation to provide visual or haptic feedback during the rehabilitation process. Furthermore, the integration of cloud platforms facilitates the generation of digital clinical histories, representing a key tool for healthcare professionals to evaluate longitudinal therapeutic progress and make evidence-based decisions. Thus, IoT-based devices represent an evolution of the traditional approach, transforming rehabilitation into a continuous, personalized, and connected process adaptable to the patient's changing needs.

Within this framework, the RECOVGLOX project introduces a smart glove prototype designed to support hand motor rehabilitation. The glove integrates flexible resistive sensors, embedded microcontrollers, and a cloud-based data visualization platform, forming a low-cost, adaptable, and accessible solution for personalized rehabilitation in both clinical and home settings.

Methodology

The development of the RECOVGLOX prototype was divided into four main phases: mechanical design, electronic integration, software development for data capture and processing, and the creation of interfaces for remote visualization [see Figure 1]. Each stage was approached with the objective of ensuring system functionality, data capture accuracy, and scalability.

Box 1

Desarrollo de Guante Inteligente: Fases y Componentes



Figure 1

Process flow diagram illustrating the methodology for the development, assembly, and data handling of the RECOVGLOX prototype

Source: authors

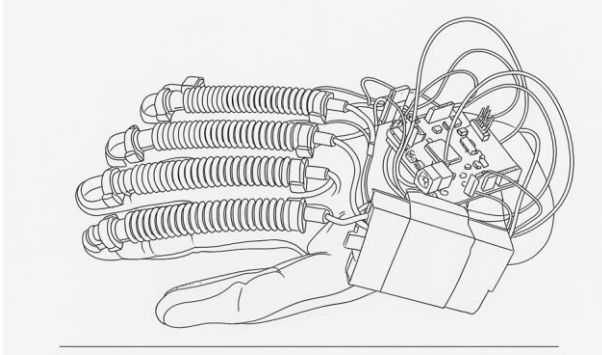
Mechanical Design

The mechanical design of the RECOVGLOX prototype focused on ensuring comfort, adaptability, and functionality, allowing prolonged use without interfering with the natural movements of the hand. Elastic textile materials were combined with structural components made from PLA filament to balance ergonomics, durability, and ease of fabrication.

Preliminary design and anatomical distribution

The initial design of the glove was developed through a hand-drawn sketch that outlined the proportions of the human hand and the strategic placement of flexible resistive sensors [see Figure 2]. This conceptual sketch was later digitized and used as a reference during the prototype fabrication phase. The anatomical distribution of the sensors was specifically aligned with the metacarpophalangeal [MCP] and interphalangeal [IP] joints of each finger to ensure precise tracking of flexion and extension movements while preserving the natural range of motion.

This approach is consistent with previous methodologies that emphasize accurate sensor placement based on anatomical landmarks to optimize data acquisition. For instance, a low-cost wearable system developed by other researchers positioned resistive sensors over the MCP and IP joints to effectively monitor angular displacement during finger movement without restricting natural biomechanics [Chacon, Plaza, & Cifuentes, 2018]. This principle of alignment was fundamental in the RECOVGLOX prototype to ensure ergonomic design, sensor reliability, and functional performance during rehabilitation exercises [see Figure 3].

Box 2**Figure 2**

Hand-drawn anatomical sketch of glove with proposed sensor placement

Source: authors

Box 3**Figure 3**

Photograph of the final prototype of the glove showing the sensor placement

Source: authors

Hybrid structural components

The structural configuration of the RECOVGLOX glove was developed using a hybrid approach that combines soft, flexible textile materials with rigid 3D-printed components.

This strategy allows for both comfort during use and structural stability for sensor integration and electronic housing.

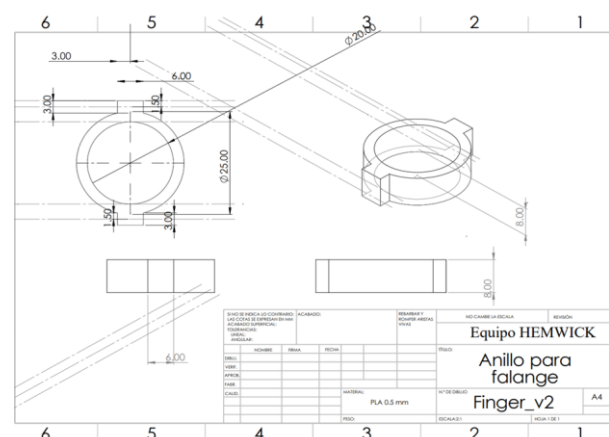
In contrast to other glove-based designs that incorporate dorsal rigid supports fabricated through additive manufacturing, this project implemented a more cost-effective and sustainable solution: a recycled plastic tube was manually adapted and mounted on the dorsal side of the fingers.

This tube served to fix the flexible resistive sensors in place, ensuring proper alignment with the flexion axis of each finger. The use of lightweight and adaptable components for sensor positioning has proven effective in other wearable glove systems focused on manual motion capture [An, Park, Kim, Lee, Cho, Koo, & Shin, 2025].

Only a limited number of parts were designed using computer-aided tools. Specifically, the 3D-printed rings for the middle phalanges were modeled in SolidWorks and fabricated using PLA filament [see Figure 4]. These rings maintained a slight tension on the distal ends of the sensors, enhancing their responsiveness without compromising comfort.

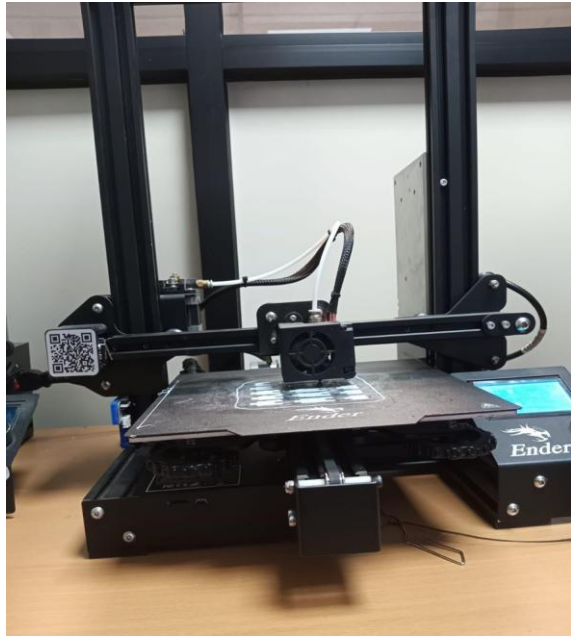
This type of mechanical integration reflects the principles of functional modularity and ergonomic adaptation essential in current wearable rehabilitation technologies.

This hybrid design approach demonstrates a practical balance between functionality, user comfort, sustainability, and performance, particularly important in the context of low-cost and scalable rehabilitation tools.

Box 4**Figure 4**

SolidWorks drawing of 3D-printed rings for sensor fixation on finger phalanges

Source: authors

Box 5**Figure 5**

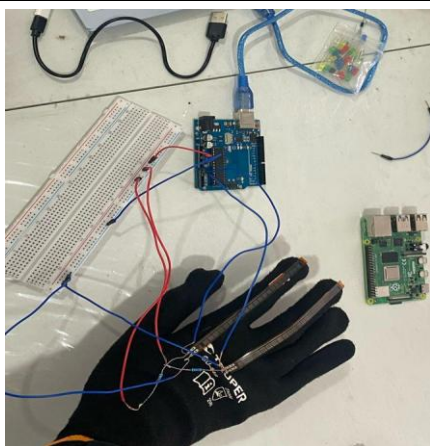
Photograph of 3D printer fabricating the ring pieces

Source: authors

Additionally, an external 3D-printed enclosure was developed and mounted on the wrist to protect the microcontroller and wiring distribution without hindering hand flexion [see Figure 5].

Sensor integration

Flexible resistive sensors were employed, widely validated in motor rehabilitation for their sensitivity to curvature changes. These sensors detect changes in electrical resistance when bent, enabling precise measurement of finger movements [Liu, Luo, Kuang, Wan, Liang, Jiang, Cong, & Hen, 2024] [see Figure 6].

Box 6**Figure 6**

Sensor resistance readings during finger flexion

Source: authors

Actuation module

A compact servomotor was mounted at the wrist, providing active assistance during specific therapeutic exercises [see Figure 7]. This module does not restrict voluntary hand movement and can be programmed to assist passive or active motions. This design draws from previous works that use soft actuators or external motors to promote neuroplasticity without compromising user comfort [Yap, Lim, Nasrallah, & Yeow, 2017]. Unlike systems that rely on pneumatic actuation to achieve movement [BARRERA CALDERÓN & RODRÍGUEZ HERNÁNDEZ, 2025], the RECOVGLOX prototype uses an electromechanical approach that ensures minimal external components and simplifies the overall system structure.

The servomotor was carefully selected for its lightweight and low-profile characteristics, ensuring minimal interference with natural wrist and finger kinematics during use. It offers precise position and speed control via PWM signals, enabling smooth and customizable actuation profiles tailored to individual therapy needs. The motor's torque output is sufficient to assist finger flexion without causing discomfort or risking injury.

Control algorithms incorporate safety features such as acceleration limits and position boundaries, preventing abrupt or excessive movements. Integration with the Arduino microcontroller allows real-time adjustment of the motor based on sensor feedback, facilitating adaptive assistance that responds to the user's voluntary effort. This closed-loop control supports graduated rehabilitation protocols, encouraging active participation while providing necessary support.

The servomotor's compact size and ergonomic placement at the wrist enable a minimally intrusive design, preserving wearer comfort and freedom of movement. Wiring is routed through flexible tubing to prevent entanglement and ensure durability. Additionally, therapists can remotely adjust actuation parameters through the user interface, allowing therapy sessions to be personalized in real time according to patient progress.

Overall, this servomotor module effectively balances functional assistance with user comfort and safety, making it a practical component of the RECOVGLOX prototype for promoting repetitive, controlled finger flexion movements essential in hand motor rehabilitation.

Box 7

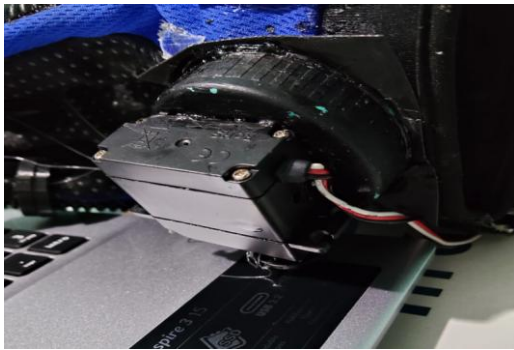


Figure 7

Servomotor module on the bottom of the wrist

Source: authors

Cable management and modularity

To organize and protect system wiring and sensors, flexible tubing was used to cover the flexible sensors themselves, providing mechanical protection and reducing damage from bending or abrasion during use [see Figure 8]. The entire electrical circuit, including the Arduino board, was mounted on the wrist area, protected by a 3D-printed enclosure.

This arrangement ensures user safety by preventing exposed wires that could snag or cause discomfort. It also maintains a compact, ergonomic design that facilitates mobility and simplifies system maintenance. This approach aligns with best practices in the design of portable motor rehabilitation devices [Zhu, Gong, Chu, Wang, Hu, & Su, 2022].

Box 8

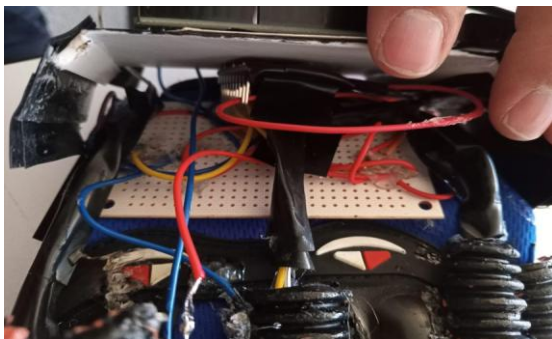


Figure 8

Routing electrical wiring over the wrist

Source: authors

Electronic Integration

The electronic integration of the RECOVGLOX prototype ensures seamless interaction among sensors, actuation, and control, all while maintaining a compact wearable format. The system employs flexible resistive sensors, an Arduino Uno microcontroller, a servomotor, and protected cabling using flexible tubing.

Sensor circuit and signal acquisition

Each flexible resistive sensor connects to an analog input pin on the Arduino Uno, forming part of a voltage divider circuit that converts resistance changes into readable analog voltage [0–1023]. This approach accurately captures finger curvature and is widely used in rehabilitation devices [Biggar & Yao, 2016] [see Figure 9].

Box 9

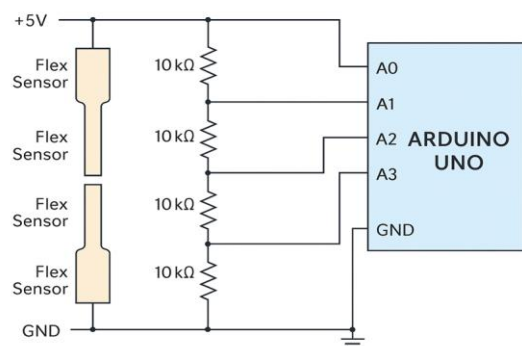


Figure 9

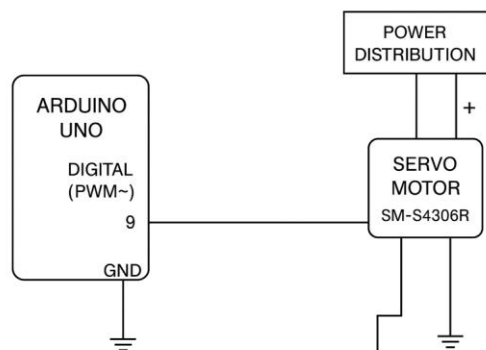
Wiring diagram: sensor to Arduino analog input via voltage divider

Source: authors

Actuation and control system

A micro servomotor is attached to digital pin D9 of the Arduino. The code implements predefined movement routines and sensor-threshold-based assistance, allowing active participation in exercises. Power for the servomotor and sensors is provided by the Arduino's 5 V regulator.

The selected servomotor offers sufficient torque while remaining compact enough not to hinder wrist movement. Similar approaches utilizing compact servomotors controlled by microcontrollers have demonstrated effectiveness in wearable rehabilitation devices, balancing actuation power and user comfort [Ahmed, Sattar, Shahnawaz, Saeed, Khan, & Khan, 2021] [see Figure 10].

Box 10**Figure 10**

Electrical schematic of servomotor control and power distribution

Source: authors

Programming and Calibration

The microcontroller was programmed using the Arduino IDE with a custom script that:

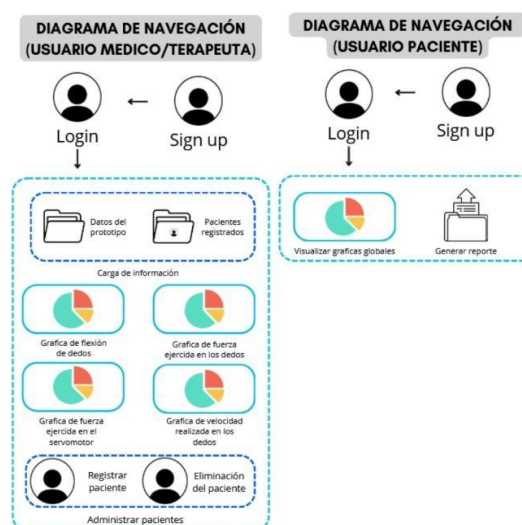
1. Continuously reads the analog values from the resistive flexible sensors connected to the Arduino's analog inputs.
2. Measures the force exerted by the user using a pressure sensor located on the fingertip of the index finger.
3. Estimates the servomotor's force based on PWM signal parameters and current consumption, thus obtaining an approximation of the mechanical effort applied.
4. Calculates the finger flexion angle by interpolating the analog sensor values, using as reference the minimum [rest position] and maximum [full flexion] values obtained during an initial manual calibration.
5. Measures the servomotor operating speed, calculated from the variation of the output shaft angle over time during active assistance routines.
6. Sends all data via serial communication to a laptop, where a Python script receives, processes, and automatically uploads the data to a cloud database [Firebase] for storage and remote visualization.

Calibration was performed manually by recording sensor readings at rest position and maximum flexion, with the purpose of normalizing measurements for each user before starting therapy sessions.

Development of Web and Mobile Interfaces

To deliver an accessible and seamless user experience, two complementary platforms were developed: a mobile application and a web interface. The mobile app was built using Flutter, a cross-platform framework that enables a single codebase for both Android and iOS devices, simplifying maintenance and accelerating future updates.

The web interface follows a client-server architecture, with the front-end implemented in React to enable dynamic and interactive user experiences, and the back-end developed with Node.js and Java to manage business logic, data processing, and integration with cloud databases. The navigation logic of both platforms is illustrated in Figure 11.

Box 11**Figure 11**

Navigation diagram

Source: authors

Both platforms are integrated with Firebase, facilitating real-time data synchronization from the prototype. They also provide comprehensive graphical visualizations of the measured parameters and offer customizable therapy settings. These features empower therapists to remotely monitor patient progress while encouraging patient autonomy—factors that have been demonstrated to improve adherence and outcomes in stroke rehabilitation [Inoue & Fushimi, 2015].

Screenshots of the web interface are shown in Figure 12, while Figure 13 presents the corresponding mobile application interface.

A core aspect of the testing was to verify the device's responsiveness and ability to adapt to partial user input. For users who were able to initiate a flexion movement but could not complete it due to weakness or fatigue, the RECOVGLOX system successfully detected the initiation through rising analog values and automatically triggered servomotor assistance to complete the motion. This intelligent transition between voluntary and assisted movement contributed to a more natural rehabilitation experience, avoiding abrupt or robotic interventions.

In addition to confirming the glove's actuation capabilities, the tests also evaluated how the system responded to repeated use. Across multiple trials, the servomotor demonstrated consistent torque delivery without overheating or loss of precision. The flexible sensors maintained stable readings over time, showing minimal drift and high repeatability.

This consistency is critical in therapeutic applications where long-term reliability directly impacts patient progress monitoring.

Furthermore, the physical structure of the glove proved to be well-tolerated during prolonged use. Participants reported that the materials used, such as elastic textiles and 3D-printed supports, did not cause skin irritation or significant discomfort, even after several consecutive sessions. The dorsal sensor fixation method—based on a recycled plastic tube—remained effective in preserving sensor alignment while allowing sufficient finger mobility.

This set of observations provided a foundation for more detailed assessments in the following areas, including signal quality, real-time data processing, actuation behavior, user interface performance, and overall usability in simulated therapy environments.

Data Capture and Processing

The flexible sensors embedded on the glove fingers captured coherent and repeatable analog signals associated with user finger movements. These signals corresponded to variations in electrical resistance during flexion, demonstrating the system's ability to detect grasp-related movements precisely.

Real-time data processing through a Python script enabled the generation of flexion graphs during testing sessions, which facilitated immediate visual feedback of joint mobility [see Figure 15]. This real-time processing capability is consistent with previous research highlighting the benefits of embedded signal analysis in rehabilitation settings [Giggins, Persson, & Caulfield, 2013].

Box 15



Figure 15

Real-time flexion graph captured during a rehabilitation session involving four-finger grasp movement

Source: authors

Servomotor Control for Assisted Grasp
The integrated servomotor provided smooth and controlled assistance to the four fingers involved in grasping. Thumb movement was not included in this initial prototype. The system allowed for passive motion, enabling patients with limited mobility to perform grasp-like gestures safely.

This approach aligns with other studies using soft robotics for finger flexion in stroke rehabilitation [Heung, Tang, Shi, Tong, & Li, 2020]. Customization of movement intensity and speed allowed therapists to adapt therapy sessions to patient needs.

Remote Visualization and Monitoring

The web and mobile interfaces reliably displayed real-time flexion data. Through Firebase integration, therapists could monitor patient progress remotely and review session history. Adjustable therapy parameters and session recording fostered personalization and adherence—key elements in modern telerehabilitation frameworks [Giggins et al., 2013].

Nurse-Led Usability Testing

Usability testing was conducted with four nurses, who interacted with the device to simulate real-world clinical use.

Objective: Assess usability for both patient and clinical staff.

Findings: Nurses reported positive feedback regarding the setup, comfort, and intuitive interface. The motor's responsiveness was praised for its gradual and safe assistance. Some suggestions included adding visual progress indicators and feedback tones during calibration.

Photographs taken during these sessions illustrate the interaction with the system [Figure 16] and the collaborative calibration process between the development team and nursing staff [Figure 17].

Box 16



Figure 16

Nurse performing a simulated rehabilitation session using the RECOVGLOX prototype

Source: authors

Box 17



Figure 17

Development team working collaboratively with nurses during calibration and evaluation of the glove

Source: authors

Limitations and Future Work

Although preliminary results are promising, the system requires more extensive clinical validation to assess long-term therapeutic impact. Future improvements may include integrating thumb movement, refining sensor calibration, and enhancing mechanical stability.

Additionally, exploring advanced sensor technologies, such as multi-axis inertial measurement units [IMUs] or piezoelectric sensors, could improve motion capture accuracy and responsiveness. Enhancements in wireless communication protocols and power management would also increase user comfort and device autonomy, enabling longer and more flexible therapy sessions. Furthermore, developing adaptive control algorithms capable of real-time adjustment to individual patient needs could optimize assistance levels and promote more effective neuroplasticity.

Expanding the system's compatibility with other rehabilitation devices or virtual reality platforms may also enrich therapy experiences and increase patient engagement. From a clinical perspective, conducting longitudinal studies with diverse patient populations will be essential to evaluate efficacy across different types and severities of motor impairment. Additionally, incorporating user feedback loops and ergonomic assessments can guide iterative design improvements to maximize comfort, ease of use, and compliance. These efforts follow recommendations in robotic rehabilitation literature [Maciejasz, Eschweiler, Gerlach-Hahn, Jansen-Troy, & Leonhardt, 2014].

Discussion

The results obtained with the RECOVGLOX prototype highlight the significant potential of sensorized IoT-based gloves in hand motor rehabilitation. The system's ability to accurately capture finger flexion patterns through flexible sensors demonstrates successful integration of mechanical and electronic components. This supports the notion that continuous and objective motion tracking is essential for evaluating patient progress and guiding therapy—an approach validated in prior studies involving biofeedback and motion sensors [Giggins et al., 2013].

The implementation of a servomotor as a source of passive motor assistance provides an important therapeutic advantage, especially for patients with limited voluntary movement.

Controlled, repetitive movements induced by the motor contribute to promoting neuroplasticity and facilitating functional recovery, consistent with findings on the effectiveness of soft robotic actuators in stroke rehabilitation [Heung et al., 2020].

Furthermore, assisted therapy has been shown to improve motor outcomes by enabling patients to execute movement sequences that would otherwise be painful or impossible, as emphasized by foundational research in neurorehabilitation [Aisen, Kerkovich, Mast, Mulroy, Wewn, Kay, & Rethlefsen, 2011].

From a technological perspective, the use of serial communication between the Arduino microcontroller and the local processing system [via a Python script] represents a low-cost yet functional architecture. This configuration enables real-time signal acquisition and processing, while also supporting cloud storage via Firebase, enhancing remote access and long-term data management. Such a modular and scalable system design is especially valuable in low-resource or home-based rehabilitation scenarios, where cost and simplicity are critical factors [Maciejasz et al., 2014].

The web and mobile interfaces developed using React, Node.js, and Flutter, respectively, significantly contribute to the accessibility and clinical usability of the device. These platforms allow for remote monitoring, customization of therapy parameters, and session recording, reinforcing patient autonomy and enabling constant feedback from therapists. This aligns with previous reports indicating that digital tools supporting telerehabilitation and remote supervision improve patient engagement and therapy continuity [Giggins et al., 2013].

An additional strength of the study lies in the usability testing conducted with nursing staff, which revealed positive feedback regarding the device's ergonomics, ease of use, and responsiveness. Their input highlights the importance of clinical validation with end-users, and suggests that RECOVGLOX is intuitive enough to be adopted in professional environments with minimal training.

Despite these achievements, the prototype still presents areas for improvement. First, the hardware robustness—particularly in sensor fixation and cable management—requires refinement to ensure reliability under prolonged use. Second, the precision of measurements could benefit from advanced calibration methods and higher-sensitivity materials. Most importantly, the system's therapeutic impact must be validated through clinical trials with real patients, allowing for a detailed assessment of long-term motor recovery outcomes [Maciejasz et al., 2014]. While RECOVGLOX is currently optimized for adult patients suffering from post-stroke hemiparesis, the necessity of specialized solutions for other age groups is recognized in the literature; for instance, devices like Handhelper have been designed specifically for pediatric hand rehabilitation [Barrera Guevara, González Pérez, Moreno Suárez, & Vidal Rojas, 2025].

In summary, RECOVGLOX emerges as a scalable, adaptable, and user-friendly platform for hand motor rehabilitation. By combining IoT capabilities, real-time signal processing, and mobile accessibility, the system offers a promising approach to democratizing access to rehabilitation technologies, especially in under-resourced or remote settings. Its design aligns with current trends in digital health and patient-centered care, contributing to the development of more inclusive, effective, and connected rehabilitation solutions.

Conclusions

The development and preliminary evaluation of the RECOVGLOX prototype demonstrate the high potential of sensorized gloves based on IoT technologies for supporting hand motor rehabilitation. The successful integration of flexible sensors, real-time data acquisition, embedded control, and cloud-based communication enabled accurate tracking of finger joint movements and effective passive motor assistance through servomotor actuation.

The inclusion of intuitive web and mobile interfaces significantly enhanced the user experience by enabling remote monitoring, therapy customization, and longitudinal tracking of patient progress. These capabilities not only facilitate clinical follow-up but also promote patient autonomy—two key factors in improving adherence to rehabilitation protocols, particularly in home-based or decentralized care settings.

The system aligns with emerging trends in digital rehabilitation, where accessibility, adaptability, and user-centered design are essential for scaling therapy beyond conventional clinics.

Moreover, the positive feedback obtained during preliminary usability tests with healthcare professionals reinforces the feasibility of integrating RECOVGLOX into multidisciplinary rehabilitation programs.

Nonetheless, to move toward clinical deployment, further research is needed. This includes conducting controlled clinical trials to validate long-term therapeutic efficacy, refining the mechanical robustness of the prototype, and optimizing the sensor calibration and signal accuracy under diverse usage conditions.

In conclusion, RECOVGLOX provides a scalable and cost-effective technological solution that bridges the gap between academic innovation and practical clinical application. Its modular architecture and ease of use make it a strong candidate for implementation in both rehabilitation centers and home therapy environments, ultimately contributing to enhanced quality of life for individuals with motor impairments and to the advancement of patient-centered digital health systems.

Annexes

All complementary materials related to the RECOVGLOX prototype—including electronic schematics, CAD models, source code [Arduino, Python, and Flutter], experimental data, and user manuals—are openly accessible through the following public repositories:

[Main Repository – RECOVGLOX Hardware and Firmware Database Management – Backend Services Web Interface – Frontend Application](#)

Declarations

Conflict of interest

The authors declare no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the content of this article.

Author Contribution

Ojeda-Hernández, Mario Alberto and *Barreto-Ocampo, Santiago*, as team members, actively participated in the design and development of the RECOVGLOX prototype, including electronic integration, functional design, and embedded software programming.

Ledesma-Uribe, Norma Alejandra and *Juárez-Santiago, Brenda* provided academic guidance, methodological supervision, and critical review of the technical documentation and report.

All four authors participated in the writing, review, and final approval of this article.

Availability of data and materials

Funding

This research did not receive external funding or financial support from institutions, universities, or companies.

Acknowledgements

The authors thank the institutional and technical support provided by the Universidad Tecnológica de San Juan del Río, as well as the collaboration and dedication of the team members: Aldo Gustavo Ayala Mejía, Héctor Coronel Limias, Santiago Barreto Ocampo, Mario Alberto Ojeda Hernández, Moisés Jacob Medina Salmerón, Edgar Ortega Cabrera, Ramiro Rivera Paz, and Francisco Javier Gutiérrez Araujo, who contributed significantly to the development of the RECOVGLOX prototype. Special recognition is also extended to Dr. Brenda Juárez Santiago and Dr. Norma Alejandra Ledesma Uribe for their valuable academic support and guidance throughout the project.

Abbreviations

IoT	Internet of Things
RECOVGLOX	Acronym for RECOVERY GLOVES with "X" representing adaptability for anyone
SEAES	Higher Education Evaluation and Accreditation System of Mexico
MCP	Metacarpophalangeal [joint in the fingers]

Article

IP	Interphalangeal [joint in the fingers]
PLA	Polylactic Acid [3D printing material]
PWM	Pulse Width Modulation
IMUs	Inertial Measurement Units
Arduino IDE	Integrated Development Environment for Arduino programming
USB	Universal Serial Bus
GUI	Graphical User Interface
API	Application Programming Interface
VR	Virtual Reality

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Proposed prosthetic device for energy storage and return for the lower limbs



Dispositivo protésico propuesto para el almacenamiento y retorno de energía para las extremidades inferiores

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Classification:

Area: Engineering
Field: Engineering
Discipline: Mechanical Engineering
Subdiscipline: Mechanical design

 <https://doi.org/10.35429/JP.2025.9.20.2.1.12>

History of the article:

Received: October 19, 2025

Accepted: December 30, 2025





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Abstract



A prosthetic scheme is presented for the design of transtibial lower limb prostheses for replacement in users with moderate energy activities. It is based on elastic and rigid components that allow energy storage and return during the gait phases. The design is based primarily on the location of the centres of mass of the biological regions that are being replaced. A computational tool was developed to support the design, which calculates the location of the centres of mass. The results were verified against those obtained from healthy biological limbs of a population ranging in height from 150 cm to 189 cm. The calculation tool was found to have a variation of around 1%, which is considered acceptable and favours the stability of the prosthesis and its overall interaction to achieve a viable and functional design.

Resumen

Se presenta un esquema de diseño de prótesis de miembro inferior transtibial, para usuarios con actividades de energía moderada. El cual se basa en componentes elásticos y rígidos que permiten el almacenamiento y retorno de energía durante las fases de la marcha. El diseño se basa principalmente la ubicación de los centros de masa de las regiones biológicas que son reemplazadas. Se realizó una herramienta computacional como apoyo al diseño, que calcula la ubicación de los centros de masa, cuyos resultados se verificaron con los obtenidos de miembros biológicos sanos de una población cuyas tallas oscilan entre los 150 cm y 189 cm. Se obtuvo que la herramienta de cálculo presenta una variación de alrededor de 1%, lo que considera aceptable y que favorece la estabilidad de la prótesis y su interacción en conjunto para el logro de un diseño viable y funcional.

Proposed prosthetic device for energy storage and return for the lower limbs		
Objetives	Methodology	Contribution
 + 50 million of people require a prosthesis for lower limb. A dynamic foot is a viable alternative.	Define: Type of amputation, level of activity, configuration of the biological centre of mass and the prosthesis, loads and geometry, and establish the prototype.	 Prosthesis designed for a range of sizes from 165 to 177 cm with a difference of less than 1.2% between centres of mass.

Centre of mass, dynamic foot, prosthesis design

Dispositivo protésico propuesto para el almacenamiento y retorno de energía para extremidades inferiores		
Objetivo	Metodología	Contribución
 + 50 millones de personas requieren prótesis de miembro inferior. El diseño de pie dinámico es una alternativa viable.	Se define: Tipo de amputación, nivel de actividad, configuración del centro de masa biológico y de la prótesis, cargas y geometría, para llegar a establecer el prototipo.	 Prótesis diseñada para tallas de 165 a 177 cm, para actividades moderadas, y diferencia menor a 1.2% entre los centros de masa biológico y de prótesis.

Centro de masa, diseño de prótesis, pie dinámico.

Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: Bedolla-Hernández, Jorge, Islas-ZistecatI, Rolando, Bedolla-Hernández, Marcos and Cruz-García, José Michael. [2025]. Proposed prosthetic device for energy storage and return for the lower limbs. Journal of Physiotherapy and Medical Technology. 9[20]1-12: e2920112.



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Introduction

As a result of various types of health problems, trauma caused by car or work accidents, or certain congenital conditions, patients may require the amputation of biological limbs through surgery. In general, an amputation is defined as the loss of one or more parts of the human body, involving surgery [Asif et al., 2021]. Among these conditions, it has been identified that the most common cases of amputation involve the lower limbs, which is considered to significantly affect the mobility of people suffering from this condition [Perkasa et al., 2025].

On the other hand, this condition is key in any person, since the fundamental difference between humans and other mammals is the ability to walk upright on two feet [Vladu et al., 2024]. In this regard, the World Health Organisation estimates that the global demand for prostheses is between 35 and 40 million people [Chadwell et al., 2020]. However, data such as that reported by the National Institute of Health estimates that 57 million people worldwide live with a lower limb amputation [Kyriakidis et al., 2025]. Similarly, although data on amputations in Mexico are not entirely consistent, there are an estimated 780,000 leg amputations, and the National Health and Nutrition Survey indicates that more than 5 million people in Mexico have mobility problems related to this issue [Mexico, 2024].

Based on statistics on lower limb amputations in the population, it has been established that the design of prostheses to replace such limbs plays a crucial role in the recovery of physical and psychological characteristics and promotes the social integration of people with amputated limbs [Alluhydan et al., 2023]. Based on this idea and on the demand for biological replacements that contribute to the better adaptation of people with lower limb amputations, it is considered necessary to develop prostheses that effectively contribute to restoring mobility and, in general, to re-establishing the well-being of people with amputated limbs. In addition to the above, it is considered that in the design of lower limb prostheses, it is necessary to take into account that the development of artificial replacements depends on various factors, depending on each particular case.

However, in general, when designing such replacements, it is essential to consider factors such as biocompatibility, weight, safety, effectiveness, and user comfort.

To this end, it is established that an important aspect is the analysis of the biomechanical parameters derived from the positions and movements of the body's centre of mass and the amputated parts [Simonetti et al., 2021].

On the one hand, the constant evolution of prostheses is driven by technological advances and new research focused on individuals requiring replacements, which allows for the exploration of advanced materials, robotic technologies, and exoskeletons [Sopiyan et al., 2025]. Studies have been conducted on this topic, such as the one presented by Alluhydan et al. [2023], which includes a comprehensive review of recent advances in prosthetic design, as well as the respective methodologies and relevant findings. However, the economic aspect is another factor that must be considered in order to meet the main requirements of people with amputations. This is considering that 90% of people with disabilities that significantly affect their mobility live in developing or emerging countries; while, similarly, in developed countries, most people with lower limb amputations belong to sectors of the population with low economic status [Althahabi et al., 2025].

Given that the main function of lower limb prostheses is to support the recovery of mobility in people who have undergone this type of amputation, the development of accessible prostheses becomes a key factor in the rehabilitation of amputees, with a view to improving their quality of life.

While cost is a factor, it should not be the basis for demeriting or conditioning the main characteristics required of a prosthesis. To contribute to this aspect, research has been conducted in which the specifications of the prosthesis, together with its performance, reliability, and response to the user, are considered so that the total cost of manufacturing and materials is kept to a maximum of USD 100 [Falbriard et al., 2022], or research in other cases, where the design of transtibial prostheses must be sustainable and cost-effective [Sopiyan et al., 2025].

Lower limb amputations can be classified in different ways depending on the different levels they represent. One of the main classifications is based on the location of the amputation, referring to the anatomical location [Wong et al., 2016]. Figure 1 shows the main classification of lower limb amputations.

Box 1

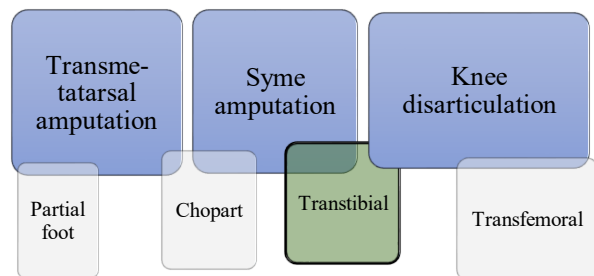


Figure 1

Classification of lower limb amputations

Adapted from Alluhydan et al., [2023]

Given the variety of lower limb amputations, this paper focuses only on transtibial amputation. This refers to the removal of the lower part of the leg, including a portion of the tibia, while preserving the knee. The interest in studying this type of amputation stems from the fact that it is one of the most common types of lower limb amputation and occurs for various reasons, including trauma, vascular disease, and complications from diabetes [Alluhydan et al., 2023].

When designing prostheses, it is important to bear in mind that standardising them for the entire community is no easy task, as the level of mobility, gender and age of each patient must be taken into account [Manz et al., 2022]. For people with lower limb amputations, it is necessary to determine the suitability of passive, quasi-passive, and active prostheses. It has been found that passive ankle and foot prostheses, quasi-passive prostheses, and active prostheses [dynamic feet] provide improvements in quality of life [Lathouwers et al., 2023].

In this regard, a quasi-passive alternative is prostheses known as dynamic feet [Falbriard et al., 2022], which are designed and configured geometrically and materially to store and return energy and are suitable for people with moderate to high activity levels.

Energy storage and return prosthetic feet are passive devices that are widely used and manufactured with elastic materials that function as springs to store and release energy during the gait cycle [Saemua & Rooppakhun, 2025]. The preference for dynamic foot prostheses [with energy storage and return] is due to their performance during walking, as they are attributed with greater thrust power with a higher centre of mass velocity [Asif et al., 2021]. In particular, in the case of lower limb amputations, an important aspect that requires special attention and analysis is the distribution of loads and stresses similar to those present in the biological limb [Kyriakidis et al., 2025].

In addition to the conditions associated with lower limb amputation, walking is altered exponentially, leading to lower back pain. The body begins to adopt altered motor control/behaviour strategies, resulting in instability along with increased thoracolumbar movement. Which results in altered pelvic and trunk behaviours to be altered when performing activities such as walking [Butowicz et al., 2019].

In accordance with the above, it is established that lower limb prostheses represent an alternative for regaining mobility and quality of life; however, there are still several areas of opportunity in the design of these components. Prostheses must be adapted according to the type of amputation and the level of personal activity. Based on the fact that the main types of amputations are transtibial amputations and that one of the main trends is the dynamic foot [due to its benefits] with energy storage and return, this study presents a design proposal for this type of prosthesis.

For this study, the design focuses on determining the location of the centres of mass of the removed biological part. To this end, a computational interface is established that allows this position to be calculated, and this data is used to establish the configuration of the dynamic foot. The aim is to ensure that the distribution of loads in the prosthetic element is analogous to that in the removed biological part. The proposed design takes as its main elements three components of simplified geometry. These correspond to two rigid elements that provide the stability of the system, and a flexible element that connects the former.

This configuration provides the rigidity, cushioning and energy recovery characteristics of a dynamic foot when walking with the prosthesis. Its behaviour resembles that of a biological foot. In addition to the interface for locating the centres of mass, numerical simulations are performed using commercial software and the finite element method to verify the reliability of the proposed element. This allows the load distribution of the proposed element to be corroborated.

The socket that allows connection to the stump is added to the element thus obtained. The complete system thus obtained is modelled to check the correspondence of the load distribution and location of the centres of mass, whose data is compared with that expected from a healthy biological part.

The first section of this manuscript covers the importance of lower limb prostheses, along with the general characteristics of a semi-passive transtibial prosthesis with energy return. The second section presents the methodology proposed for the development of the dynamic foot prosthesis design. In the initial stage, the characteristics and level of activities to be met by the prosthesis are established. In addition, based on age ranges, the potential population estimated to be susceptible to the application of the transtibial lower limb prosthesis is defined as a percentage.

The procedure for defining the centres of mass of amputated lower limbs is also established. To this end, a computational tool is designed and developed to calculate the location of the centres of mass of the amputated limbs, as well as the components of the prosthesis that will replace them. This allows for a relatively small difference between the centre of mass of the proposed prosthesis in each case and the amputated biological limbs being replaced. Subsequently, the main load conditions supported by the prosthesis during the gait cycle are established. Loads and moments are determined to establish the materials and configuration, leading to the design of the proposed prosthesis. The third section presents the results of the prosthesis and compares them with the requirements of potential users. Finally, the conclusions of the study are presented, summarising the validity and viability of the proposed prosthesis.

2. Methodology

The methodology used in the study consists of four central aspects: establishing the required characteristics of transtibial prostheses together with anthropometric definitions, obtaining a tool for determining centres of mass, analysing forces and stresses on the foot, and designing the prosthesis assembly.

2.1 Prosthesis characteristics

In order to define the characteristics of prostheses for the transtibial amputee population, the notes and considerations made by Legro et al. [2001] are taken as a representative basis for defining the population and type of prosthesis based on biological aspects and common activities performed by patients. Energy levels are established that correspond to the activities performed by the patient.

This study reports that for high energy levels [hunting, basketball, and other high-energy sports], the population of men and women with transtibial amputations was 13.5% and 4%, respectively. This means that moderate-energy activities [which are considered to include low-energy and sedentary activities] represent 86.5% and 96% of the total activities that a person performs. On the other hand, this study groups the energy level of the activities performed into age intervals. As shown in Figure 2, the percentages of moderate activities are highest for ages 20-39, 40-59, and 60-83.

Based on the above, it is established that the characteristics of the prosthesis focus on a range of moderate activities, which, as can be seen in Figure 2, account for the highest percentage of activities for all ages of patients with prostheses who have transtibial amputation.

This is considered to cover the widest range of activities [excluding high-impact activities] for a level of activity and for the highest percentage of people in different age groups. This definition of activities also allows us to establish that a passive or semi-passive system, such as the dynamic prosthetic foot, covers the main requirements for the level of activities and ages.

2.2 Interface tool for calculating centres of mass

The design of the tool for calculating centres of mass, based on the healthy biological lower limb, facilitates comparison of the location between the centres of mass that originally represent the biological limbs in contrast to that of an amputated limb and the prosthesis that replaces it. To obtain the calculation tool, a methodology is followed that relates the size of each limb to the location of its centre of mass. Given that the location of the centre of mass is a key indicator for quantifying the stability of the prosthesis and the loads that arise as a result of it.

Box 2

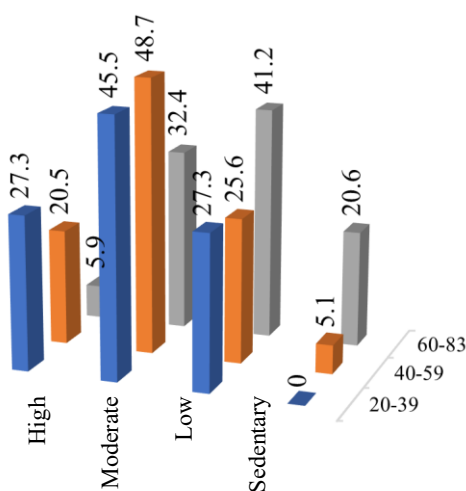


Figure 2

Distribution by age and energy level of activities.

Adapted from Legro et al. [2001]

To obtain a customised centre of mass estimate, the Statically Equivalent Serial Chain [Gonzalez et al., 2014] is used. To do this, it is essential to consider the segments one by one that are analysed in the chain, in this case: thigh, calf and foot.

By treating each segment as a link with constant dimensions, it can be observed that the positions of the links change according to the phase of gait. The anthropometric values from Winter [2009] greatly facilitate the measurement of the lower limbs, since the length of each body limb can be obtained from a person's height [H]. Equations [1] to [4] allow the segmental lengths of the foot, calf, and thigh to be determined.

$$L_F = H * 0.152 \quad [1]$$

$$A_P = H * 0.039 \quad [2]$$

$$L_P = (H * 0.285) - A_P \quad [3]$$

$$L_M = (H * 0.530) - L_P \quad [4]$$

From the information obtained from the lengths of the members in the chain under analysis, the mass of each of these sections is also obtained. In this case, equations [5] – [6] are used for segmental masses in males, and equations [7] – [8] are used for females. This provides the mass of the lower limbs for any person with only their total mass.

$$M_{PH} = M_{MH} = mt * (0.0433) \quad [5]$$

$$M_{FH} = mt * (0.0137) \quad [6]$$

$$M_{MM} = M_{PM} = mt * (0.0481) \quad [7]$$

$$M_{FM} = mt * (0.0129) \quad [8]$$

Based on this data and by parameterising a measurement percentage, the centre of mass is obtained distally or proximally. In the case under study, the centres of mass were obtained proximally, as shown in equations [9]-[16].

$$CMh_{muslo} = L_M * 0.4241 \quad [9]$$

$$CMh_{pamtorrilla} = L_P * 0.4554 \quad [10]$$

$$CMh_{pie\ alto} = A_P * 0.1901 \quad [11]$$

$$CMh_{pie\ largo} = L_F * 0.4415 \quad [12]$$

$$CMm_{muslo} = L_M * 0.4313 \quad [13]$$

$$CMm_{pamtorrilla} = L_P * 0.4538 \quad [14]$$

$$CMm_{pie\ alto} = A_P * 0.1901 \quad [15]$$

$$CMm_{pie\ largo} = L_F * 0.4014 \quad [16]$$

In the centres of mass for the foot in the tool configuration, two different measurements are taken; that is, the centre of mass is taken from the proximal sagittal view of the rearfoot to the forefoot, and the other measurement is taken proximally, but with respect to the floor for verification purposes.

The anthropometric measurements considered in the calculations of the tool can be used for completely healthy individuals, and the existing analysis for obtaining anthropometric measurements of amputees follows the same principle. For this purpose, each limb of the human body is divided into segments approximating a truncated cone in order to determine its volume and subsequently its centre of mass.

2.3 Stresses and loads

To understand how foot loads make contact during each walking cycle, it is necessary to take into account the reaction forces that occur during the cycle. The load axis is considered a fundamental aspect for establishing gait and cadence.

In order to determine the centre of load for its application in the calculation tool, a study was conducted on 60 volunteer patients who participated in the study. Postural analysis using a flat grid was used to define the load axis.

The data collected from the participants included age, sex, height, weight, foot size, measurement from the calcaneus to the load axis, and height of the arch of the foot. From this data and based on the tool designed to obtain the centres of mass of the lower limb [healthy and amputated], the load axis was obtained according to the sizes corresponding to the participants in the study.

For the analysis of the gait cycle and the loads that occur throughout it, reaction forces must be taken into consideration. Where the areas of the foot with the highest pressure, with different activities and in different environments, for load distribution [W], 60% of W is supported by the rearfoot [heel] and 40% of W by the forefoot, as shown in Figure 3.

Box 3

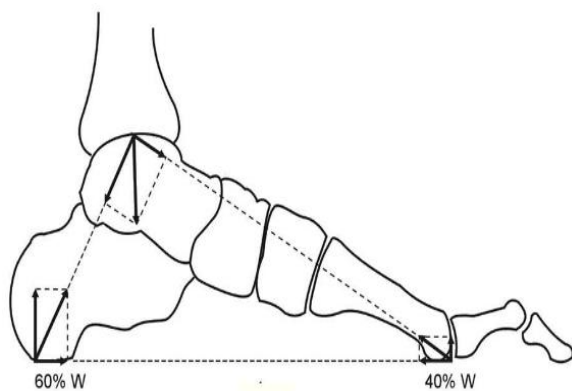


Figure 3

Load distribution

Adapted from Voegeli [2003]

If the foot is divided into sections corresponding to the rearfoot, midfoot, and forefoot, and plantar pressures are considered, it is established that the entire stance phase of gait, where the greatest pressure and reaction force are found, consists of the following positions: a] first position with only the rearfoot in contact with the floor; b] second position with the entire sole of the foot in contact with the floor, covering 2% to 40% of the gait phase; c] third position for pre-rocking, the angle of plantar flexion for a healthy person is taken to be around 30° to 50°, with the forefoot making all the contact.

The second position of the gait cycle represents most of the contact phase, where the rearfoot, midfoot, and forefoot do not lift off the ground. This phase represents a completely vertical force from the tibia to the ankle and a normal force connecting to the ankle. For positions 1 and 3, the analyses are very similar, as the principle for breaking balance is the same when standing, whether for plantar flexion or dorsiflexion. For the development of the analysis, free-body diagrams help to understand how to apply forces in a model so that its representation closely approximates what happens in normal gait without pathologies.

2.4 Proposed design

The design of the dynamic prosthetic foot takes into account the personal requirements of patients. Figure 4 shows the considerations established in a matrix displaying the design requirements and patient requirements considered for this study, based on Quality Function Deployment [QFD].

This establishes a useful methodology for gathering patient demands based on the relationship between operating characteristics and satisfaction techniques.

The prosthetic foot configuration proposed in this study consists of three main components [in addition to the connecting socket], corresponding to an upper part and a lower part made of 7075-T6 aluminium and an intermediate part made of SBR [styrene-butadiene] elastomer. As part of the research, it is considered that 7075-T6 aluminium [known as aeronautical or aerospace aluminium] meets the mechanical specifications required for the project.

The advantages of using this material are: corrosion resistance, wear resistance, good surface adhesion, excellent machinability, and reduction of machining times by up to 80% compared to other metallic materials. On the other hand, SBR-type elastomer is a material widely used in applications where cushioning, flexibility, and wear resistance are required.

These qualities make this elastomer an excellent choice for functional components of prosthetic feet, especially in areas where shock absorption and energy return are needed during walking, as is the case with the proposed dynamic foot.

3. Results and Discussions

3.1 Characteristics of the prosthesis

As established in section 2.1 and section 1, the main requirement on which the proposed design is based corresponds to a dynamic foot with energy return during walking. Considerations for achieving rigidity and cushioning together are based on the union of two rigid materials and one with considerable deformation capacity between the rigid ones.

Box 4

		Legend							
		⊕	⊖	⊙	⊚	⊛	⊜	⊝	⊞
		Strong Relationship	Moderate Relationship	Weak Relationship					
		9	3	1					
Demedanded Quality (a.k.a. "Customer Requirements" or "Whats")	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Adjusting the geometry and weight of elements	Adjusting anthropometric geometry	Elastomer absorption	Surface contact uniformity	Fatigue resistance	Mechanical resistance	Mechanical elements	Lightweight material
	Centre of mass alignment	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Stable running	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Shock absorption	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Responsiveness	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Durability and resistance	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Reliability	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
No electronic systems	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Weight	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)		10	10	10	10	6	6	1	4
Max Relationship Value in Column		9	9	9	9	9	9	9	9
Weight / Importance		517.5	408.8	336.8	431.6	314.0	314.0	338.6	184.7
Relative Weight		18.1	14.3	11.8	15.1	11.0	11.0	11.9	6.8

Figure 4

Design requirements versus customer requirements

Own source

The materials defined for the prosthesis under study are 7075-T6 aluminium and SBR elastomer. In addition, the definition for the lower limb prosthesis corresponds to a moderate level of energy in the activities to be performed. This classification also includes low-energy and sedentary activities, in order to broaden the universe of the potential target population.

Therefore, it is considered that this proposed system covers on average more than 90% of the potential users of this type of prosthesis, for age ranges from 20 to 83 years. This is in accordance with the information and discussion presented in section 2.1.

3.2 Computer tool for calculating centres of mass

The results obtained for the tool used to determine the centre of mass of biological limbs and the proposed prosthesis are compared with the results of Drillis et al. [1964]. In their study, the lengths and centres of mass analysed were determined from human cadavers and supplemented with approximations using methods of submerging body parts to determine volumes and masses. From this, a maximum difference of 10% was obtained with the data estimated by the tool designed here, which is therefore considered acceptable for the proposed purpose.

To verify the reliability of the tool, the centres of mass are obtained for both healthy and amputated limbs.

It should be noted that a section for determining the centres of mass for the lower limbs has been added to the calculation tool, specifically for obtaining the centre of mass of the calf, the foot and the total centre of mass of the whole.

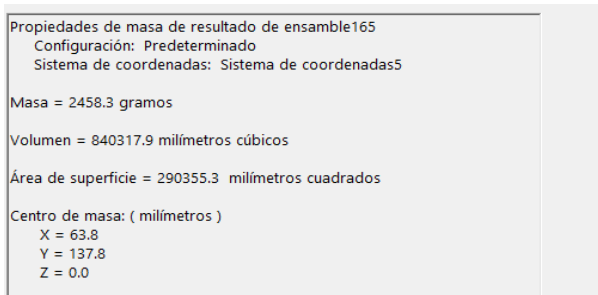
As a representative sample for the study, the case with nominal anthropometric values for an average person 165 cm tall, weighing 70 kg, with a proximal stump circumference of 35 cm, a distal circumference of 25 cm and a total stump length of 14.5 cm was considered. Using the results calculation tool, the predefined lengths, masses, and centres of mass of the lower limb for amputation are obtained. If the patient has undergone a unilateral amputation, the tool for determining centres of mass provides a default value for determining the location of the centre of mass of the amputated limb, including the stump to which the prosthesis is attached.

The prosthetic component must include other components, such as the socket and connector. For these conditions, the tool provides the centre of mass value, together with the value of an added mass to adjust the centre value of the prosthesis to the centre of mass of the amputated biological limb. A representative example is shown in Figure 5 for the tool data and the configuration obtained from that example. Figure 6 shows the prosthesis for patients with a height range from 165 cm to 167 cm.

Table 1 shows the comparison of the centres of mass obtained with the tool for a biological limb and for the proposed prosthesis configuration.

Based on the data obtained from the centre of mass tool, the proposed configuration for the prosthesis, and the percentage differences in the centres of mass shown in Table 1, it is concluded that the configuration is adequate to represent the mass distribution of the biological limb and thus contribute to reducing the load modifications that occur in the patient due to the prosthesis.

Box 5



a]

Assembly result mass properties 165
Configuration: Default
Coordinate system: Coordinate systems 5
Mass = 2458.3 grams
Volume = 840317.9 cubic millimetres
Surface area = 290355.3 square millimetres
Centre of mass: (millimetres)
X=6.8
Y=137.8
Z=0.0

b]

Figure 5

Centre of mass of prosthetic component with added mass for a person 165 cm to 167 cm tall, where a] screenshot in native language of the code, and b] translation

Own source

Box 6

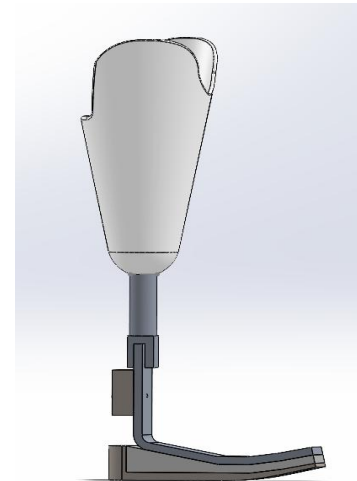


Figure 6

Dynamic prosthetic foot developed with added mass for a person between 165 cm and 167 cm tall.

Own source

Box 7

Table 1

comparativa del centro de masa biológico vs el centro de masa protésico de la diferencia porcentual

Talla [cm]	Diferencia x [%]	Diferencia y [%]
165	0.0166	0.0090
166	0.3098	0.0090
167	0.6031	1.2212
168	-1.8123	-1.1912
169	-1.5269	-0.6031
170	0.0806	-0.0149
171	0.3659	0.5731
172	0.6513	1.1613
173	-0.612	-1.1195
174	-0.3311	-0.5479
175	-0.0501	0.0235
176	0.2308	0.5951
177	0.5118	1.1667

Own source

3.3 Stresses and loads

The results of stresses and strains for the three main stages of the running cycle indicated in section 2.3 are presented below. To this end, simulations were performed using the finite element method and surface-surface contact parameters were taken in order to avoid penetration into the materials.

In the contact interaction constraints between the elements, a 'Tie' type is defined for the elastomer surfaces in contact with the upper and lower parts of the dynamic prosthetic foot.

According to the information in section 2.3, there are three main load positions. In the first and third positions, contact occurs practically in one region of the foot, either the rearfoot or forefoot, respectively.

Meanwhile, the second position during gait corresponds to contact between the entire sole of the foot and the surface.

Figure 7 shows the support and load conditions considered for each of the main load positions, and Figure 8 shows the corresponding stress results obtained for each of these positions.

Box 8

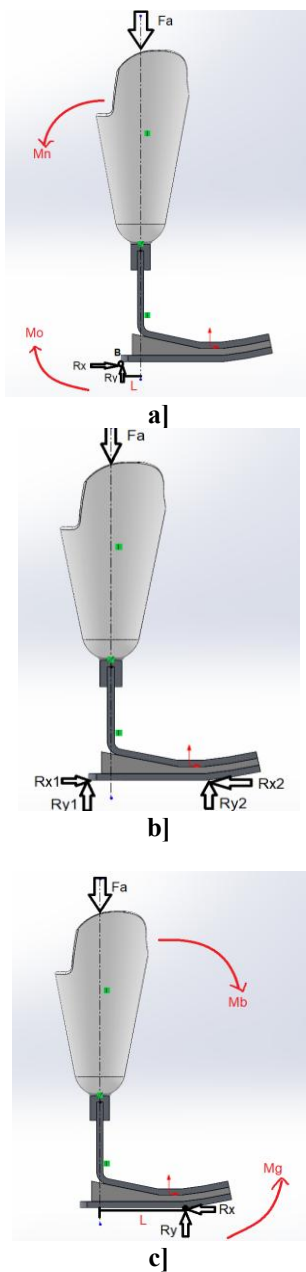


Figure 7
Load considerations for the three main positions of the prosthesis during walking; where: a) first position, b) second position, and c) third position

Own source

Box 9

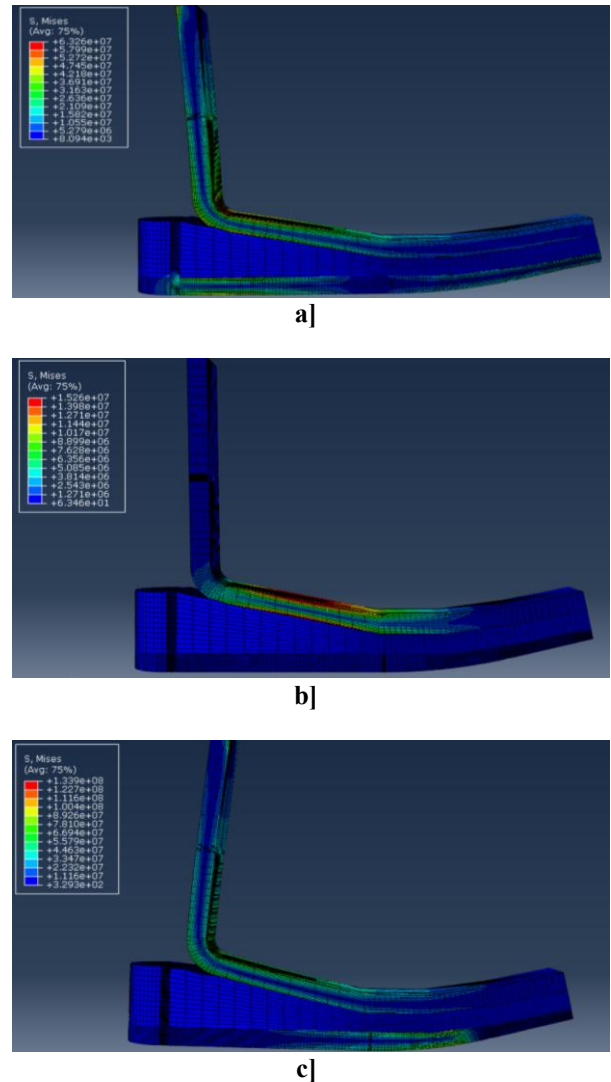


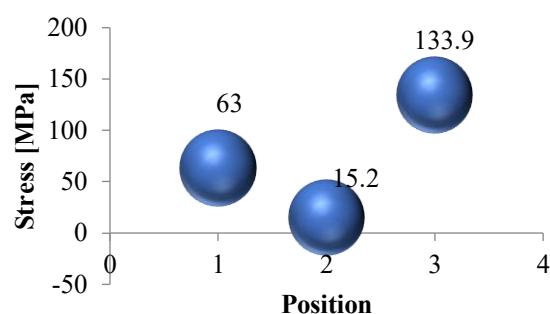
Figure 8
Stress results for the three main positions of the prosthesis based on the loads considered during walking; where: a) first position, b) second position, and c) third position

Own source

In accordance with ISO 10328 regulations, the load applied to the model must be 2.2 times greater than the nominal load for an ideal safety factor. Therefore, according to Figures 7-8, the maximum stress value is 281.2 MPa for the metatarsal position, compared to 133.9 MPa for the nominal load. This equates to a stress difference of 147.3 MPa.

Taking into account the tensile strength value of aluminium with classification 7075-T6, which is 572 MPa, it is below the maximum stress obtained by applying the safety factor of 2.2 as specified in the standard.

Therefore, the result obtained from the finite element analysis is below the minimum stress required for the design of the dynamic prosthetic foot, as shown in Figure 9 for maximum stresses in the three positions.

Box 10**Figure 9**

Maximum effort obtained for the 3 positions, with nominal load

Own source

Conclusions

Based on the results of the calculation interface, geometric design, and centre of mass of the dynamic prosthetic foot, it is concluded that the proposed and developed prosthesis prototype achieves a dynamic prosthetic foot design based on anatomical, biomechanical, and engineering parameters.

The calculation tool for determining centres of mass proved to be viable according to the results obtained, as it presents a maximum difference of 10% in the results, which indicates an acceptable value for anthropometric data respectively.

In the analysis of the centre of mass of the prosthetic component, minimal variations were identified between the model and the biological foot, for values with a height range of 165 cm to 167 cm. with a minimum value of 0.009% and a maximum value of 1.22% for the range from 168 cm to 172 cm, between 0.01% and 1.19%, and for the range from 173 cm to 177 cm, between 0.02% and 1.16%.

These results show that the behaviour of the centre of mass of the proposed design closely approximates that of the biological foot, which is essential for ensuring stability and comfort when walking. Likewise, the 3D design created using software [CAD] and simulations [CAE] made it possible to verify the structural performance for the three positions [heel, standing, and forefoot], confirming its reliability and functionality.

Declarations**Conflict of interest**

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

All authors contributed equally to the conception of the idea, the research methodology, and the simulations performed.

Availability of data and materials

Most of the data presented and supplementary data presented in a representative manner in this work form part of the degree thesis. Islas, R [2025], Diseño de un Pie Protésico Dinámico [Design of a Dynamic Prosthetic Foot] , [thesis to obtain the degree of: master in mechatronic engineering]. Tecnológico Nacional de México / Instituto Tecnológico de Apizaco.

Funding

This work has been funded by Tecnológico Nacional De México, as part of project: Estudio de Esquema de Alternativas en el Proceso de Aprovechamiento de Energía de Escala Reducida Para Sistemas No Convencionales, [grant number: 22406.25-P].

Acknowledgements

The authors would like to thank the National Technological Institute of Mexico [TecNM] for the financial support received for the development of this work.

Abbreviations

A_p	Foot height
CMh_{muslo}	Centre of mass of male thigh
$CMh_{pamtorri}$	Centre of mass of male calf
$CMh_{pie\ alto}$	Centre of mass of male foot [high]
$CMh_{pie\ largo}$	Centre of mass of male foot [length]
CMm_{muslo}	Centre of mass of female thigh
$CMm_{pamtorri}$	Centre of mass of female calf
$CMm_{pie\ alto}$	Centre of mass of female foot [high]

$CMm_{pie\ largo}$	Centre of mass of female foot [length]
H	Total height of the person
L_M	Thigh length
L_P	Calf length
L_F	Foot length
M_{MH}	Male thigh mass
M_{PH}	Male calf mass
M_{FH}	Male foot mass
M_{MM}	Female thigh mass
M_{PM}	Female calf mass
M_{FM}	Female foot mass
mt	Total mass of the person

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Discussions

Alluhydan, K., Siddiqui, M. I. H., & Elkanani, H. [2023]. [Functionality and Comfort Design of Lower-Limb Prosthetics: A Review](#). Deleted Journal, 2[3].

We are plastic

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Classification:

Area: Medicine and Health Sciences
 Field: Medicine
 Discipline: Environmental public health
 Subdiscipline: Pollution and Environmental Toxicology

<https://doi.org/10.35429/JP.2025.9.20.3.1.13>

History of the article:

Received: October 15, 2025
 Accepted: December 30, 2025



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Abstract

This research analyzes microplastic pollution and its effects on the environment, human health, and society. The main sources are identified as tire wear, the washing of synthetic textiles, and the use of single-use plastics. These particles are dispersed through air, water, and soil, entering the food chain and accumulating in human organs, the placenta, breast milk, and blood. Genetic, hormonal, and neurological risks are documented, as well as ecological impacts such as reduced marine photosynthesis and crop damage. Inadequate waste management and a lack of regulation are also evident. The leading role of Rwanda and Peru in promoting international agreements to regulate the entire plastic cycle is highlighted. The conclusion is that this is a structural problem that demands urgent scientific, political, and social responses.

Resumen

Esta investigación analiza la contaminación por microplásticos y sus efectos en el medio ambiente, la salud humana y la sociedad. Se identifican como fuentes principales el desgaste de neumáticos, el lavado de textiles sintéticos y el uso de plásticos desechables. Estas partículas se dispersan por aire, agua y suelo, ingresando a la cadena alimentaria y acumulándose en órganos humanos, placenta, leche materna y sangre. Se documentan riesgos genéticos, hormonales y neurológicos, así como afectaciones ecológicas como la reducción de fotosíntesis marina y daño a cultivos. Además, se evidencia una gestión inadecuada de residuos y falta de regulación. Se destaca el liderazgo de Ruanda y Perú en la promoción de acuerdos internacionales para regular el ciclo completo del plástico. Se concluye que este es un problema estructural que exige respuestas científicas, políticas y sociales urgentes.

WE ARE PLASTIC		
Objectives	Methodology	Contribution
Identify sources and presence of microplastics.	Documentary, qualitative.	provides a comprehensive and up-to-date overview of the environmental and human health impacts caused by microplastics, highlighting the need for regulations, increased public awareness, and future lines of scientific research.
Analyze their impact on human health.	Critical review of recent scientific literature.	
Evaluate their effect on the environment.	Scientific journals, documentary articles, websites.	
Review recent scientific literature.	Analyze the environmental and human health impact of microplastics.	
Propose mitigation actions and strategies.	Allows for the collection and analysis of information relevant to the study's objectives.	

Microplastics, Human Health, Environmental Pollution

SOMOS PLÁSTICO		
Objetivos	Metodología	Contribución
Identificar fuentes y presencia de microplásticos.	Documental, de tipo cualitativo.	Aperta una visión integral y actualizada sobre los impactos ambientales y en la salud humana causados por los microplásticos, destacando la necesidad de regulaciones, mayor conciencia pública y líneas futuras de investigación científica.
Análisis su impacto en la salud humana.	Revisión crítica de literatura científica reciente.	
Evaluate their effect on the environment.	Revistas científicas, artículos documentales, sitios web.	
Revisar la literatura científica reciente.	Análisis el impacto ambiental y en salud humana de los microplásticos	
Proponer acciones y estrategias de mitigación.	Permite recopilar y analizar información relevante para los objetivos del estudio.	

Microplástico, Salud humana, Contaminación ambiental

Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: Hernández-Rodríguez, María Guadalupe, Ortega-Chávez, Laura Antonia, Santos-Benítez, Lina Susana and García-González-Héctor. [2025]. We are plastic. Journal of Physiotherapy and Medical Technology. 9[20]1-13: e3920113.



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Introduction

The development of synthetic materials, such as plastics, has represented a milestone in the history of science and technology. By studying the structure and behavior of atoms and molecules, humanity has been able to replicate and modify natural processes to synthesize new substances with unprecedented properties.

These innovations have given rise to materials that do not exist in nature. These synthetic polymers, commonly known as plastics, have profoundly transformed multiple sectors of contemporary society and have been designed to respond to diverse everyday needs, including medicine, the food industry, electronics, and transportation.

Plastics emerged as a versatile and economical solution, radically transforming global production and consumption.

Their low cost, durability, and versatility explain their global proliferation. However, the massive accumulation of plastic waste has led to global environmental and health problems. The indiscriminate use of this "miracle material" has triggered an unprecedented environmental and health crisis.

Particularly concerning is the ubiquitous presence of microplastics—fragments smaller than 5 mm—that have been detected in terrestrial, marine, and atmospheric ecosystems, including remote regions such as mountain peaks and deep ocean sediments.

Recent studies have demonstrated their infiltration into the human body, with findings in organs, tissues, blood, the placenta, and body fluids. This chronic exposure raises significant questions about their physiological effects, particularly given the ability of microplastics to act as vectors of toxic substances and endocrine disruptors.

Despite a growing body of research, the underlying biological mechanisms and long-term impacts of these pollutants remain unclear.

In this context, it is urgent to analyze the causes, characteristics, and consequences of exposure to microplastics, as well as to propose strategies to mitigate their impact.

This paper aims to study this phenomenon from a critical perspective, integrating recent scientific evidence and reflecting on the role we, as a society, play in the generation, use, and final destination of plastic. Only in this way can we responsibly address this modern dilemma that threatens both the planet and our health.

General Objective

The main objective of this research is to analyze the environmental impact and potential effects on human health associated with exposure to microplastics, based on a critical review of recent scientific literature. This research aims to understand the magnitude of the problem, its biological implications, and the need to establish mitigation and regulatory strategies at the global level.

What is plastic?

Plastic is a petrochemical derivative, which is why many large plastic companies are subsidiaries of large oil companies.

Oil is pumped from the ground and undergoes a process of fractional distillation and cracking [a chemical process by which the original compound is broken down into simpler, smaller compounds]. It is then converted into different chemicals that polymerize so that the molecules connect and create different types of plastics, as shown in Figure 1. This manufacturing process itself creates its own pollution, such as greenhouse gases.

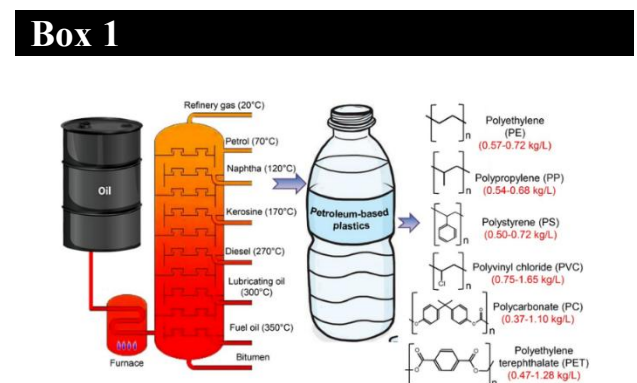


Figure 1
Manufacturing of a variety of petroleum-based plastics
ResearchGate: Environmental Monitoring and Assessment

The various plastics produced are converted into other products that are transported around the world.

Problem

It's hard to understand how astronomically large the numbers are when talking about the plastics industry.

The United Nations Environment Programme [UNEP] has indicated that one million plastic bottles are purchased every minute worldwide—this equates to 1.3 billion bottles a day—and most of these are used only once and discarded. Furthermore, UNEP estimates that 500 billion plastic bags are used each year [UNEP, 2019].

This high consumption rate of plastic bottles, mostly single-use, generates a large amount of plastic waste that ends up in landfills or polluting the environment, including the oceans. [UNEP, 2019].

These figures demonstrate the magnitude of plastic pollution worldwide and the need to address this problem.

Plastic is a product derived from crude oil, and its growing demand is significantly driving the consumption of petrochemical feedstocks such as naphtha. [The Energy Journal, 2022].

Bloomberg New Energy Finance [2024] warns that, due to the sustained growth of the plastics industry, the use of oil for petrochemical purposes could double by 2050.

This would represent up to 20% of global oil demand, with an estimated volume of 18 million barrels per day.

This trend is related to the decline in oil use in transportation due to electrification and improved energy efficiency, which has led major oil companies to redirect their investments toward the petrochemical industry.

According to a report by Bloomberg New Energy Finance [BNEF, 2024], global investments in clean energy reached \$1.8 trillion, surpassing those in the fossil fuel sector for the first time.

Demand for plastics such as polyethylene [PE], polypropylene [PP], and PET [polyethylene terephthalate] could increase by 90% by mid-century. This expansion will be driven primarily by Asia, particularly China, followed by the Middle East, regions that are emerging as the main centers of global petrochemical production. This global phenomenon poses environmental, economic, educational, and health implications. [El diario de la energía, 2024].

Methodology

This research is based on the documentary approach, as it is based on the analysis and compilation of information from secondary sources, such as scientific journals, newspaper articles, documentaries, and resources available in digital media. The choice of this approach responds to the need to examine and systematize relevant content to achieve the objectives set forth in the study, through a critical and reasoned review of the existing literature. The methodology used follows the recommendations of the United Nations Environment Program [UNEP, 2023].

Theoretical Framework

Previous studies conducted by the University of Minnesota have shown the presence of microplastics in snow and rain, confirming their widespread dispersion in the urban environment. According to Dr. Mary Kosuth [2017, 2018], these often-invisible particles are released from everyday objects and are already part of natural cycles. The lack of transparency regarding the effects of these materials represents a global environmental and health risk.

For her part, ecologist Chelsea Rochman [2024] warns that microplastic particles smaller than 5 mm come not only from poorly managed waste but also from the wear and tear of tires, paints, and synthetic fibers.

These light and persistent particles can enter the atmosphere, water bodies, and the food chain. It is estimated that between 10 and 20 million tons of plastic enter the oceans each year, progressively integrating into the planet's ecological cycles.

It's difficult to understand, but almost every plastic molecule created over time still exists somewhere, in some state of degradation, because it never disappears.

It goes from being a piece of trash to smaller and smaller particles that become microscopic.

One of the main sources of microplastics in the environment is the improper management of plastic waste, particularly large plastic waste that, over time and with exposure to environmental factors, fragments into increasingly smaller particles.

This process of physical degradation contributes significantly to microplastic pollution in terrestrial and aquatic ecosystems.

Box 2



Figure 2

Microscopic plastic particles

iStock

Among the most common sources of primary microplastics are industrial paints used in buildings and maritime infrastructure, as well as the wear and tear of automobile, motorcycle, and aircraft tires, the residues of which are released as fine dust and dispersed into the air or carried by water into bodies of water.

Various studies have indicated that, in countries such as China, Norway, and Denmark, the wear and tear of tires in circulation represents one of the main sources of microplastics released into the environment. This constant friction generates tiny particles that, when carried by rainwater or wind, end up accumulating in soils, rivers, and oceans. [Redondo Hasselerharm, 2024].

Accordingly, a report by the International Union for Conservation of Nature [IUCN] estimates that approximately 28% of primary microplastics that reach the oceans come from the wear and tear of vehicle tires, making this source one of the most significant globally. [Redondo Hasselerharm, 2024], [Free Newspaper of Aragon, 2025].

Box 3



Figure 3

Microplastic particles from the wear of car tires in the ocean.

Shutterstock

Additionally, the increasing use of synthetic fibers such as polyester and nylon in the textile industry represents a significant source of microplastics. During garment washing, these fibers are released in the form of microfibers, which pass through wastewater treatment systems and end up accumulating in rivers, lakes, and oceans.

The continuous release of these fibers makes synthetic textiles a persistent and difficult-to-mitigate source of microplastic pollution.

As mentioned, it is estimated that between 10 and 20 million tons of plastic generated on land reach the oceans each year. A fraction of this waste remains on the sea surface, floating and being carried by ocean currents; another fraction progressively fragments into smaller particles until they become microplastics that can enter the atmosphere and disperse globally. [Oberbeckmann & Labrenz, 2020].

Some of the remaining plastic sinks and settles on the seabed, where it is ingested by organisms at various trophic levels, thus joining the food chain.

Recently, it has been documented that certain microorganisms colonize these fragments, using them as substrate, turning plastic into a new habitat in aquatic ecosystems. [Grover Castañeta, et al., 2020]

This phenomenon demonstrates that plastic waste is already part of the planet's natural cycles, such as the water cycle, carbon cycle, dust cycle, and atmospheric currents, with ecological implications that are not yet fully understood.

Microplastics Without Borders: Global Pollution, Environmental Justice, and Consequences for Marine, Agricultural, and Human Ecosystems. Antonio Bay Estuarine Waterkeeper

Between 2016 and 2019, the San Antonio Bay Estuarine Waterkeeper organization and Diane Wilson systematically documented the illegal dumping of plastic pellets by Formosa Plastics in Texas.

For approximately 27 years, Formosa Plastics has dumped industrial waste into this body of water, including plastic microfragments known as polyethylene and polypropylene pellets. These particles, easily mistaken for food by aquatic fauna, have been ingested by various species, including fish and mollusks such as oysters, in whose bodies traces of these materials have been found. As a result, microplastic pollution has had a direct impact on the health of the species that inhabit this area, affecting local ecosystems and altering food chains.

Local fishermen began to notice alarming changes in the quality of their catches, such as the shrimp, which had an abnormal, cottony texture, indicating possible contamination. This situation marked the beginning of the decline of traditional fishing activity in the region. As a result, numerous boats remain idle, fish markets have closed, and much of the community has lost its livelihood. Currently, consumption of seafood such as fish, shrimp, and oysters from these bays is restricted due to public health risks.

Box 4



Figure 4

Microplastic pollution in San Antonio Bay
San Antonio Bay Estuarine Waterkeepers

In response to this environmental and social crisis, Diane Wilson, along with volunteers, conducted a systematic collection of more than 2,500 samples and over 7,000 visual records over two and a half years.

This evidence supported a federal lawsuit under the Clean Water Act. In December 2019, a historic \$50 million settlement was reached, the largest of its kind in the U.S., which included environmental mitigation projects and the company's commitment to a "zero discharge" policy.

Palawan, Philippines

In Palawan, Philippines, Justine Marey Bitlac [a scientist at the UP Marine Science Institute] has analyzed seawater samples, finding a large amount of microplastics. A study of mussels found that they contain between one and three microplastic particles. It was also observed that mollusks that ingest microplastics have reduced their size and are unable to settle in the areas where they usually do.

Adana Turquía

According to Dr. Sedat Gundogdu of the Microplastics Research Group at Çukurova University, the Eastern Mediterranean Sea is one of the most plastic-polluted areas, with beaches receiving up to 35 kg of plastic waste per kilometer every day. This pollution is exacerbated by the export of plastic waste from developed countries to nations like Turkey, a phenomenon he calls "waste colonialism."

He also highlights the intensive use of plastics in agriculture—through plastic mulches and irrigation systems—which end up becoming embedded in the soil, giving rise to what he calls "plastic soil." This practice, without adequate regulation, introduces plastics into the food chain, generating environmental and human health risks. [Gündoğdu et al., 2022].

Box 5



Figure 5

Plastic in agriculture

iStock

The disastrous use of plastic in agriculture around the world is endangering food safety and potentially human health, according to a report by the Food and Agriculture Organization of the United Nations [FAO].

Box 6



Figure 6

Plasticization of soil

Shutterstock

Rochester Institute of Technology

According to Christy Tyler, professor of environmental science at the Rochester Institute of Technology, the presence of microplastics in the environment is so widespread that it is virtually inevitable that all humans will be exposed to them.

Recent research has shown that certain plants can absorb microplastics directly from the soil, incorporating them into their roots, stems, and even fruits. When consumed, these particles enter the human body, raising concerns about their potential health effects. Agrawal Nina [May 2025].

Several studies have shown that the presence of microplastics in soil can interfere with essential physiological functions of plants, including the process of photosynthesis.

This compromises the efficiency of light harvesting and biomass production, which is particularly concerning for staple crops such as wheat, rice, and corn.

Disruption of this fundamental biological process could trigger significant impacts on agricultural productivity, food security, and the global ecological balance. [Bailey et al., 2025]

Box 7



Figure 7

photosynthesis

Shutterstock

Recent studies have shown that plant exposure to microplastic particles can lead to decreased growth, which is an additional factor in the reduction of agricultural yields, already affected by extreme weather events. [Bailey et al., 2025]

Plants and marine organisms such as phytoplankton are essential for oxygen production and CO₂ capture. However, microplastic pollution has been shown to reduce their chlorophyll levels by between 10.96% and 12.84%, affecting photosynthesis.

This compromises both air quality and oxygen availability in aquatic ecosystems. [Bailey et al., 2025]

Microplastics in humans

We know that microplastics are in our environment, in the food we eat and the water we drink, even in the air we breathe—they are present in everything, said Richard Thompson, a marine biologist at the University of Plymouth, who coined the term "microplastics" in his article "We Are Exposed," published in 2004.

However, science is still unable to determine the degree of threat posed by their presence in our bodies.

Researcher Imari Walker-Franklin, PhD, of RTI International and author of the book "Plastics," warns that the exact quantity and type of chemical compounds present in plastic products is still unknown. This is because such information is protected under industrial confidentiality clauses, considered trade secrets that prevent knowledge of the exact "recipe" used by each manufacturer.

Research is currently underway to determine whether plastic particles accumulate in specific parts of the human body and, if so, to analyze the exposure dose and potential health effects of constantly ingesting these chemicals.

The toxicity of microplastics and their endocrine impact

Dr. Pete Myers, chief scientist at Environmental Health Sciences, has warned that although the study of microplastic toxicity is still in its early stages, there is already sufficient evidence to indicate that these materials act as vectors for chemical compounds harmful to human health.

One of the most sensitive areas to this exposure is the endocrine system, made up of glands such as the pituitary, pineal, parathyroid, thyroid, thymus, adrenal, islets of Langerhans, testes, and ovaries. This system regulates fundamental processes of human development, from organ formation to reproduction.

Myers emphasizes that some substances present in plastics can interfere with hormonal signaling, even at extremely low doses, due to biological amplification mechanisms. This implies that minimal amounts of these compounds can trigger significant health effects, altering neurological, reproductive, and metabolic functions.

Therefore, it is urgent to further research into chronic exposure to these chemicals, as well as to regulate their industrial use. [Myers, 2022].

Dr. Shanna Swan, a renowned environmental and reproductive epidemiologist, shows in her book, "Countdown," [2021], how chemicals present in our modern environment are negatively affecting human health and fertility.

A 2017 study led by Dr. Shanna Swan revealed that sperm counts in Western men have declined by more than 50% over the past four decades. If we compile the data on sperm counts and how much they have declined and project them forward to 2045, many adult and young men will be unable to reproduce in more traditional ways. The plastics used during artificial insemination interfere with this process. [Davis, 2020]

Genital abnormalities are also more common in male infants, precocious puberty in girls, and impaired ovarian quality in women. Swan attributes these alterations to endocrine disruptors, chemicals present in everyday products such as plastics, cosmetics, pesticides, and canned foods, which interfere with the human hormonal system. [Swan & Colino, 2021].

Phthalates

There are countless chemicals deliberately included in different types of plastic that we know disrupt hormones.

Stephanie M. Engel, Ph.D., professor at the Gillings School of Global Public Health at the University of North Carolina at Chapel Hill, points out that phthalates, known as ubiquitous chemicals due to their widespread presence, are incorporated into numerous consumer products to make plastics more flexible and fracture-resistant.

Phthalates are found in hundreds of automotive, household, food, and personal care items: food packaging, detergents, vinyl flooring, clothing, furniture, and shower curtains; car oil, lubricants, and adhesives; rain and stain-resistant products; and dozens of products including shampoo, soap, hairspray, and nail polish; and they make fragrances last longer.

Phthalates are found in hundreds of automotive, household, food, and personal care products: food packaging, detergents, vinyl flooring, clothing, furniture, and shower curtains; car oil, lubricants, and adhesives; rain and stain-resistant products; and dozens of products including shampoo, soap, hair spray, and nail polish; and they make fragrances last longer.

Phthalates must be listed among the ingredients on product labels unless they are added as part of the scent. Under current U.S. Food and Drug Administration regulations, phthalates can be labeled simply as fragrances, although they could make up to 20% of the product, according to studies.

Phthalates are also found in PVC plumbing and construction products, and in items such as medical tubing, garden hoses, and some children's toys. Approximately 8.4 million metric tons of phthalates and other types of plasticizers are consumed annually worldwide, according to European Plasticizers, an industry trade association.

Studies have linked phthalates to childhood obesity, asthma, cardiovascular problems, cancer and reproductive problems, genital malformations, and undescended testicles in male babies, low sperm counts, and low testosterone levels in adult men.

A report published by Sandee LaMotte for CNN [2021] highlights that phthalates are negatively affecting neurological development in children. The TENDR [Targeting Environmental Neuro-Developmental Risks] group, made up of scientists, health professionals, and child advocates, warns about the neurotoxic effects of these chemicals and demands their immediate ban to protect children's health.

What is BPA, and what are the concerns about it?

El bisfenol A [BPA] es un compuesto químico industrial utilizado desde la década de 1950 en la fabricación de plásticos de policarbonato y resinas epóxicas. Estos materiales se encuentran comúnmente en botellas de agua, envases de alimentos, latas metálicas, tapas de botellas, tuberías de agua e incluso en algunos selladores dentales.

Various studies have shown that BPA can migrate into foods and beverages from their containers, raising concerns about its potential health effects. It has been associated with alterations in brain and prostate development in fetuses, infants, and children, as well as with childhood behavioral disorders.

Furthermore, studies suggest potential links to hypertension, type 2 diabetes, and cardiovascular disease, and even cancers such as breast and prostate cancer.

Although the U.S. Food and Drug Administration [FDA] considers current levels of BPA exposure in food to be safe, it continues to monitor the available scientific evidence. As a preventative measure, it is recommended to choose products labeled "BPA-free," avoid heating plastics in microwaves or dishwashers, and prefer glass, stainless steel, or porcelain containers, especially for hot foods and beverages. [Tips to Reduce BPA Exposure, n.d., 2023]

Box 8



Figure 8

BPA free product

Free use

ROMA

In previous research led by Dr. Antonio Ragusa [2021] from Fatebenefratelli Hospital and the

University Biomedical Campus, plastic fragments were detected in human placentas donated by women after childbirth. Some of these particles correspond to polypropylene, a type of plastic commonly used in packaging and single-use products.

Given these findings, it has been hypothesized that breast milk could also be exposed to microplastic contamination, prompting new lines of study focused on child health and early exposure to plastic contaminants. These results are consistent with those obtained by García and Pérez [2022], who also found microplastics in breast milk samples. In a study involving 34 mothers, microplastics were found in 26 breast milk samples.

Researchers have observed that these particles can be incorporated into cells [the fundamental unit of life], altering their structure and function. In the early stages of fetal development, this intrusion could alter DNA expression, with potential long-term consequences for the baby's health.

Box 9



Figure 9

Plastic during pregnancy

iStock

It's worth noting that plastic itself isn't the problem: it's a versatile and valuable material in many contexts, such as the manufacture of cardiac or joint prostheses. The real challenge lies in the indiscriminate and disposable use of plastic in everyday products such as water or soft drink bottles.

The goal of these studies is not only to generate knowledge, but also to raise awareness and promote a critical reaction to the industry that, in pursuit of economic profit, promotes the excessive use of plastic at the expense of human health and the planet. [Ragusa, A., 2023].

Professor Dick Vethaak of the Institute for Risk Assessment Sciences at Utrecht University warns that both plastics and their additives can have genotoxic and epigenetic effects, meaning they can alter DNA and increase vulnerability to cancer, even in future generations.

Furthermore, plastic particles can induce low-grade inflammatory responses, which is worrying given that chronic inflammation is a precursor to many chronic diseases. Their presence in the blood means that these particles can reach sensitive organs such as the bone marrow or the brain.

For her part, Susan Freinkel, author of *Plastic: A Toxic Love Story*, points out that, despite current knowledge about the risks of plastic, its production continues to increase. This is partly due to the rise of "cracking," a technology that harnesses excess natural gas to make plastic pellets. [Freinkel, 2011].

One example is the Gulf Coast Growth Ventures [GCGV] plant, dedicated to the manufacture of petrochemical products, specifically polymers and polymer feedstocks, used in the production of a wide variety of high-performance everyday products, such as clothing, food containers, packaging, agricultural films, and building materials. Located in Portland, Texas, the facility began operations in 2022 and is currently one of the largest in the world.

The plant, operated by ExxonMobil and Sabic, produces 1.1 million tons of ethylene annually and releases significant amounts of pollutants such as fine particulate matter [PM10 and PM2.5] and volatile organic compounds [VOCs], including benzene, to which the WHO considers safe exposure to be zero [Freinkel, 2011].

AMSTERDAM

Dr. Gavin Ten Tusscher, a pediatrician at Dijklander Hospital [Netherlands], has investigated the effects of dioxins generated by plastic incineration, highly toxic compounds linked to cancer, birth defects, immunosuppression, and respiratory diseases.

These persistent, lipophilic substances accumulate in fatty tissues and can be transferred from mother to fetus through the placenta and breast milk, exposing newborns to contaminants even before birth.

In studies such as Endocrine disruptors [EDs] and hormone-dependent cancers by [H Rochefort, 2017], Environmental Pollution as a Risk Factor in Testicular Tumour Development: Focus on the Interaction between Bisphenol A and the Associated Immune Response, [Nava-Castro et al., 2019] and Breast and prostate glands affected by environmental substances [Bleak and Calaf, 2021], a correlation has been observed between plastic production and the increase in cancers such as breast, prostate, testicular and thyroid. Since fetuses develop rapidly and are biologically more vulnerable, perinatal exposure to dioxins could affect key organs such as the brain, lungs or teeth, with long-term consequences that could manifest decades later. [Tusscher T., 2002].

HUFFPOST: An alarming amount of plastic is burned every second

The improper management of plastic waste represents a global environmental and health crisis. In many developing countries, where there is no efficient waste management infrastructure, millions of tons of plastic are dumped in rivers or burned in the open, generating serious consequences. According to a report by organizations such as Tearfund and WasteAid, an amount of plastic equivalent to the volume of a double-decker bus is burned or discarded every second, totaling approximately 70 million tons annually.

This practice releases toxic compounds that are highly dangerous to human health, including dioxins, which can cause cardiovascular and respiratory diseases, liver and kidney damage, and neurological disorders. In cities such as Muncar [Indonesia] and Jenjarom [Malaysia], where frequent plastic waste fires have been documented, local communities are directly exposed to these pollutants.

In contrast, industrialized countries like the United States, despite having more regulated recycling and incineration infrastructure, export much of their plastic waste to Southeast Asian nations, where it often ends up being incinerated informally, perpetuating the cycle of global pollution.

Box 10



Figure 10

Plastic pollution in Asian villages

Shutterstock

Organizations such as Greenpeace and GAIA denounce this practice as a form of externalizing pollution. Meanwhile, some companies have begun to respond to social pressure through initiatives such as the Alliance to End Plastic Waste, with financial commitments and mitigation strategies. However, experts and activists agree that the real solution requires drastically reducing the production of single-use plastics and ensuring sustainable alternatives.

Emerging evidence on microplastics in the human body and their impact on health

Researchers at the Rochester Institute of Technology have used infrared microscopy to analyze tissue samples with a precision of up to 3 mm, identifying microplastic fibers and fragments just a few tens of microns in size. The findings revealed the presence of polypropylene, a common component of disposable masks, candy wrappers, and salad dressings, as well as fibers from cotton, rayon [a semi-synthetic fiber], and polyester.

Dr. Barbro Melgert, a respiratory immunologist at the University of Groningen, has developed in vitro cultured human mini-lung models to study the interaction between microplastics and the respiratory epithelium.

When these cells were exposed to nylon 6,6 particles, a complete inhibition of lung growth and an inability of the tissue to self-repair were observed, suggesting a direct toxic effect of plastic fibers on cell regeneration.

Melgert also warns about daily exposure to plastic fibers shed from common objects such as carpets, which, when released into the air, are constantly inhaled. This highlights that microplastics not only contaminate water and food, but are also present in the air we breathe.

Jeanette Rotchell, PhD, Environmental Toxicologist at the University of Hull, has conducted recent studies in which microplastics were detected in blood samples from healthy donors using laser spectroscopy.

The analysis identified particles of nylon, polystyrene [used in packaging and toothbrushes], polyethylene [plastic bottles], polypropylene, and polyethylene terephthalate, along with chemical additives such as phthalates, visually detected as grayish particles in the samples, and compounds such as PTFE [polytetrafluoroethylene], a synthetic polymer known commercially as Teflon, commonly used in non-stick coatings on cookware.

Between 1 and 13 microplastic particles were found in each 10 ml blood sample. These contaminants pose a dual risk: their physical structure can trigger inflammatory responses, and their chemical composition can leach toxic compounds, exacerbating damage to the body.

Industrial risks and exposure to plastic compounds.

The effects of industrial plastics have also been widely documented in communities near chemical plants. In areas of high industrial concentration, such as the southern US, a notable increase in cancer rates has been identified, leading to the nickname "Cancer Alley." Polyvinyl chloride [PVC], a derivative of vinyl chloride, is one of the most concerning substances due to its toxic effects during manufacturing. It is commonly used in packaging, medical products, and construction materials.

Testimonials from workers chronically exposed to these compounds reveal serious health consequences,

including severe neurological damage and amputations, as in the case of a worker at the Formosa plant, who lost the use of his limbs after years of exposure to ethylene chloride and vinyl chloride.

Also, as previously mentioned, recent studies have detected microplastic particles in human placentas and even in breast milk samples, demonstrating their ability to cross fundamental biological barriers. It has been observed that these microplastics can integrate into key cellular structures during fetal development, altering genetic expression and compromising healthy embryonic development.

International initiatives to regulate the plastic life cycle: leadership from Rwanda and Peru

Rwanda and Peru have positioned themselves as leaders in promoting international regulation that covers the entire plastic life cycle: from its production, design, and use, to its final disposal and release into the environment. Christina Dixon of the Environmental Investigation Agency points out that there is currently no legal obligation at the regional, national, or international level requiring plastic producers to disclose the quantity, composition, or destination of the materials they generate. This lack of transparency impedes effective control of plastic pollution globally.

Rwanda, for its part, has shown concrete progress. Juliet Kabera, director of the Rwanda Environment Management Authority, explains that her country banned plastic bags in 2004 and enacted a law on the subject in 2008. This had positive effects: litter was reduced, water flow in canals improved, and new businesses with sustainable alternatives emerged. However, the challenge persists with other disposable products such as straws and cutlery. Therefore, Rwanda is promoting a broader international alliance to foster structural changes in plastics production and consumption through cooperation and the development of sustainable markets.

MÉXICO: Gulf of California, Gulf of Mexico, and the Caribbean Sea

In Mexico, numerous studies have addressed and analyzed the impact of microplastics on human health and the health of various animal species. An example of this is a study conducted in three regions of the country [La Paz, Baja California Sur, in the Gulf of California region; Puerto Morelos, Quintana Roo, in the Caribbean Sea region; and the port of Veracruz, Veracruz, in the Gulf of Mexico region], which estimated the amount of microplastics present in the stomach contents of commercially important fish in these three regions.

The research was conducted in collaboration with Greenpeace UK, the National Autonomous University of Mexico [UNAM], the Autonomous University of Baja California Sur, and the University of Veracruz.

This research, the result of a collaboration between Mexican civil society organizations and scientists, analyzes how plastic pollution affects the oceans, biodiversity, and the economy by infiltrating fish consumed locally, which can pose a potential health risk.

The study found that 37% of the sampled fish contained identifiable plastic fragments, including polyester, ethylene-vinyl acetate, nylon, polyethylene, polypropylene, and cellophane. Veracruz was the region with the highest number of findings, as of the 20,718 microplastics recorded, 1,865 corresponded to fish from this area, while La Paz had only 110. The difference in microplastic ingestion between regions could be related to the degree of urbanization and human activity in each coastal area.

Conclusion

This research demonstrates that microplastics represent one of the most complex environmental and health threats of the 21st century, due to their ubiquity, persistence, and ability to penetrate multiple levels of ecosystems and the human body.

It is confirmed that these particles, originating primarily from the wear and tear of tires, synthetic textiles, and single-use plastics, have invaded soil, water, food, air, and human tissue, generating constant and involuntary exposure in the global population.

Ecologically, microplastics disrupt fundamental processes such as marine photosynthesis, affect the development and reproduction of aquatic species, and decrease agricultural productivity, compromising food security and biodiversity.

In terms of human health, scientific evidence indicates that these particles can cross biological barriers such as the placenta, blood, and lungs, acting as vectors for toxic compounds with genotoxic, endocrine, immunological, and neurological effects, even at very low doses.

Furthermore, the lack of transparency regarding the chemical composition of plastics and the absence of global regulatory frameworks controlling their production, distribution, and disposal have been documented. The inadequate management of plastic waste, particularly in developing countries, contributes to a transnational environmental crisis that demands collective, equitable, and urgent solutions.

In response to this problem, the emerging leadership of countries such as Rwanda and Peru in promoting international treaties to regulate the entire plastic cycle stands out, an initiative that paves the way for global environmental governance based on justice, transparency, and shared responsibility.

In short, microplastics have ceased to be an emerging problem and have become a structural challenge that demands a profound transformation in consumption, production, and regulatory models. Only through an interdisciplinary, preventive, and cooperative approach will it be possible to mitigate their impacts and protect human and planetary health for present and future generations.

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Determination and evaluation of official tests on rosemary extract tablets [as a finished product]




Determinación y evaluación de las pruebas oficiales a comprimidos de extracto de romero [como producto terminado]

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Classification:

Area: Medicine and Health Science
Field: Medical sciences
Discipline: Pharmacology
Subdiscipline: Preparation of medications

 <https://doi.org/10.35429/JP.2025.9.20.4.1.5>

History of the article:

Received: October 01, 2025

Accepted: December 30, 2025

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Abstract

Rosemary [*Rosmarinus officinalis*] is a plant rich in a wide variety of active ingredients, for example, caffeic acid derivatives, such as rosmarinic acid, which could range from the prevention and treatment of bronchial asthma, spasmodic disorders, peptic ulcers, inflammatory diseases, etc. The objective was to perform official or pharmacopoeial tests on rosemary total extract tablets. The following were evaluated: identity, disintegration, dissolution, titration and dose uniformity. The identity results show the presence of phenols in general, such as caffeic acid derivatives, among which rosmarinic acid stands out. In disintegration, $\bar{x} = 6.6$, $s = 0.5477$ and a $CV = 8.2984$ were obtained; the dissolution shows a Q value $> 80\%$, $\bar{x} = 87.59$, $s = 2.33$ and $CV = 4.65$; The assessment yields $\bar{x} = 103.526$, $s = 20.922$ and a $CV = 2.0209$ and the dose uniformity has a $CV = 3.9818$ and an acceptance criterion of 85 to 115%.

Resumen

El Romero [*Rosmarinus officinalis*] es una planta rica en una gran variedad de principios activos, por ejemplo los derivados del ácido cafeico, como el ácido rosmarínico, que podría abarcar desde la prevención y el tratamiento del asma bronquial, trastornos espasmódicos, úlcera péptica, enfermedades inflamatorias, etc. El objetivo fue realizar las pruebas oficiales o farmacopeicas en los comprimidos de extracto total de romero. Se evaluó: identidad, desintegración, disolución, valoración y uniformidad de dosis. Los resultados en identidad muestran la presencia de fenoles en general como los derivados del ácido cafeico entre los que destaca el ácido rosmarínico; en la desintegración se obtuvo un $\bar{x} = 6.6$, $s = 0.5477$ y un $CV = 8.2984$; la disolución muestra un valor de $Q > 80\%$, $\bar{x} = 87.59$, $s = 2.33$ y $CV = 4.65$; la valoración arroja $\bar{x} = 103.526$, $s = 20.922$ y un $CV = 2.0209$ y la uniformidad de dosis tiene un $CV = 3.9818$ y un criterio de aceptación de un 85 a un 115 %.

Determination and evaluation of official tests on rosemary extract tablets (as a finished product)

Objetivo	Methodology	Contribución
Perform official or pharmacopoeial tests on total rosemary extract tablets 	Determination of: 1. Identity 2. Disintegration 3. Dissolution 4. Assessment 5. Dose uniformity 	Prevention and treatment of bronchial asthma, spasmodic disorders, peptic ulcer, inflammatory diseases, among others. 

Rosmarinus Officinalis, Rosemary Extract, Tablets

Determination and evaluation of official tests on rosemary extract tablets (as a finished product)

Objetivo	Metodología	Contribución
Realizar pruebas oficiales o farmacopeicas en comprimidos de extracto total de romero 	Determinación de: 1. Identidad 2. Desintegración 3. Disolución 4. Valoración 5. Uniformidad de la dosis 	Prevención y tratamiento del asma bronquial, trastornos espasmódicos, úlcera péptica, enfermedades inflamatorias, entre otras. 

Rosmarinus officinalis, extracto de romero, comprimidos

Area: Strengthening of the scientific community

Citation: Orta-Martínez Felipe, Hernández-Salas, Claudia, Regalado-Barrera, José David and Reyes-Escobedo, Fuensanta del Rocío. [2025]. Determination and evaluation of official tests on rosemary extract tablets [as a finished product]. Journal of Physiotherapy and Medical Technology. 9[20]1-5: e4920105.



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Introduction

Rosemary [*Rosmarinus officinalis*] is one of the most studied plants from an experimental perspective. However, the plant and its derivatives lack clinical studies that would allow for routine clinical use [Ruiz, 2000; Almela, 2006; Montes de Oca, 2010; Tschingeri and Bucar, 2010]. The results of an experimental study indicate that the plant has extensive therapeutic potential, especially those derived from caffeic acid, such as rosmarinic acid, which could include the prevention and treatment of bronchial asthma [Musa and Chalchat, 2008], spasmodic disorders, peptic ulcers, inflammatory diseases, liver toxicity, ischemic heart disease, coronary artery disease, cataracts, impaired sperm motility, and cancer [Al-Sereiti et al., 1999].

Other experiments indicate that rosemary has hepatoprotective properties against toxicity induced by azathioprine and carbon tetrachloride [Hoeftler et al., 1987; Sotelo-Felix et al., 2002; Amin and Hamza, 2005], blocking the elevation of plasma transaminases and drug-induced necrosis [Amin and Hamza, 2005]. The protective effect could lie in phenolic compounds [Fahim et al., 1999]. Carnosol is possibly responsible for this effect, which, in isolation, would have a similar effect to larger parts of the plant [Sotelo-Félix et al., 2002]. One of the most important results of these experiments is its hepatoprotective and liver antioxidant properties. In order to synthesize a new medicine in the laboratory, the pharmaceutical industry usually starts with the active ingredients and subsequently [Miranda, 2006] proceeds to improve its activity, modifying its chemical formula or accompanying it with other synergistic principles [which enhance the action], local regulators or correctors [Bakirel et al., 2008], as well as other substances [natural or not] whose characteristics depend on the dosage formula to be used [the so-called pharmaceutical form] [Iraizoz, 2001].

Methodology

Identity

Ten rosemary tablets were crushed, resuspended in 25 mL of alcohol, filtered, and a 15 mL aliquot of the filtrate was taken. Three drops of 5% ferric trichloride in saline solution were added, and the coloration generated by this reaction was observed [Alonso, 2004 and Lema, 2013].

Disintegration

Five samples of 12 tablets each were evaluated, two baskets with 6 tablets each were mounted in the disintegrator, distilled water at a T of 37 °C was used as the disintegration medium, the disintegrator was turned on and the time it took for all the tablets to disintegrate was recorded [EUHU, 2000; Játiva, 2009 and FEUM, 2011].

Dissolution

Five samples of six tablets each were processed. One tablet and 900 mL of 0.2 M sodium phosphate tribasic buffer were placed in each of the six buckets. Dissolver equipment 2 was used at 50 rpm for 30 minutes.

Once the time had elapsed, a 5 mL aliquot was taken, filtered, calibrated, and the absorbance was read. A reference solution containing 100 µg/mL was also prepared. [FEUM, 2011].

Assessment

Ten tablets were weighed and crushed, and a sample solution was prepared by taking the amount of powder equivalent to 50 mg of extract as PA. A reference solution was prepared with a concentration of 1.5 mg/mL of rosemary extract. Once the sample and reference solutions were prepared, the absorbance of both solutions was determined in a spectrophotometer [FEUM, 2011].

Dose uniformity

The mass variation method was used, with 5 samples of 10 tablets each weighed individually, and the results of the 5 titrations were used [FEUM, 2011].

Results

Identity

Table 1 shows that some of the components of rosemary extract with hepatoprotective activity were identified, such as phenolic acids, among which rosmarinic acid stands out.

Box 1

Table 1

Phenolic components of rosemary extract

Alcoholic extraction	FeCl ₃ al 5% en NaCl al 0.9%	Coloration
Phenols in general	Positive	Red-wine
Pyrogallotannin tannins	Negative	-----
Pyrocatecholic tannins	Negative	-----
		--

Disintegration

Of the 5 samples of 12 tablets, all tablets completely disintegrated within 7 minutes, indicating that they pass the test. [Table 2]

Box 2

Table 2

Disintegration time of rosemary tablets

Samples of 12 tablet	Time in minutes
Disintegration 1	7
Disintegration 2	7
Disintegration 3	6
Disintegration 4	6
Disintegration 5	7
\bar{x}	6.6
S	0.5477
C.V.	8.2984

Disintegration time of rosemary tablets. \bar{x} = mean, s = standard deviation, and C.V. = coefficient of variation

As shown in Table 2, the acceptance criteria established by the FEUM show that rosemary tablets do pass the disintegration test.

Dissolution

Box 3

Table 3

Dilution of the 5 samples of 6 tablets of total rosemary extract

Sample	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	x	s	C.V.
D-1	83.19	84.87	92.43	84.03	91.59	98.31	89.07	6.01	6.74
D-2	84.03	93.27	81.51	85.71	99.15	94.95	89.77	6.99	7.79
D-3	82.35	82.35	86.55	92.43	84.87	83.79	85.39	3.80	3.80
D-4	85.59	84.79	83.89	84.74	82.20	83.05	84.04	1.25	1.25
D-5	92.50	99.16	91.66	82.50	83.33	89.16	89.71	6.22	6.22
\bar{x}	85.53	88.88	87.20	85.88	88.22	89.85	87.59	4.85	5.48
S	4.07	7.07	4.76	3.84	7.10	6.72	2.68	2.33	2.55
C.V.	4.76	7.96	5.46	4.47	8.05	7.48	3.06	48.1	46.5

Dissolution percentage of rosemary extract tablets [Rosmarinus offisinalis]. D - 1 to D - 5 = Samples 1 to 5, Q - 1 to Q - 6 = cuvette no. and Q value [% dissolved], \bar{x} = average, s = standard deviation and C.V. = Coefficient of Variation.

The 5 samples of rosemary extract tablets do pass the dissolution test since when applying the formula and calculating the Q value, all the tablets show a Q value greater than 80%, the range or acceptance criterion established by the FEUM for tablets, as shown in Table 3.

Box 4

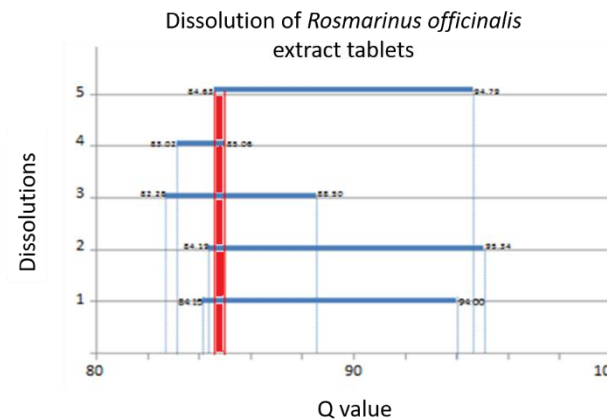


Figure 1

Disolución de *Rosmarinus officinalis*

In figure 1, the dissolution range of rosemary extract tablets is observed, this means that *Rosmarinus offisinalis* extract tablets have a dissolution or dissolve in 84.5 to 85%.

Assessment

Box 5

Table 4

Determination of the titration of 5 samples

Ratings	Sample absorbance	Reference absorbance	[real] (mg)	[theoretical] (mg)	Assessment (%)
V-1	1.175	0.170	103.67	100	103.67
V-2	1.170	0.175	100.28	100	100.28
V-3	1.173	0.167	105.35	100	105.35
V-4	1.174	0.169	105.35	100	105.35
V-5	1.174	0.171	102.98	100	102.98
\bar{x}	1.175	0.1704	103.526	100	103.526
S	0.00192	0.00296	2.0922	0	2.0922
C.V.	0.1639	1.7408	2.0209	0	2.0209

Titration value of rosemary extract tablets. V-1 to V-5 titration 1 to 5. Abs. Sample = sample absorbance, Abs Ref. Reference absorbance, [actual] = actual concentration, [theoretical] = theoretical concentration, \bar{x} = average, s = standard deviation and C.V. = Coefficient of Variation.

En la figura 4 se observa que las muestras pasan la prueba de valoración ya que caen dentro de un rango que va de un 95 a un 105 %, criterio de aceptación que establece la FEUM para comprimidos.

Dose uniformity

Table 5 shows how each of the assessments was used to calculate the dose uniformity for each of the samples. The following results were obtained:

Box 6

Table 5

Dose uniformity	85 – 115 %	75 – 125 %	C. V. (%)
UD ₁ con V ₁	✓	-----	4.362
UD ₂ con V ₂	✓	-----	5.307
UD ₃ con V ₃	✓	-----	3.313
UD ₄ con V ₄	✓	-----	3.965
UD ₅ con V ₅	✓	-----	2.962

Dose uniformity of rosemary extract tablets. Unit 1 with V1 to Unit 5 with V5 = Dose uniformity 1 with titration 1 to Dose uniformity 5 with titration 5. C.V. = coefficient of variation, = passes dose uniformity test

The range allowed to accept the dose uniformity test is 85 to 115% and a coefficient of variation $\leq 6\%$, if one or more tablets fall outside this range another 20 tablets are taken and the range is now 75 to 125% and a coefficient of variation $\leq 7.5\%$ and only under these conditions do the samples pass the dose uniformity test.

Conclusion

The medicinal product [Rosmarinus officinalis extract tablets] has the desired physical and organoleptic characteristics and/or properties, which guarantee that, when evaluated with the Official Trials or Tests established by the FEUM, this medicinal product meets the requirements and acceptance criteria.

The new Rosmarinus officinalis extract tablets meets the Universal, Pharmacopoeic, or Official Tests required for a medicinal product to be considered of good quality and be marketed. The results of these Identity, Disintegration, Dissolution, Titration, and Dose Uniformity tests fall within the permissible ranges established by the Pharmacopoeia of the United Mexican States, which are supported by the World Health Organization and documents such as Remington's "Pharmacy" and Lackman's "The Theory and Practice of Industrial Pharmacy."

These tests performed on rosemary extract tablets [Rosmarinus officinalis] are reproducible by adapting them to the conditions of the Industrial Pharmacy Laboratory of the Academic Unit of Chemical Sciences of the Autonomous University of Zacatecas, where the entire experimental part of this project was carried out.

Declarations

Conflict of interest

Los autores declaran no tener ningún conflicto de intereses. No tienen ningún interés financiero en conflicto conocido ni relaciones personales que pudieran haber influido en el artículo presentado en este artículo.

Author contribution

Orta-Martínez Felipe: Contributed to the processing of rosemary samples for identification, disintegration, and dissolution.

Hernández-Salas, Claudia: Contributed to the analysis of the results.

Regalado-Barrera, José David: Contributed to the search for the background of this investigation.

Reyes-Escobedo, Fuensanta Del Rocío: Contributed to the in the preparation of the manuscript.

Availability of data and materials

Open databases were accessed for this research, since platforms such as Google Scholar and Scopus, served as the basis for said work.

Funding

This research did not receive any funding. The expenses incurred were covered by the participating researchers.

Acknowledgements

We thank the Autonomous University of Zacatecas for being the place that facilitated this research

Abbreviations

CV	Coefficiente de variación
ml	Mililitro

Orta-Martínez Felipe, Hernández-Salas, Claudia, Regalado-Barrera, José David and Reyes-Escobedo, Fuensanta del Rocío. [2025]. Determination and evaluation of official tests on rosemary extract tablets [as a finished product]. Journal of Physiotherapy and Medical Technology. 9[20]1-5: e4920105.

<https://doi.org/10.35429/JP.2025.9.20.4.1.5>

Article

mg	Miligramo
FeCl ₃	Cloruro de hierro
NaCl	Cloruro de sodio
UD	Uniformidad de dosis

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Instructions for Scientific, Technological and Innovation Publication

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https://marvid.org/research_areas.php [No.10 TNRoman]

Area:

Field:

Discipline:

Subdiscipline:


DOI: <https://doi.org/>

Article History:

Received: [Use Only ECORFAN]

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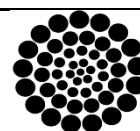
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General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features.

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

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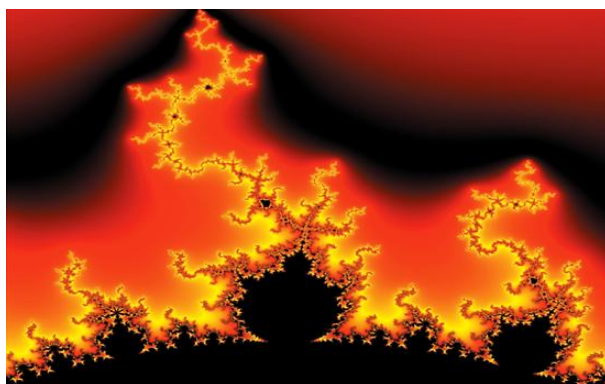


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$$Y_{ij} = \alpha + \sum_{h=1}^r \beta_h X_{hij} + u_j + e_{ij} \quad [1]$$

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Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Conclusions

Clearly explain the results and possibilities of improvement.

Annexes

Tables and adequate sources.

The international standard is 7 pages minimum and 14 pages maximum.

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Acknowledgements

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Abbreviations

List abbreviations in alphabetical order.

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ANN Artificial Neural Network

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“Proposed prosthetic device for energy storage and return for the lower limbs”

Bedolla-Hernández, Jorge, Islas-Zistecatl, Rolando, Bedolla-Hernández, Marcos and Cruz-García, José Michael

Tecnológico Nacional de México / Instituto Tecnológico de Apizaco

“We are plastic”

Hernández-Rodríguez, María Guadalupe, Ortega-Chávez, Laura Antonia, Santos-Benítez, Lina Susana and García-González-Héctor.

Tecnológico Nacional de México/ Instituto Tecnológico de Chihuahua II

“Determination and evaluation of official tests on rosemary extract tablets [as a finished product]”

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