International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 03 March 2025
Page No: 908-914
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0130

Sprained Ankle Robotic Exerciser by Using Rehabilitation Therapy

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Abstract
The portable mechanical design with a suitable mechatronic design and actuators that regulate ankle motion in all of its possibilities is where the proposed work's originality lies. Numerous individuals experience challenges related to their ankles. These issues might arise from uncomplicated causes; however, they can also serve as potential indicators of more severe underlying conditions. Rehabilitation training is typically conducted through personalized sessions led by a physiotherapist, as it demands the complete focus of the physiotherapist. We have designed this robotic machine to help the physiotherapist and also a patient can handle himself carefully with less aid of a person. There are numerous causes of ankle pain. The most frequent reasons are normal wear and tear, arthritis, and trauma. Anywhere around our ankle, we could experience discomfort or stiffness, depending on the cause. Additionally, we might not be able to bear any weight on our ankle due to swelling. Rest, ice, and over-the-counter (OTC) pain relievers typically help with ankle pain. A medical professional will treat arthritis and injuries. In many cases, these disorders can be treated without surgery. It provides a pattern of plantarflexion, dorsiflexion, inversion and eversion movements. Surgery may be necessary for severe ankle injuries, particularly shattered bones. If various nonsurgical therapies fail to alleviate our acute ankle pain, we may also require surgery.

Keywords: *Ankle Injury recoverment, Ankle exerciser, Rehabilitation Techniques, Sprained ankle therapy, Ankle Patterns, Self-assist mode.*

1. Introduction

A sprained ankle is a common injury when the tissue that connects your ankle bones and supports your ankle (ligaments) is torn or stretched beyond its limits, often after a fall, ankle roll or twist [1]. A sprained ankle is when the ligaments in your ankle are torn. A broken ankle or ankle fracture is when one or more of the bones in your ankle break. Severe sprains and fractures have similar symptoms (pain, swelling, bruising, tenderness) and are both caused by twisting or rotating your ankle, tripping or falling, or trauma to your ankle. Sprains heal faster, but it can take up to six weeks for a broken ankle to heal. The ankle joint is critical to locomotion by sustaining the load of the whole body while exerting key forces during push-off, leg swing, and center of mass advancement during the human gait. Numerous studies have demonstrated that high intensity repetitive movements play an important role in the effectiveness of robotic therapy. The ankle joint is considered one of the most important structures that support body weight. That is why it belongs to one of the most frequently injured areas in the human body. Every year, millions of people around the world suffer from a fracture or dislocation of the ankle joint. [3] The sprained ankle robotic exerciser is a rehabilitation tool that uses regulated and automated therapeutic movements to help people heal from ankle injuries. Pain, swelling, and limited mobility can result from ankle injuries, which are frequently brought on by trauma, arthritis, or normal wear and tear. Manual physiotherapy, which is the foundation of traditional rehabilitation techniques, necessitates ongoing physician supervision. Recovery delays could result from these approaches' unpredictability and reliance on the availability of therapists. In order to overcome these obstacles, this robotic system combines sensors, actuators, and mechatronic parts to provide systematic rehabilitation activities with the least amount of human involvement. Sensors that monitor range of motion, stiffness, and flexibility are used by the system to detect the patient's ankle motion. Actuators produce regulated movements based on the data gathered, directing the ankle through crucial rehabilitation activities such dorsiflexion, plantarflexion, inversion, and eversion. In order to prevent undue strain and aid in recovery, a feedback mechanism makes sure that the pace and intensity of motions are modified in accordance with the patient's development. The primary objective of this project is to design and develop a portable robotic device that assists in ankle rehabilitation, addressing the needs of individuals suffering from ankle-related issues such as pain, stiffness, and limited mobility. The device aims to provide a mechatronic solution that enables controlled ankle motion across various directions, thereby facilitating effective rehabilitation exercises. By integrating actuators, sensors, and control systems, the machine will allow both physiotherapists and patients to engage in rehabilitation sessions with greater flexibility and efficiency. Another key objective is to reduce the reliance on physiotherapists during recovery, allowing patients to perform rehabilitation exercises independently with minimal supervision. This will not only make rehabilitation more accessible but also help reduce the strain on healthcare providers. The device is designed to be portable, making it convenient for home use and reducing the need for frequent hospital or clinic visits. Additionally, the project seeks to improve the overall rehabilitation process by offering a cost-effective solution that combines the benefits of traditional therapy with modern technology. By automating some of the rehabilitation tasks, the device will enhance the quality of care and recovery outcomes for patients while reducing treatment costs and recovery time [2]. A fracture of the ankle joint is a violation of bone integrity due to a direct impact or because of indirect mechanisms. Exercises performed during leg sprains should be long-term, repetitive and with a low load. In this regard, the development and use of active rehabilitation devices is gaining momentum . For ankle rehabilitation, this robotic exerciser offers an affordable, dependable, and efficient alternative that guarantees scheduled therapy and better patient outcomes. The technology is a major advancement in physiotherapy since it combines automation and rehabilitation, allowing patients to heal more quickly, safely, and effectively.[4-9]

2. Literature Survey

People of all ages are susceptible to ankle injuries, a common musculoskeletal problem that can cause pain, decreased mobility, and an elevated risk of re-injury. Manual physiotherapy, weight training, and guided movement exercises are the mainstays of traditional rehabilitation techniques, all of which necessitate ongoing medical supervision. Despite their effectiveness, these methods could be constrained by patient adherence, therapist availability, and human error. Robotic rehabilitation systems have drawn interest as an alternate approach to overcoming these obstacles and improving recovery via automated and regulated therapy. The application of robotically assisted devices in physical therapy has been the subject of numerous studies. Robotic devices have been created by researchers to help patients recover from lower limb injuries by offering repetitive, targeted movements that increase joint flexibility and muscle strength. With the help of sensors and actuators that control motion, these gadgets guarantee precise rehabilitation activities without putting users under undue pressure. Research indicates that, in contrast to conventional rehabilitation, robotic therapy improves range of motion, speeds up recovery, and strengthens neuromuscular coordination. To help those with limited movement, wearable robotic exoskeletons and assistive technology have also been studied. These devices use position and force sensors to track limb movements and modify the intensity of therapy as necessary. The advantages of biofeedback integration, which uses real-time data to tailor

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therapeutic sessions, are highlighted by certain study. This method enables adaptive rehabilitation, in which the system adjusts training regimens in response to patient development to guarantee the best possible recovery. Intelligent robotic rehabilitation devices are the result of recent developments in mechatronics and control systems. Research has indicated that the integration of AI-based control and machine learning algorithms allows devices to learn from patient responses, gradually improving treatment regimens. Long-term results are improved by these improvements, which help make rehabilitation programs more effective and patient-specific. Additionally, patients who might not have quick access to rehabilitation facilities can now be monitored remotely by physiotherapists thanks to wireless connectivity and Internet of Things (IoT) integration. The possibility of portable rehabilitation equipment for home-based therapy has attracted attention. According to research, patients can perform rehabilitation sessions in their own surroundings thanks to robotic exercisers that are lightweight and portable. One essential component that has been emphasized is the capacity to remotely monitor development, which allows medical professionals to evaluate advancements and modify treatment regimens as necessary. This improves patient convenience and lessens the need for repeated hospital stays. By adding sensor-driven motion control, real-time feedback systems, and adaptive therapy modes, the sprained ankle robotic exerciser expands on these previous investigations. The gadget facilitates safe and efficient therapy by guaranteeing regulated ankle movements, including dorsiflexion, plantarflexion, inversion, and eversion. This approach offers constant therapy sessions that are customized to the patient's needs while minimizing human interaction when compared to traditional methods. The efficiency of robotic rehabilitation in enhancing motor function, lowering pain, and avoiding re-injury is supported by current studies. These results are supported by the suggested system, which provides an adaptable, effective, and technologically advanced ankle healing option. To further develop robotic therapeutic applications, future research could concentrate on improving AI-based learning capabilities, optimizing actuator responsiveness, and incorporating virtual rehabilitation environments [10].

3. Proposed System

The suggested design is a wearable, lightweight device that is simple to set up and can be customised for various patients or users and exercise types. Additionally, the actuation's lightweight cable-based design makes it naturally. Because of the small mass of the moving parts and the small wrench needed to activate the system, consumers can feel comfortable. To assess the innovative device's viability in terms of maximum cable tension, wearer's ankle joint load, and range of motion, kinematic and static models have been created. To enable regulated rehabilitation therapy, the sprained ankle robotic exerciser combines hardware and software components. A safe and efficient recuperation process is ensured by the system's automatic and adjustable actions. The software system guarantees real-time control, monitoring, and data analysis, while the hardware consists of actuators, sensors, a microcontroller, a power supply unit, and structural support. The hardware-software connection enables the accurate performance of therapeutic activities according to patient needs. A microcontroller, like an Arduino or Raspberry Pi, serves as the central processing unit and is the foundation of the hardware system. It controls the actuators that provide movement after receiving input from sensors. The system's sensors could include force sensors, which measure pressure, and inertial measurement units (IMUs), such as the MPU-6050, which track ankle movement in several directions. By giving real-time input, these sensors make sure that movements stay inside acceptable bounds. Position encoders also aid in maintaining accuracy by tracking the precise angle of motion. The ankle must be guided through regulated movements by the actuators, which include stepper motors and servo motors. For rehabilitative activities like dorsiflexion, plantarflexion, inversion, and eversion, servo motors are the favored choice because to their accuracy and smooth motion control. A specialized motor driver circuit powers the motors, controlling the voltage and current to guarantee steady operation. In the event of unexpected discomfort, the system

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also has an emergency stop function to avoid putting undue strain on the ankle. The electrical energy required to run the sensors, microprocessor, and actuators is supplied by a power supply unit. The device can be made portable and user-friendly by using an AC power converter or rechargeable battery. An ergonomically designed mechanical frame supports the whole hardware arrangement, providing appropriate ankle support and comfort throughout therapeutic sessions. [11-15]

3.1 Block Diagram

For processing sensor data and managing actuator movements, the software system is essential. The microcontroller is programmed using the Arduino IDE, which allows it to read sensor inputs and communicate the proper signals to the motors. Depending on the microcontroller being utilized, either Python or Embedded C is used to develop the software. The gadget can modify movement direction and intensity according on the patient's progress because the control algorithm adheres to a predetermined set of therapeutic routines. The system incorporates a Graphical User Interface (GUI) for real-time monitoring. Patients or physiotherapists can choose therapy modes, monitor progress, and change workout parameters using this interface. Depending on the functionalities needed, Python with Tkinter, MATLAB, or LabVIEW can be used to create the GUI. Furthermore, remote monitoring is made possible by wireless communication modules like Bluetooth or Wi-Fi, which let medical practitioners modify therapy sessions in real time depending on data. The hardware and software link guarantees the robotic exerciser's accurate and flexible operation. The system is effective because it combines motor control, sensor feedback, and user-friendly software, offering a dependable and automated rehabilitation solution. The efficacy of ankle rehabilitation may be significantly increased in the future by cloud data storage and AI-based therapy modifications. For controlled therapy, the injured ankle robotic exerciser combines software and hardware. An Arduino or Raspberry Pi serves as the microcontroller, servo or stepper motors are used for movement, and sensors such as force, position, and IMU (MPU-6050) are used for real-time monitoring. Stability and portability are guaranteed via a mechanical framework and power source. Figure 1 shows Block diagram of Proposed System.

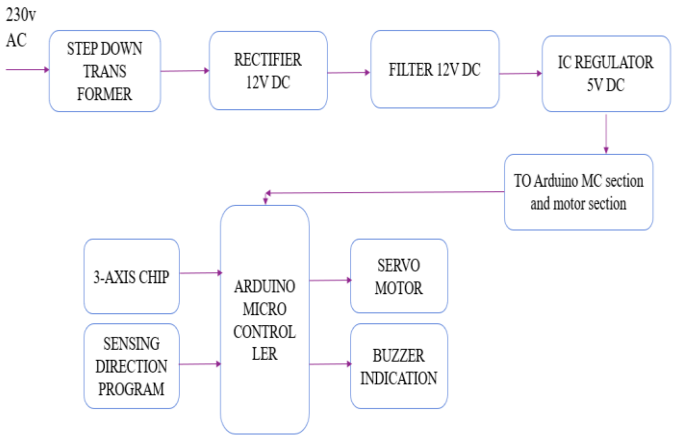

Figure 1 Block diagram of Proposed System

3.2 Flow Chart

For motion control, sensor processing, and data logging, the software makes use of the Arduino IDE and Embedded C/Python. Customization of therapy is possible through a graphical user interface (GUI), and remote monitoring is made possible by wireless networking. Reliance on physiotherapists is decreased and rehabilitation efficiency is increased thanks to the system's automated, secure, and customized therapy. proposed system bridges this gap by providing an affordable, portable, and effective respiratory support mechanism, particularly for patients requiring non-invasive ventilation and continuous monitoring. Future enhancements, including an improved power management system and adaptive ventilation algorithms, will further optimize the system’s efficiency and usability across diverse healthcare applications. For effective therapy, the injured ankle robotic exerciser adheres to a predefined flowchart. Using IMU, force, and position sensors, the system first gathers ankle movement data during the patient assessment phase. After processing this input, the Arduino/Raspberry Pi microcontroller calculates the necessary motion. Depending on the therapy settings, the actuators—servo or stepper motors, for example—perform regulated movements such dorsiflexion, plantarflexion, inversion, and

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eversion. To avoid undue strain, a real-time feedback loop continuously assesses progress and modifies motion intensity. For user engagement, data is recorded and shown on a graphical user interface (GUI). The device guarantees safe, individualized treatment, and wireless connectivity enables physiotherapists to monitor patients remotely for additional therapy adjustments. Figure 2 shows Therapeutic Device Workflow.

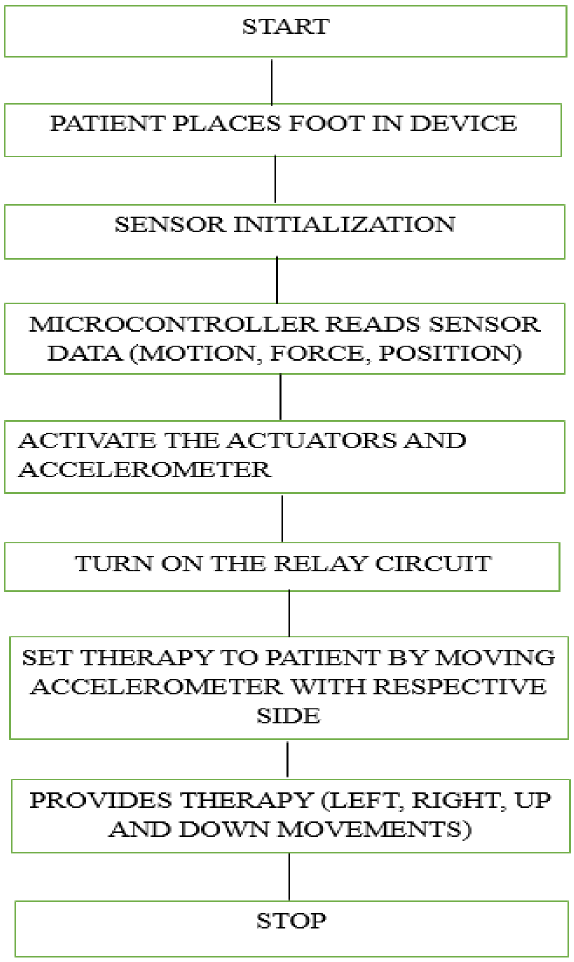

Figure 2 Therapeutic Device Workflow

4. Result and Discussion

By helping with precise ankle motions, the sprained ankle robotic exerciser effectively delivers regulated rehabilitation therapy. The system safely and gradually recovers by performing dorsiflexion, plantarflexion, inversion, and eversion. Real-time monitoring is ensured by sensor feedback, which permits modifications in response to patient requirements. Smooth motion is produced by combining servo motors with microcontroller-based control, which reduces strain and increases mobility. The findings show that by preserving consistency and lowering reliance on humans, automated therapy improves recovery efficiency as compared to manual physiotherapy. The device is appropriate for both home and clinical use due to its portable nature. Future developments like remote monitoring and AI-driven therapy adaption could increase the efficacy of rehabilitation even more. The gadget shows promise for use in contemporary physiotherapy applications. Figure 5 shows Ankle Exercises. [16]

4.1 Problem Identification – Survey

This Literature survey represented a type of injury acquires due to ankle sprain to sports players. Figure 3 shows Sports Injury Distribution by Type (Age 25-40). Figure 4 shows Ankle Sprain.

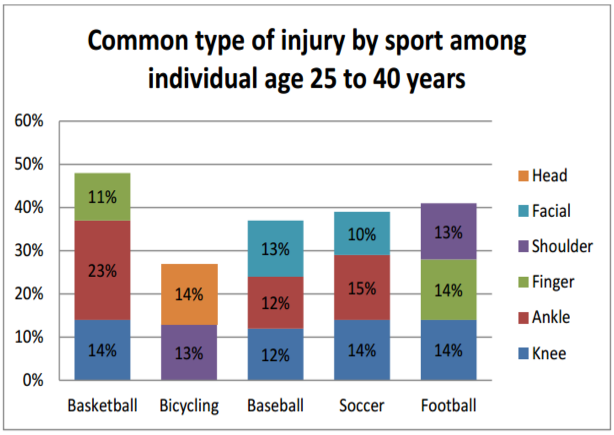

Figure 3 Sports Injury Distribution by Type (Age 25-40)

Figure 4 Ankle Sprain

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https://doi.org/10.47392/IRJAEH.2025.0130

4.2 Patterns of Movements

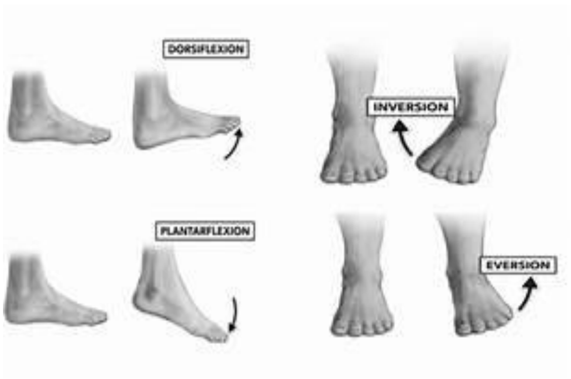

Figure 5 Ankle Exercises

4.3 Future Scope

The robotic exerciser for damaged ankles holds great promise for future developments in rehabilitation. Personalized therapeutic modifications depending on patient progress may be made possible by integration with machine learning and artificial intelligence (AI). Physiotherapists may be able to monitor patients remotely and adjust treatment methods because to wireless connectivity and Internet of Things integration. Home-based therapy may become more accessible with the use of ergonomic, lightweight materials that enhance comfort and portability. For an interactive rehabilitation experience, advanced models can include haptic feedback and virtual reality (VR).As robotic therapy gains acceptance in healthcare, this device can play a crucial role in post-surgical recovery, sports injury rehabilitation, and preventive therapy, ensuring faster and more efficient recovery. Movement control can be improved with additional advancements in sensor and actuator precision, guaranteeing safer and more efficient rehabilitation.

Conclusion

The sprained ankle robotic exerciser offers an innovative solution for rehabilitation by providing automated, controlled, and precise ankle movements. It reduces dependency on physiotherapists while ensuring consistent and effective therapy. The integration of sensors, actuators, and real-time feedback mechanisms allows personalized rehabilitation based on patient progress. The device enhances mobility, reduces recovery time, and minimizes the risk of re-injury through structured therapy. Its portable and user-friendly design makes it suitable for both clinical and home-based rehabilitation. Future improvements, such as AI-driven therapy customization and remote monitoring, can further enhance its effectiveness. This project contributes to modern physiotherapy advancements, making rehabilitation more accessible, efficient, and patient-centric, ensuring better recovery outcomes for individuals with ankle injuries [17-18].

References

[1]. Devidas, Kalpana. "Robotic-assisted ankle rehabilitation utilizing electrical stimulation and virtual reality training paradigms." J. Electrical Systems 20.1s (2024): 1048-1060.

[2]. Ni, M., Liu, J., Sun, Z., & Sun, T. (2024). Design and experiment of an ankle rehabilitation robot after fracture surgery. Journal of Mechanisms and Robotics, 16(12).

[3]. Yildirim, Emre, et al. "Design, Development and Hybrid Impedance Control of an Ankle Rehabilitation Robot." Journal of Mechanics in Medicine and Biology (2024): 2450028.

[4]. Zhetenbayev, N., Sergazin, G., Jamwal, P., Uzbekbayev, A., & Sagidoldin, D. (2024). Development of a portable and compact robotic ankle rehabilitation system. Vibroengineering Procedia, 54, 128-134.

[5]. Al-Shamkhani, Dina, Alaa Al-Ibadi, and Maria Elena Giannaccini. "Soft robot for ankle rehabilitation." 2023 16th International Conference on Developments in eSystems Engineering (DeSE). IEEE, 2023.

[6]. Doroftei, I., Cazacu, C. M., & Alaci, S. (2023, June). Design and experimental testing of an ankle rehabilitation robot. In Actuators (Vol. 12, No. 6, p. 238). MDPI.

[7]. Gonçalves, Rogério Sales, et al. "A user-friendly nonmotorized device for ankle rehabilitation." Robotics 12.2 (2023): 32.

[8]. Nguyen,et.al, Non-negative adaptive mechanism-based sliding mode control for parallel manipulators with uncertainties, 2023 (Vol.74, Issue 2, p 2771 to 2787).

[9]. Payedimarri, Anil Babu, et al. "Effectiveness of platform-based robot-assisted

rehabilitation for musculoskeletal or neurologic injuries: a systematic review." Bioengineering 9.4 (2022): 129.

[10]. Pedaran, A., Zareinejad, M., Talebi, H. A., Soleimanifar, M., Ahmadjou, A., & Ashoori, M. (2022, November). Design and implementation soft robotic rehabilitation device for ankle motion exercises.(pp. 317-322). IEEE.

[11]. Zhetenbayev, N., Zhauyt, A., Balbayev, G., & Shingissov, B. (2022). Robot device for ankle joint rehabilitation: A review. Vibroengineering Procedia, 41, 96-102.

[12]. Covaciu, Florin, Adrian Pisla, and Anca-Elena Iordan. "Development of a virtual reality simulator for an intelligent robotic system used in ankle rehabilitation." Sensors 21.4 (2021): 1537.

[13]. Dong, M., Zhou, Y., Li, J., Rong, X., Fan, W., Zhou, X., & Kong, Y. (2021). State of the art in parallel ankle rehabilitation robot: a systematic review. Journal of NeuroEngineering and Rehabilitation, 18, 1-15.

[14]. Guzmán-Valdivia, César H., et al. "Design, development and control of a therapeutic robot incorporating aquatic therapy for ankle rehabilitation." Machines 9.11 (2021): 254.

[15]. Zhai, Xiaoxue, et al. "Effects of robot-aided rehabilitation on the ankle joint properties and balance function in stroke survivors: a randomized controlled trial." Frontiers in Neurology 12 (2021): 719305.

[16]. Abu-Dakka, F. J., Valera, A., Escalera, J. A., Abderrahim, M., Page, A., & Mata, V. (2020). Passive exercise adaptation for ankle rehabilitation based on learning control framework. Sensors, 20(21), 6215.

[17]. Alvarez-Perez, Marian G., Mario A. Garcia-Murillo, and J. Jesús Cervantes-Sánchez. "Robot-assisted ankle rehabilitation: A review." Disability and Rehabilitation: Assistive Technology 15.4 (2020): 394-408.

[18]. M. Russo and M. Ceccarelli, (2020) Analysis of a wearable robotic system for ankle rehabilitation.