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# Nitinol-based Robot for Ankle Rehabilitation: Gamification and Management

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## Introduction

Exercises for ankle rehabilitation can be monotonous and repetitive. Utilizing robots and games can enhance current procedures, establish a connection with the patient, and lessen the burden placed on the physiotherapist. In this paper, a Pong game and an ankle rehabilitation robot with two nitinol wire actuators are shown to perform plantarflexion and dorsiflexion exercises on the feet. Nitinol is a type of smart material with a high volumetric mechanical energy density and the ability to produce translational motion. A two-state discrete antagonistic control is suggested for the actuators. The system was tested on healthy participants as well as stroke patients. The outcomes showed that the robot followed the instructions and was safe. The robot did not firmly plantarflex or dorsiflex the foot when the participant applied an opposing force. The actuators acted antagonistically during the game to flex to the foot in response to the up-and-down motions of the player's bat. These actions demonstrated that a nitinol-based ankle rehabilitation robot and a simple game could provide interactive rehabilitation exercise. The patient's experience, participation, and compliance with the rehabilitation routine are expected to be enhanced by the robot, as is the quantitative tracking of the patient's recovery progress.

## Description

Ankle rehabilitation is a treatment that takes a long time, costs a lot of money, and requires commitments from both patients and physiotherapists. The patient must actively participate in and adhere to the prescribed treatment, and the physiotherapist must manually assess and carry out the repetitive rehabilitation routine. However, the evaluation may be subjective based on the therapist's knowledge and experience. The ankle rehabilitation robot can overcome these limitations thanks to a number of advantages. The robot can provide a variety of exercises, including both passive and active rehabilitation, in one system. Additionally, it can provide a wealth of data that can be utilized for diagnosis, prognosis, treatment compliance, and record maintenance. Last but not least, it makes it easier for physiotherapists to focus on performance monitoring and strategy instead of worrying about the insignificant aspects of rehabilitation. Ankle rehabilitation robots can be broken down into two main categories: robots with platforms and wearables Platform robots are stationary robots with movable platforms. These robots typically weigh a lot and require a lot of space for storage and use. Popular platform robots include the Rutgers Ankle, CARR (Compliant Ankle Rehabilitation Robot), parallel manipulator robots, and other robots proposed by. Because they are stationary, these robots cannot be used for gait training. Wearable robots, on the other hand, are small and light, and their primary purpose is to assist patients in gait training by adjusting the orientation of their feet.

One of the most common types of wearable robots is the ankle–foot orthosis (AFO) that was proposed by. Parallel manipulator robots are frequently utilized for stationary knee and ankle rehabilitation exercises. It can produce development of up to six levels of opportunity and has a fundamental and conservative development. The robot's well-known dynamic behavior can be derived using the conventional closed-loop kinematic chain method. Additionally, it has a rigid structure and precise movement; As a result, it is safe for rehabilitation and was developed as a CARR with a torque capacity and a workspace that can be reconfigured to provide two distinct motion sets: Examples include plantar flexion-dorsiflexion, inversion-eversion, and internal-external ankle rotation. An ankle rehabilitation robot with two pairs of pneumatic artificial muscles, an ankle plantar flexion dorsiflexion and inversion eversion robot, and a parallel robot with three linear actuators for active, active-assistive, and active-resistance exercises were developed. The robot's impedance can change in response to the user's involvement, reducing the amount of assistance it provides as the user gets more involved [1-4].

The utilization of various actuations and materials is a recent development in robotics. One of the materials being studied and widely used in delicate robots and restoration robots is nitinol, also known as shape memory compound. It is a mixture of nickel and titanium. It has a remarkable capacity to retain its shape after deformity and a high capacity for weight proportion. At higher temperatures, nitinol changes from martensite to austenite, returns to its original state, and has a pulling force several times greater than its own weight. When the temperature drops in the opposite direction, it changes from an austenite to a martensite state, making it easy to deform by an external force. Nitinol is well-known for its recoverable strain and low cooling rate. In the previous work, the nitinol wire actuator was designed and developed to circumvent the first restriction.

This paper is divided into the following sections: describes the design of the ankle rehabilitation robot. In addition, the gamification and control of the robot, as well as the particulars of the experiment on healthy people and stroke patients, are discussed. Additionally, it discusses the experiment's outcomes and performance as a whole. It also discusses the robot's advantages and disadvantages, as well as a few possible strategies for overcoming them in the future. One of the things that sets this robot apart from other robots, like in, is that it only uses one load cell. Other robots, like in, use multiple load cells. By measuring the force that is exerted by the user when they flex their foot, the load cell determines the user's intention to move the bat up and down during the game. This information is also linked to the activation of the gastrocnemius and tibialis anterior muscles, which are both responsible for the plantar flexion and dorsiflexion of the foot, respectively [5].

## Conclusion

This method eliminates the electromyogram (EMG), which is susceptible to crosstalk and requires precise electrode placement for reliable results. However, this may not be sufficient if additional investigation is required. The incorporation of an electromyogram (EMG) by the robot might give a more complete picture of the patient's recovery. EMG sensors can be placed there to monitor the patient's tibialis anterior and gastrocnemius muscle activation during the game. During the rehabilitation exercise, this can be combined with the data gathered by the load cell using the method outlined in to determine whether the muscles are able to properly flex the foot upward and downward. The proposed robot has mechanical limitations. The current design only allows dorsiflexion and plantarflexion, whereas other robots, like in, can perform foot eversion and inversion. Furthermore, the robot is massive and bulky; As a result, mobile rehabilitation will not benefit from it.

## Acknowledgement

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## Conflict of Interest

None.

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