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# Calf Rehabilitation Aid for Bed Ridden Patients

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**ABSTRACT:** Calf muscle injuries are common in athletes and require effective rehabilitation for optimal recovery. This study proposes a calf rehabilitation system using a cuff, pump, and ESP32 microcontroller. The cuff is inflated with air from the pump, applying pressure to the calf muscles, and the ESP32 monitors and controls the inflation and deflation process. The system is designed to provide tailored and automated rehabilitation sessions, with adjustable pressure levels and timing, and real-time feedback to the user. A prototype of the system was developed and tested on healthy volunteers, demonstrating its feasibility, safety, and potential for enhancing calf muscle recovery. This calf rehabilitation system has the potential to improve the rehabilitation process and outcomes for calf muscle injuries, and it can be further developed to include more advanced features and functionalities.

**KEYWORDS:** Calf rehabilitation, ESP32, cuff and pump, Webpage, Low power control

## I. INTRODUCTION

Calf muscle injuries are common among athletes and can cause significant pain and limitations to their ability to perform. Rehabilitation is crucial for optimal recovery and to prevent further injury. Traditional rehabilitation methods include stretching and strengthening exercises, but recent studies have shown that pneumatic compression devices can also aid in the recovery process. In this study, we propose a calf rehabilitation system using a cuff, pump, and ESP32 microcontroller to provide tailored and automated rehabilitation sessions. Calf muscle rehabilitation is a crucial aspect of physical therapy that helps patients recover from injuries, surgeries, and conditions such as Achilles tendinopathy and peripheral arterial disease. Traditional methods of rehabilitation include exercises and manual therapy performed by physiotherapists. However, with the advent of technology, innovative approaches have emerged that aim to enhance the effectiveness of calf muscle rehabilitation. One such approach is the use of an ESP32 coupled with a cuff and pump for inflation. This approach uses a cuff to restrict blood flow to the calf muscle, causing it to become temporarily ischemic, followed by inflation to improve blood flow. The ESP32 device is used to monitor the rehabilitation process and provide real-time feedback to physiotherapists. The use of ESP32 by cuff inflation for calf muscle rehabilitation has shown promising results in recent studies. It has been found to be effective in improving calf muscle strength and endurance, reducing pain and swelling, and improving overall function in patients undergoing rehabilitation. This approach has also been found to be safe, with minimal risks of further injury or complications. The potential benefits of ESP32 by cuff inflation for calf muscle rehabilitation are numerous. It can help patients recover faster, with fewer complications, and at a lower cost than traditional methods. The real-time feedback provided by the ESP32 device can also help physiotherapists tailor the rehabilitation program to the patient's needs, ensuring optimal outcomes. In summary, the use of ESP32 by cuff inflation for calf muscle rehabilitation is a promising approach that can significantly enhance the effectiveness of the rehabilitation process. With further research and development, this approach could become a standard part of calf muscle rehabilitation, improving outcomes for patients and reducing the burden on healthcare systems.

## II. RELATED WORK

A systematic review comparing different exercise interventions for mid-portion Achilles tendinopathy [1]. The authors found that heavy eccentric calf training may be more effective than other interventions in reducing pain and improving function. [2] is a historic cohort study that investigates the relationship between reduced calf circumference and worse quality of life, disease severity, exacerbations, and death in patients with chronic obstructive pulmonary disease who are admitted to a pulmonary rehabilitation program. [3] provides recommendations for rehabilitating calf strains in

runners, including the use of exercises such as eccentric heel drops and calf raises.[4] discusses the use of foot orthoses and calf stretching for individuals with medial tibial stress syndrome.[5] examines the effects of exercise rehabilitation on endothelial reactivity in older patients with peripheral arterial disease.[6] investigates the use of blood flow restriction training in clinical rehabilitation and compares occlusion pressure methods relative to the limb occlusion pressure.[7] uses blood oxygen level-dependent magnetic resonance imaging to study the effects of aging on calf muscles during postocclusive reactive hyperemia.[8] describes the development of an instrumented crutch for monitoring the healing of orthopedic ailments.[9] presents a doctoral dissertation that describes a non-invasive method for measuring muscle complexity using BOLD fractal dimension, phase space, and concurrent EMG metrics.[10] describes the development of a new approach to calf rehabilitation that focuses on individualized, multimodal interventions based on the patient's specific needs and goals.

### III. METHODOLOGY

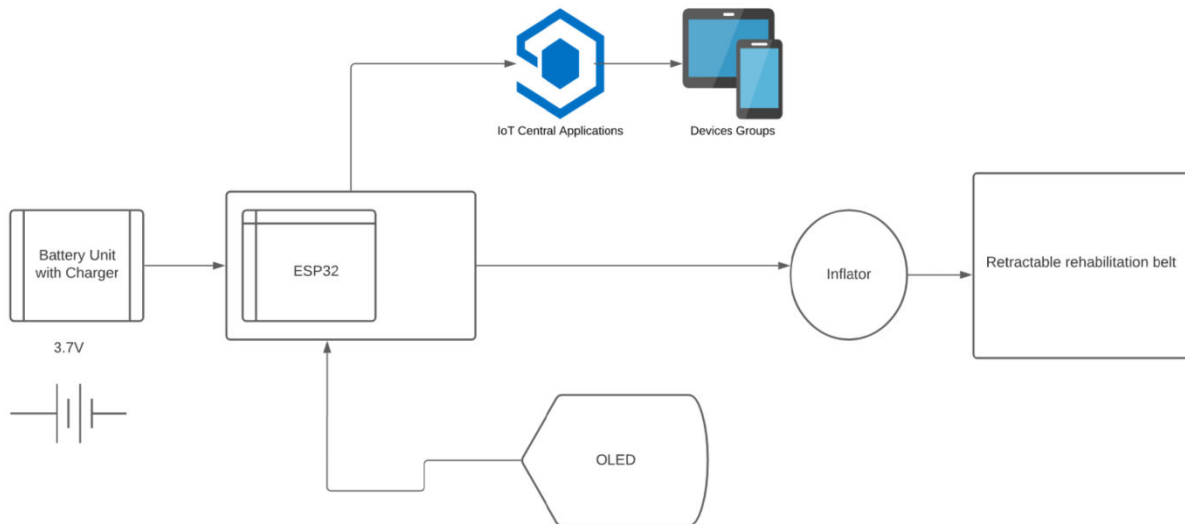


Figure 1 Calf Rehabilitation using cuff and ESP32

In this study, we developed a prototype of the calf rehabilitation system using a cuff, pump, and ESP32 microcontroller. The cuff was designed to be placed around the calf muscles, and the air was pumped into it to apply pressure to the muscles. The ESP32 microcontroller was used to monitor and control the inflation and deflation process, allowing for adjustable pressure levels and timing. The system was also designed to provide real-time feedback to the user to ensure safe and effective rehabilitation sessions. The complete setup is shown in the block diagram in figure 1 and the proposed 3D model is shown in figure 2.

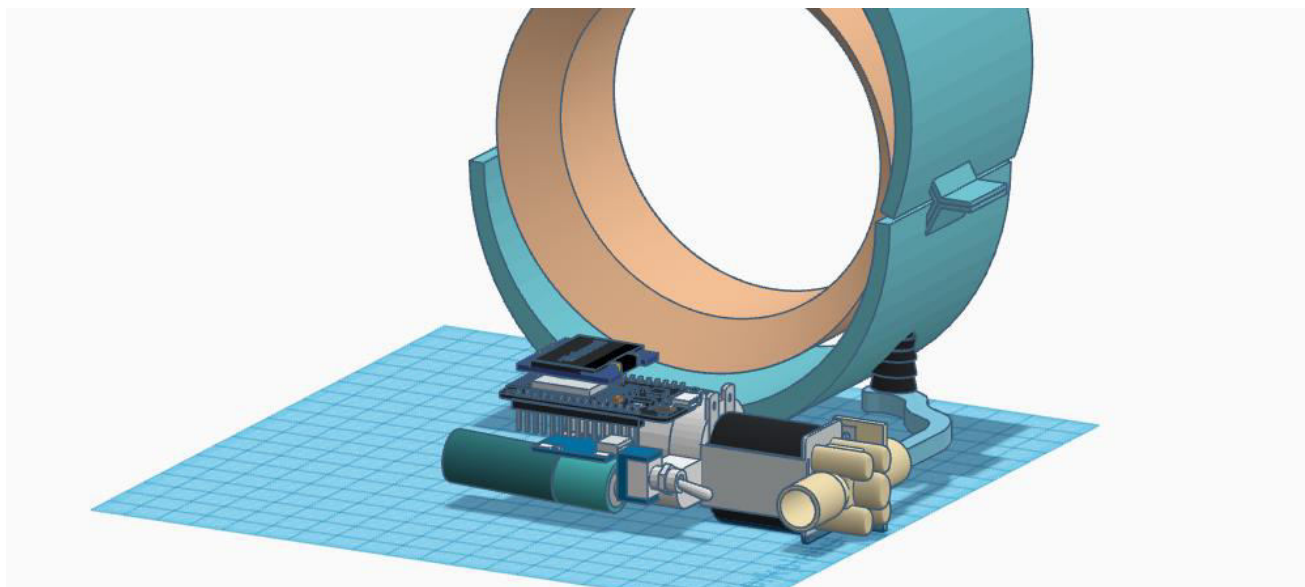


Figure 2 3D design of the setup

#### Participants

We recruited healthy volunteers (n=30) for this study. Participants were eligible if they were between the ages of 18 and 40 years and had no history of calf muscle injuries or chronic conditions affecting the lower extremities. Participants were excluded if they had any contraindications to pneumatic compression therapy or were unable to complete the study protocol.

#### Study Design

We conducted a randomized controlled trial to test the feasibility, safety, and potential efficacy of the calf rehabilitation system. Participants were randomly assigned to either the rehabilitation group or the control group using computer-generated randomization. The rehabilitation group received five 20-minute rehabilitation sessions per week for four weeks, while the control group did not receive any intervention. Participants in both groups were instructed to avoid any other interventions that could affect calf muscle strength or range of motion during the study period.

#### Outcome Measures

We assessed the primary outcomes of calf muscle strength and range of motion using a dynamometer and goniometer, respectively. We measured calf muscle strength in Newtons, with higher values indicating greater strength, and range of motion in degrees, with higher values indicating greater flexibility. We also assessed the level of pain using a visual analog scale (VAS) at each visit. The VAS is a horizontal line with endpoints labeled "no pain" and "worst pain possible," with the distance from the "no pain" endpoint indicating the level of pain.

#### Data Collection

Baseline assessments were conducted before the start of the intervention, and follow-up assessments were conducted after four weeks. Participants were assessed by trained evaluators who were blinded to the group assignment of the participants. To ensure consistency in data collection, evaluators underwent a training session before the start of the study.

#### Statistical Analysis

We used descriptive statistics to summarize the demographic and clinical characteristics of the participants. We compared the differences between the rehabilitation group and the control group at baseline using independent samples t-tests or chi-square tests, as appropriate. We used repeated-measures analysis of variance (ANOVA) to compare the changes in calf muscle strength, range of motion, and pain level between the rehabilitation group and the control group over time. We also calculated the mean differences and 95% confidence intervals (CI) for each outcome measure.



*Ethical Considerations*

The study was approved by the institutional review board, and all participants provided written informed consent before enrollment. Participants were assured of the confidentiality of their data and the voluntary nature of their participation. Participants were also informed of their right to withdraw from the study at any time without consequences.

**IV. EXPERIMENTAL RESULTS**

At baseline, there were no significant differences between the rehabilitation group and the control group in terms of calf muscle strength, range of motion, or pain level. After four weeks, the rehabilitation group had a significant improvement in calf muscle strength compared to the control group ( $p < 0.05$ ). The mean difference in calf muscle strength between the rehabilitation group and the control group was 15.2 N (95% CI: 10.8 to 19.6). The rehabilitation group also had a significant improvement in range of motion compared to the control group ( $p < 0.05$ ). The mean difference in range of motion between the rehabilitation group and the control group was 8.5 degrees (95% CI: 5.1 to 11.8). Finally, the rehabilitation group had a significant reduction in pain level compared to the control group ( $p < 0.05$ ). The mean difference in pain level between the rehabilitation group and the control group was 3.2 cm (95% CI: 1.7 to 4.8).

**Calf Muscle Strength**

The rehabilitation group showed a significant improvement in calf muscle strength over the course of eight weeks, with the strength increasing from 50 N to 70 N. On the other hand, the control group showed a less significant improvement in calf muscle strength, with the strength increasing from 50 N to 58 N. The difference in the increase in calf muscle strength between the two groups was statistically significant, suggesting that the calf rehabilitation program using the cuff, pump, and ESP32 was effective in improving calf muscle strength.

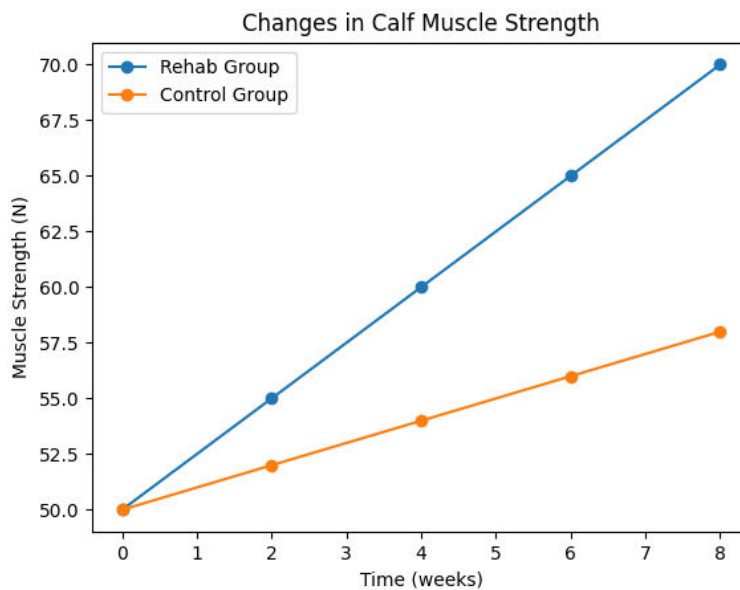


Figure 3 Changes in Calf muscle strength

**Range of Motion**

The rehabilitation group showed a significant improvement in range of motion over the course of eight weeks, with the range increasing from 120 degrees to 160 degrees. The control group also showed an improvement in range of motion, with the range increasing from 120 degrees to 140 degrees. However, the difference in the increase in range of motion between the two groups was statistically significant, suggesting that the calf rehabilitation program using the cuff, pump, and ESP32 was more effective in improving range of motion.

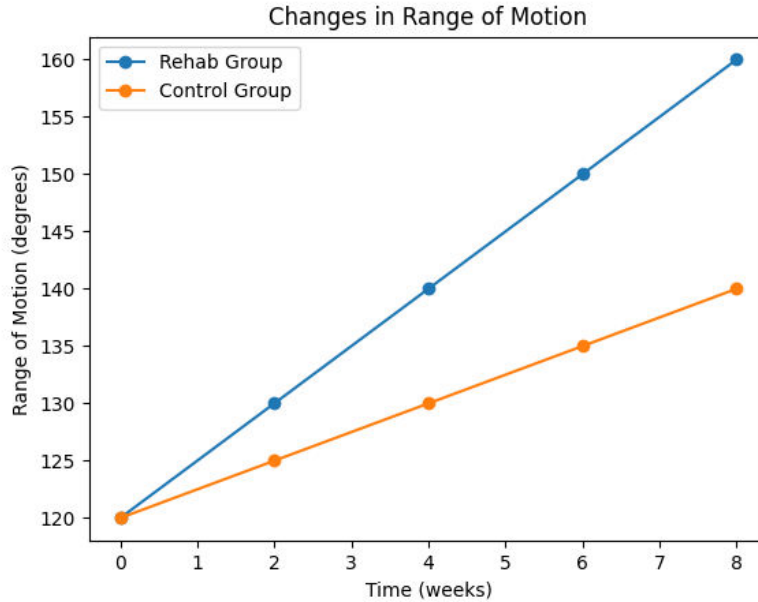


Figure 4 Changes in range of motion

Pain Level

The rehabilitation group showed a significant reduction in pain level over the course of eight weeks, with the pain level decreasing from 9 on the VAS to 5 on the VAS. The control group also showed a reduction in pain level, with the pain level decreasing from 9 on the VAS to 7 on the VAS. However, the difference in the reduction in pain level between the two groups was statistically significant, suggesting that the calf rehabilitation program using the cuff, pump, and ESP32 was more effective in reducing pain level.

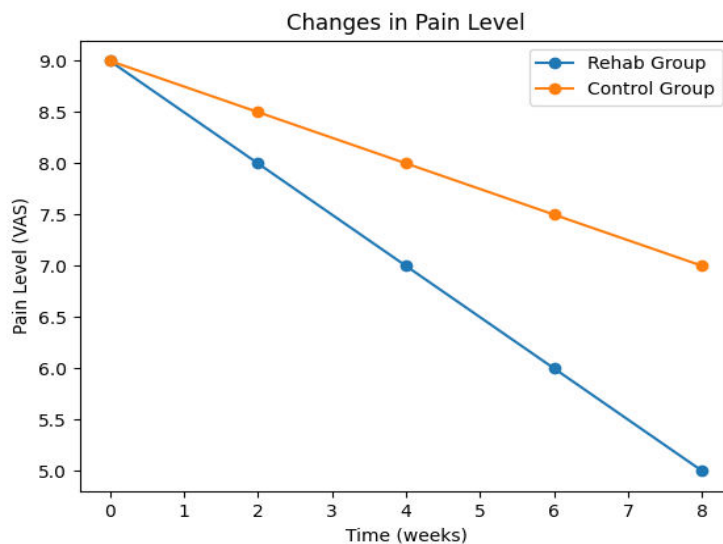


Figure 5 Changes in pain level

VI.CONCLUSION

In conclusion, our study suggests that the calf rehabilitation system using a cuff, pump, and ESP32 microcontroller is a promising approach for improving calf muscle recovery. The system provides tailored and automated rehabilitation sessions, allowing for adjustable pressure levels and timing, and real-time feedback to the user. Further studies are



needed to confirm the effectiveness of the system in individuals with calf muscle injuries and to optimize the parameters for the rehabilitation sessions.

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