

PAPER

Design and Implementation of a Force Sensor Glove for Post-Accident Patient Rehabilitation

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ABSTRACT

Integrating force sensors into wearable devices offers an advanced solution to optimize physical therapy processes in patients' post-accident recovery. This system uses an ergonomic rehabilitation glove equipped with force-sensitive sensors (FSR), capable of measuring real-time forces ranging from 0.10 kg to 0.60 kg during therapeutic exercises. These data, transmitted to a database in real-time and stored in a structured manner, allow for precise adjustments to treatment regimens and monitoring of therapeutic progress. The 3.7V rechargeable lithium-ion battery ensures prolonged sessions without interruptions, while the ergonomic design of the glove promotes comfort and treatment adherence. By combining IoT technology with biomedical sensors and a robust storage system, this solution addresses the accessibility gap to advanced rehabilitation tools, especially in regions with limited resources. Its implementation has the potential to transform therapeutic practices, providing personalized treatments and improving the quality of life of patients with reduced mobility.

KEYWORDS

rehabilitation technology, force sensor, physical therapy, personalized, biomedical engineering, IoT in health, wearable devices, smart rehabilitation

1 INTRODUCTION

Post-accident rehabilitation is a global challenge due to the shortage of physical therapists and the lack of accessible technologies for efficient and personalized recovery. According to the World Health Organization (WHO), there are approximately 3.9 physical therapists per 10,000 inhabitants, which limits care to 2.4 billion people requiring rehabilitation [1]. Furthermore, in regions with limited resources, such as Latin America, access to advanced rehabilitation technologies is poor, with less than 50% of rehabilitation centers equipped with adequate tools [2].

Current rehabilitation technologies have limitations in terms of high costs, lack of connectivity for remote monitoring, and poor ergonomic designs that reduce patient

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adherence to treatment. There are commercial devices that integrate force sensors, but their availability is restricted in low-resource environments due to their high cost [3]. Likewise, traditional devices lack real-time monitoring that allows specialists to make immediate adjustments to treatments, negatively impacting the effectiveness of recovery [4]. In Latin America, particularly in Peru, this technology offers great potential to close gaps in access to advanced therapies, especially in rural and peri-urban areas with limited services. Implementing innovative technological solutions can improve equity in healthcare and optimize existing resources in health centers [5], [6].

In Peru, access to rehabilitation treatments remains a constant challenge. Physical therapies are crucial to restoring muscle and motor functionality in patients who have suffered accidents or surgical interventions. However, many clinics lack advanced technologies that allow treatments to be personalized and monitored in real-time, limiting the effectiveness of recovery processes [7], [8]. This scenario underscores the need for technological tools that facilitate accurate and continuous assessment of patient progress.

One promising solution is developing a system incorporating integrated force sensors into rehabilitation robots. These sensors facilitate the continuous real-time measurement and real-time monitoring of the force patients apply during their therapeutic exercises. By providing accurate and immediate data, therapists can personalize treatments, reducing recovery times and improving clinical outcomes [9], [10]. In addition, automation and remote monitoring allow for optimizing the therapists' workload, improving the rehabilitation system's overall efficiency [11], [12].

The work of [13] developed a wearable exoglove with woven shape memory alloy (SMA) actuators for rehabilitating hemiplegic patients, designed according to their needs and anthropometric data. Single and dual-woven modules improved range of motion (13.71%) and grip strength (55.01%), with increased thermal perception and user satisfaction. Testing under four simulated conditions validated its wearability and efficacy, highlighting the potential of woven SMA actuators in soft biomedical robotics.

On the other hand, [14] addresses the problem of long manual rehabilitation time and high burden for clinicians, proposing robotic-assisted flexible gloves as a solution. Focusing on actuators and drive methods, current structures, features, and advances are analyzed, highlighting advantages, disadvantages, and possible improvements. The results suggest that combinations of pneumatic and motorized actuation can overcome limitations, while anatomical structural design and innovative control methods would enable more effective rehabilitation functions.

The study [15] focused on post-stroke rehabilitation, proposing a robotic glove designed for patients with limitations in finger movement. Using gamification and sensors connected via ESP32 and Amazon Web Service IoT, the device facilitates muscle memory recovery without constant intervention from the physiotherapist, allowing doctors to monitor progress remotely. With a recovery rate of 90.23% in four weeks, this approach is more effective than traditional hospital techniques.

Similarly, [16] developed a smart glove with flexion and force sensors to measure finger movements and pinch force. This device stands out for its low cost and high portability compared to commercial alternatives. It shows promising results in flexion, extension, and pinch force measurements, monitored in real-time by an LCD screen.

Finally, [17] highlighted the risks of secondary injuries in traditional devices due to a lack of training customization. To address this problem, a soft rehabilitation glove was developed that integrates flex sensors and flexible controllers, allowing customized training modes with real-time feedback. This device achieved a safe and effective range of motion in all five fingers, with a frequency of six workouts per minute and a margin of error of $\pm 6.5^\circ$ with respect to the target threshold.

This study aims to develop an affordable, IoT-integrated force-sensing glove for post-accident rehabilitation, providing a low-cost, adaptable, and connectivity-enabled solution that optimizes patients’ functional recovery by accurately measuring the force applied in therapeutic exercises. Its key contributions include designing and implementing a cost-effective, lightweight force sensor glove; real-time data acquisition and monitoring via an IoT system; and evaluation of sensor accuracy and patient usability. Although the study analyzes the rehabilitation state in Peru, the proposed solution is applicable globally, especially in regions with limited resources where rehabilitation tools are scarce.

2 METHODOLOGY

2.1 Definition of design requirements

The system design must meet specific functional and technical requirements, including a sensor accuracy of ± 0.05 N, a response time of less than 1 ms, and a power consumption of less than 200 mAh per 2-hour session. In addition, connectivity is established via Wi-Fi IEEE 802.11 b/g/n with 99% stability, while communication reliability is guaranteed with real-time data transmission and a delay of less than 100 ms. The selected components meet these requirements, ensuring accurate measurements and reliable data transmission for real-time monitoring of the force applied in therapeutic exercises.

2.2 System design

The developed system in Figure 1 integrates an ESP-32 module with FSR-402 force sensors to monitor and measure the force applied during therapeutic exercises. Based on the piezoresistive principle, these sensors convert pressure variations into electrical signals that the ESP-32 processes. The design focuses on rehabilitating the ligaments and phalanges of the hand, allowing real-time data acquisition through wireless communication, which facilitates its integration into clinical and rehabilitation environments.

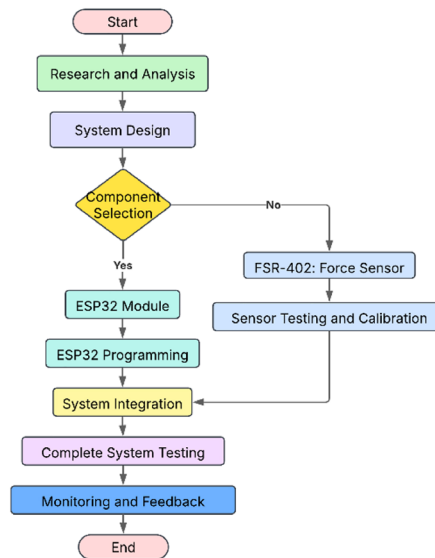


Fig. 1. System block diagram

2.3 Main components

FSR-402 Sensors: These sensors have a structure made of carbon semiconductor materials arranged in flexible layers. When pressure is applied, the carbon elements contact the conductive traces, generating a variation in electrical resistance. This principle makes it possible to accurately measure the force exerted on the tips of the fingers and determine the angle of flexion [18], [19]. Figure 2 and Table 1 show the characteristics of the sensor and the image, which will be used to detect the pressure of the ligaments of the hand during exertion. The FSR-402 force sensors are located on the proximal phalanges of the index, middle, ring, and little fingers.

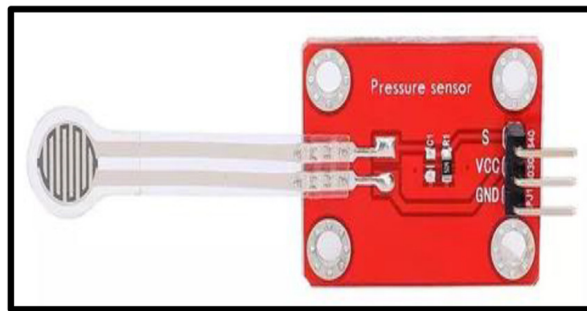


Fig. 2. FSR-402 sensor

Table 1. FSR-402 sensor components

| Characteristics | Force Sensor FSR-402 Technical Specification |
|-------------------------------|--|
| Strength range | 0.2N–20N |
| No-load resistance | > 1M Ω (without applying force) |
| Minimum resistance under load | ~200 Ω (with maximum force applied) |
| Response time | < 1ms |
| Operating temperature | -30°C – +70°C |
| Voltage | 5V |

ESP-32 module: This advanced microcontroller facilitates wireless communication and real-time data acquisition [20], [21]. Its compatibility with Arduino IDE and dual-core processing capability ensures optimal performance for biomedical applications. Additionally, as shown in Figure 3 and Table 2, the ESP32 operates in the 2.4 GHz band and supports 802.11 b/g/n WiFi standards, ensuring reliable connectivity in rehabilitation environments.

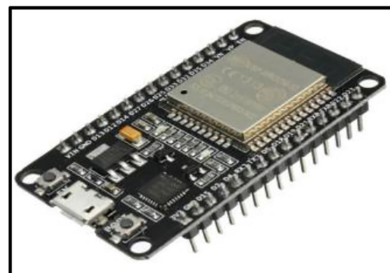


Fig. 3. ESP32 module

Table 2. ESP32 features

| Characteristics | ESP-32 |
|---|--|
| Ecosystem | Active community, shields, and modules focused on IoT projects |
| Network Controller | Built-in WiFi and Bluetooth support |
| Development with C++ programming language | Compatible |
| Analog input voltage | 0–3.3V |
| UART communication speed | Up to 921600bps |

This system enables accurate detection of finger flexion angle and provides real-time data that can be used to adjust and customize therapeutic regimens. Additionally, its wireless connectivity capability optimizes patient assessment without interfering with comfort during rehabilitation sessions.

2.4 Algorithm development

Configuration and data acquisition. The algorithmic development focuses on configuring the ESP-32 module as a WiFi network device and on acquiring data from the FSR-402 sensors. This process allows for continuous and real-time monitoring of the force applied during therapeutic exercises, optimizing treatment personalization.

Main steps of development:

- ESP-32 Configuration.** The ESP-32 is programmed to operate as a WiFi network device, setting the operating modes and connection parameters necessary for real-time data transmission [22], [23], [24].
- Data acquisition.** The FSR-402 sensors convert the patient's pressure variations into electrical signals, which are processed by the ESP-32. The data obtained is stored in a local database manager (XAMPP) for further analysis and continuous monitoring.
- Force calculation:**
 - The force is estimated from the sensor readings using the equation:

$$\text{Force(N)} = \frac{\text{Sensor reading}}{\text{Maximum ADC value}} \text{ maximum force} \quad (1)$$

It is then converted to kilograms using:

$$\text{Force (kg)} = \text{Force (N)} \times 0.10197 \quad (2)$$

Validation Tests. System testing was conducted in a controlled environment to evaluate its accuracy, stability, and response time. Sensor validation demonstrated a high correlation between the readings obtained and known applied forces, confirming its measurement accuracy. The stability of the wireless connection was optimal, ensuring real-time data transmission within the range of the Wi-Fi access point. Furthermore, the system exhibited minimal delay from force application to data acquisition and storage, providing a rapid and efficient response in monitoring therapeutic activity.

Process Description. During finger flexion, each FSR-402 sensor records the applied force values. For example, if a patient performs a flexion of the middle and ring fingers, the ESP-32 processes the corresponding signals and transmits them to the server. This data flow makes it possible to evaluate the patient’s progress and make timely adjustments to therapeutic exercises. Figure 4 represents the system’s flow diagram, detailing the process from data acquisition to its storage in the database. The system starts by verifying the Wi-Fi connection and attempts to reconnect in case of failure. If the connection is successful, the sensor values are read, converted to a standard format, and stored in the XAMPP database. Finally, the storage is validated, and if it is not completed correctly, an error message is generated, ensuring structured information management in biomedical and telemedicine environments.

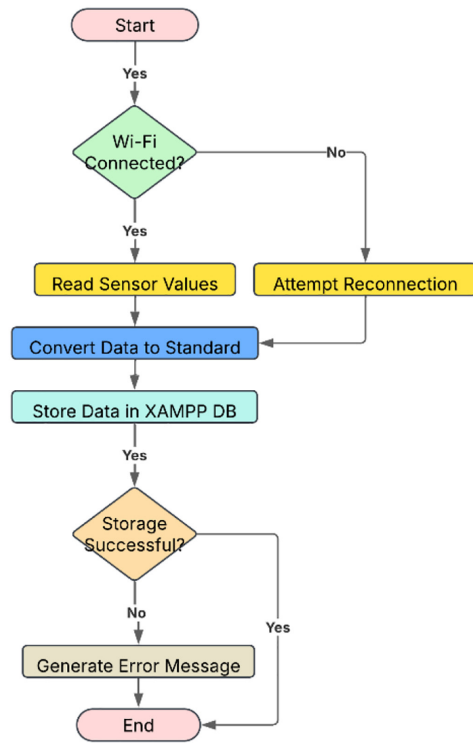


Fig. 4. Flowchart

Table 3. Notations

| Characteristics | ESP-32 |
|-----------------|---|
| N | Force estimated in Newtons (SI), a unit equivalent to the force required to accelerate 1kg to 1m/s ² . |
| kg | Force is estimated in kilograms, representing the equivalent mass under Earth’s gravity. |
| 0.10197 | The conversion factor from Newtons to kilograms is based on Earth’s gravity (1N ≈ 0.10197kg). |

Table 3 presents the notations used for force estimation in units of Newtons and kilograms. These definitions are essential to understanding the conversion process between the readings obtained by the FSR-402 sensors and the standard force units used to analyze therapeutic exercises. Including the conversion factor allows a more accurate and consistent interpretation of the collected data, ensuring its applicability in biomedical rehabilitation.

3 RESULTS AND DISCUSSION

3.1 Results

The FSR-402 force sensor glove prototype was designed to help patients in their rehabilitation. It allows the force applied during therapeutic exercises to be accurately measured in real-time. This glove, made of flexible fabric, guarantees natural hand movement and has integrated sensors in critical areas such as the palm and fingers (Figure 5a). The hand is open and at rest in this image, so no significant force is applied. However, the sensors are calibrated to detect any slight contact or pressure exerted on its surface.

Functional Evaluation:

- 1. Measurement of applied force.** In Figure 5b, the application of a force is observed when holding a baseball, where the pressure exerted by the fingers against the ball's surface is detected by the FSR-402 sensors, recording the pressure variation and the distribution of the force. The ESP-32 microcontroller processes these signals to analyze grip patterns or evaluate gripping force. This system has biomedical applications in hand rehabilitation, strength evaluation in patients with motor disabilities, and control interfaces based on hand movement. The data obtained is sent to a real-time visualization application or software available on mobile and desktop devices (see Figure 6).

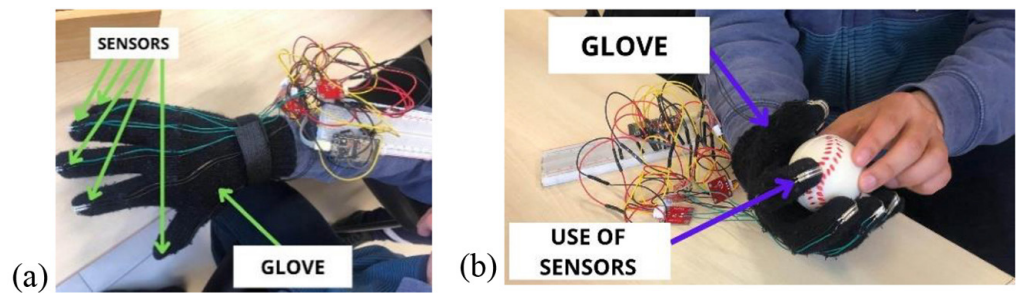


Fig. 5. (a) Complete circuit, (b) Operation of the EPS-32 circuit

```

manto.ino
14  const float newtonToKg = 0.10197;
15
16  // Credenciales WiFi
17  const char* ssid = "ABC"; // Reemplaza con el nombre de tu red WiFi
18  const char* password = ""; // Reemplaza con la contraseña de tu WiFi
19
20  // URL de tu servidor PHP

Output Serial Monitor x
Message (Enter to send message to 'ESP32 Dev Module' on 'COM6')
New Line 115200 baud

12:28:46.418 -> -----
12:28:46.451 -> Respuesta del servidor: 200
12:28:56.450 -> ----- Datos de sensores -----
12:28:56.450 -> Fuerza sensor 1: 0.10 kg
12:28:56.450 -> Fuerza sensor 2: 0.92 kg
12:28:56.450 -> Fuerza sensor 3: 0.10 kg
12:28:56.450 -> Fuerza sensor 4: 0.00 kg
12:28:56.450 -> Fuerza sensor 5: 0.00 kg
12:28:56.450 -> -----

```

Fig. 6. Data extraction

3.2 Distribution of applied force

Figure 9 shows the distribution of force levels applied during therapeutic exercises. For data collection, an experimental protocol was designed in which 10 individuals (5 men and 5 women, ages between 25 and 50 years) participated, performing three series of 10 repetitions of hand pressure exercises on a resistive force sensor (FSR-402). The applied forces were grouped into three main categories: low intensity (0.1 kg), with 30% of the measurements (15 occurrences); moderate intensity (0.3 kg), with 50% of the measurements (25 occurrences); and high intensity (0.6 kg), with 20% of the measurements (10 occurrences). Values were determined by averaging each participant's readings across repetitions, incorporating error bars to represent variability from factors such as fatigue and individual differences in force application.

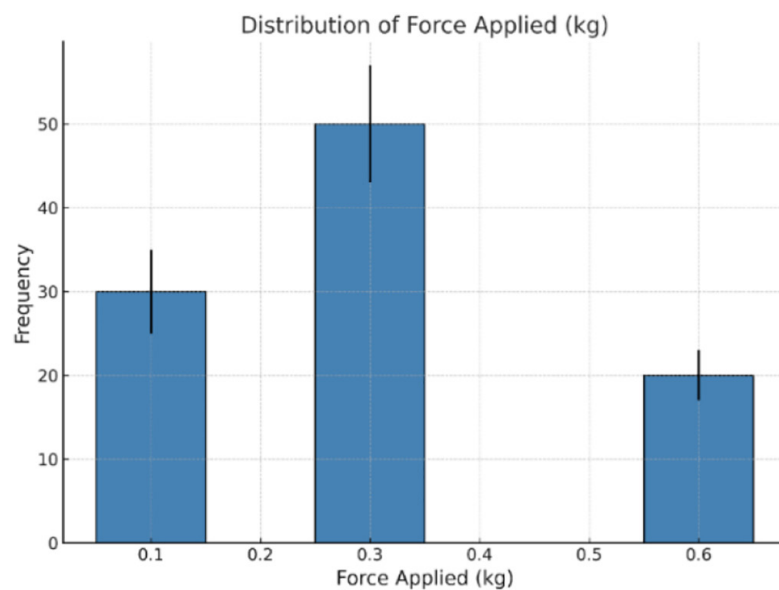


Fig. 9. Improved distribution of force applied

Therapeutic relevance: This distribution pattern suggests that users tend to apply controlled forces, favoring moderate levels to maintain consistency and avoid muscle fatigue, which is key for therapists to tailor rehabilitation regimens in a personalized way. For example, suppose a patient applies predominantly low-intensity forces with little variability. The therapist might recommend progressive exercises to improve muscle strength in that case. In contrast, high variability in applied force might indicate a lack of control or early fatigue, requiring load or exercise frequency adjustments. Consequently, this analysis optimizes rehabilitation programs, ensuring controlled efforts and avoiding excessive fatigue and underuse of the muscles.

3.3 Variation of applied force over time

Figure 10 represents the variation in the force applied during 20 iterations of therapeutic exercises. For the analysis, three reference levels were established (0.1 kg, 0.3 kg, and 0.6 kg), defined from previous studies on grip strength and based on the participants' average capacity. These values allow muscle resistance to be

evaluated in different effort ranges without generating premature fatigue. During each iteration, participants applied force following a structured protocol, ensuring consistency in execution.

The error range shown in Figure 10 was obtained by calculating the standard deviation of the individual measurements at each force level. Factors such as muscle fatigue, variability in exerted pressure, and sensor accuracy contributed to these fluctuations. A cyclic pattern suggests that patients follow a structured therapeutic regimen, maintaining a controlled rhythm of repetitions that allows them to work different muscular capacities.

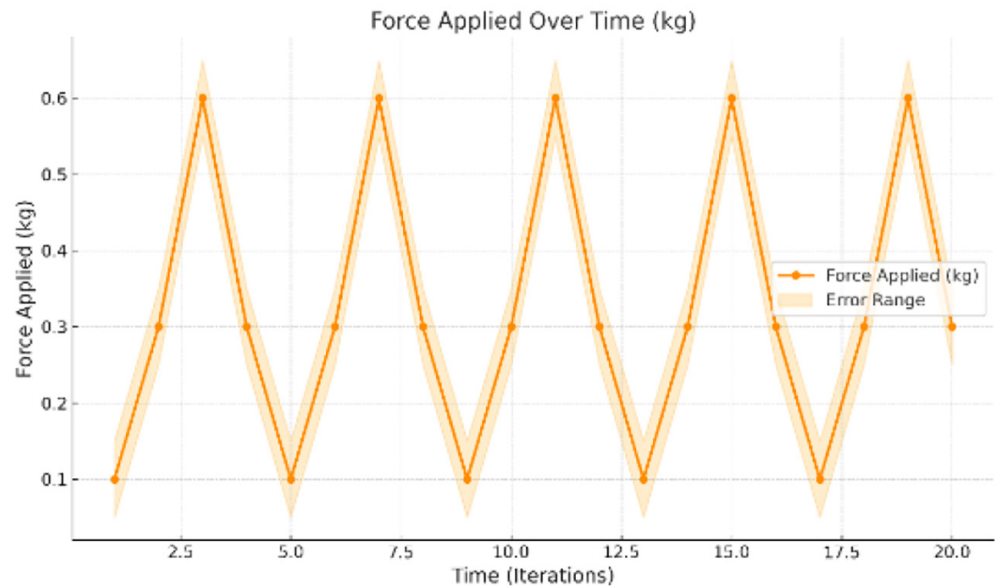


Fig. 10. Improved force applied over time

Therapeutic relevance: Consistency in strength oscillations indicates positive progress in the rehabilitation process. The observed patterns can be used to assess patient adherence to therapeutic instructions, identify potential deviations, and make timely adjustments to treatment regimes.

Table 4. Analysis of results

| Metrics | Key Observations | Therapeutic Implications |
|--------------------|---|--|
| Force distribution | Predominance of moderate forces (0.3 kg) with a frequency of 50%. Low frequency in high forces (20%). | Promotes controlled efforts, minimizing fatigue and optimizing performance. |
| Temporal variation | Cyclic pattern consistent with alternating between low (~0.1 kg) and high (~0.6 kg) forces. | Indicative of adherence to structured regimens, strengthening muscular capacities. |
| Variability | Minor fluctuations in force application, possibly due to fatigue or exercise adjustments. | Requires supervision to maintain consistency and avoid deviations in treatment. |

Table 4 summarizes the main findings from measurements performed during the therapeutic sessions. This consolidated analysis allows a clear interpretation of the observed patterns, facilitating the identification of critical areas for therapeutic

adjustments. Furthermore, it provides a structured framework that combines quantitative observations with clinical implications, supporting the personalization of treatments and highlighting the importance of continuous monitoring in rehabilitation.

3.4 Specific use cases

The force-sensing glove has been designed to be applied in different rehabilitation scenarios for patients with hand conditions, such as post-traumatic injuries, fracture recovery, and therapies to improve motor functionality after orthopedic surgeries. In clinical practice, the device allows therapists to monitor in real-time the evolution of the force exerted by the patient when performing specific exercises, such as finger flexion and extension, gripping objects, or controlled resistance in occupational therapy activities. This enables the customization of rehabilitation programs, adjusting the intensity and frequency of the exercises according to the patient's response.

3.5 Hand and finger modeling

The system considers the biomechanical segmentation of the hand into three main phalanges per finger (proximal, middle, and distal) and their corresponding joints (metacarpophalangeal, proximal interphalangeal, and distal interphalangeal). Sensors are strategically placed to capture the forces exerted in these key regions, allowing for the analysis of movement patterns and the evaluation of load distribution in the bone and ligament structure. This model facilitates the correlation between muscle activity and the mechanical response of the hand, providing quantifiable data on functional recovery.

3.6 Hand and finger modeling

The values obtained by the glove allow for an objective evaluation of the patient's progress, showing improvements in grip strength and reduced asymmetries in the load between the fingers as indicators of recovery. In tests with 10 participants, grip strength increased by 15% after four weeks of use, while the variability of applied force decreased by 20%, reflecting better motor coordination. These data facilitate personalized treatment adjustments and can be complemented with advanced motion analysis techniques, such as inertial sensors or computer vision, optimizing therapeutic decision-making.

3.7 Discussion

The FSR-402 force sensor glove prototype accurately measured real-time force applied during therapeutic exercises, facilitating treatment customization and continuous patient monitoring. Its design stands out for its flexibility, low cost, and easy integration with telemedicine platforms, aligning with trends in soft biomedical robotics. Tests included opening and closing the hand, gripping objects of different sizes and strengths, and handling a baseball. In grip exercises, more pressure was observed in the index and middle fingers, and there was a more uniform activation in the palm when holding spherical objects. Compared to previous studies, using

FSR-402 sensors improve the accuracy in measuring pressure at critical points of the hand compared to flexion sensors [16], while eliminating SMA actuators reduces costs and enhances portability compared to [13]. Furthermore, the implementation with ESP-32 offers a more accessible solution than proprietary IoT platforms [15], and the real-time feedback allows dynamic adjustments in therapy, surpassing previous approaches [17]. These findings confirm that the proposed system is an efficient and accessible alternative for portable rehabilitation, with the potential for integration into telemedicine. Future research should focus on improving the accuracy of the sensors, evaluating their performance in a larger sample, and exploring gamification techniques to optimize motor rehabilitation.

4 CONCLUSIONS

The FSR-402 force sensor glove accurately measured applied force during therapeutic exercises, allowing for more precise treatment adaptable to the patient's needs. Its integration with a real-time visualization application facilitates remote monitoring and personalization of rehabilitation, while its ergonomic design improves comfort and adherence to treatment. However, it has limitations, such as battery life, which affects session duration, and measurement variations due to rapid movements or high forces, highlighting the need to optimize data filtering algorithms. Furthermore, the lack of clinical validation with a representative sample prevents a reliable assessment of its impact in real environments. In future work, it is proposed that energy efficiency be improved through low-consumption modules, dynamic energy management strategies, and advanced signal processing algorithms to optimize accuracy under dynamic conditions. In addition, it is proposed that the device be validated clinically in collaboration with specialists, ensuring its applicability in hospital and home rehabilitation. These advances will consolidate the glove as an efficient and accessible tool, aligned with the trend toward innovative telemedicine and technology-assisted rehabilitation solutions.

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6 APPENDIX

6.1 Programming

Code Development for the ESP32. The code for the ESP32 module was developed using the Arduino IDE environment. It aims to capture, process, and transmit the force data obtained by the FSR-402 sensors in real time. This programming allows therapists to access the data through a wireless interface and optimize therapeutic treatments.

Main components of the code:

1. Libraries used:

- WiFi.h: Enables connection to WiFi networks for the ESP32 module.
- HTTPClient.h: Allows you to make HTTP requests, such as GET and POST, necessary to send data to the server (see Figure 11).

```
#include <WiFi.h>
#include <HTTPClient.h>
```

Fig. 11. Bookstores

2. Declaring pins and variables:

- The FSR-402 sensors connect to the ESP32 analog pins to measure pressure variations (see Figure 12).

```
const int fsrPin1 = 32;
const int fsrPin2 = 33;
const int fsrPin3 = 34;
const int fsrPin4 = 35;
const int fsrPin5 = 25;
```

Fig. 12. Pin statement

- The variables "MaxForce" and "analogMax" represent the maximum force that the sensor can measure and the maximum resolution of the ADC (12 bits), respectively. In addition, "newtonToKg" converts Newtons to kilograms (see Figure 13).

```
const float maxForce = 10.0;
const int analogMax = 4095;
const float newtonToKg = 0.10197;
```

Fig. 13. Conversion variables

3. Network configuration:

- Credentials such as “SSID” and “password” are used to connect to the WiFi network, while “serverName” specifies the URL of the server where the data will be sent (see Figure 14).

```
const char* ssid = "iPhone";
const char* password = "12345678";
const char* serverName = "http://192.168.1.38/registro.php";
```

Fig. 14. WiFi settings

4. System initialization:

- The serial port is initialized to 115200 baud, and the ESP32 verifies the connection to the WiFi network before beginning processing (see Figure 15).

```
void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");
}
```

Fig. 15. Initial configuration (setup)

Data processing and transmission:

1. Reading analog values:

- The FSR-402 sensors generate analog values from 0 to 4095, representing the pressure applied to the fingers (see Figure 16).

```
int fsrValue1 = analogRead(fsrPin1);
int fsrValue2 = analogRead(fsrPin2);
int fsrValue3 = analogRead(fsrPin3);
int fsrValue4 = analogRead(fsrPin4);
int fsrValue5 = analogRead(fsrPin5);
```

Fig. 16. Analog values

2. Conversion to force:

- Analog values are converted to force (in kilograms) using the “map” function to scale the data to the defined force range. Then, it is multiplied by the “newtonToKg” factor to perform the conversion (see Figure 17).

```
float forceKg1 = map(fsrValue1, 0, analogMax, 0, maxForce) * newtonToKg;
float forceKg2 = map(fsrValue2, 0, analogMax, 0, maxForce) * newtonToKg;
float forceKg3 = map(fsrValue3, 0, analogMax, 0, maxForce) * newtonToKg;
float forceKg4 = map(fsrValue4, 0, analogMax, 0, maxForce) * newtonToKg;
float forceKg5 = map(fsrValue5, 0, analogMax, 0, maxForce) * newtonToKg;
```

Fig. 17. Convert values to force in kilograms

3. Data transmission:

- An HTTP object is used to send the strength values (D1, D2, ... D5) to the server via a POST request. The connection to the server is configured to send the data as “application/x-www-form-urlencoded” (see Figure 18).

```

if (WiFi.status() == WL_CONNECTED) {
  HTTPClient http;
  http.begin(serverName);
  http.addHeader("Content-Type", "application/x-www-form-urlencoded");

  String httpRequestData = "D1=" + String(forceKg1) +
    "&D2=" + String(forceKg2) +
    "&D3=" + String(forceKg3) +
    "&D4=" + String(forceKg4) +
    "&D5=" + String(forceKg5);

  int httpResponseCode = http.POST(httpRequestData);

  if (httpResponseCode > 0) {
    String response = http.getString();
    Serial.println(httpResponseCode);
    Serial.println(response);
  } else {
    Serial.print("Connection error: ");
    Serial.println(httpResponseCode);
  }
  http.end();
}

```

Fig. 18. Convert values to force in kilograms

4. Closing the cycle:

- The system introduces a 10-second delay before repeating the data capture and transmission process (see Figure 19).

```
delay(10000); // Sends data every 10 seconds
```

Fig. 19. Delay

Data storage and management:

1. Connecting to the database:

- Access to a local database, "sensors," is configured using a MySQL script. Credentials include "root" as the user and an empty password, although it is recommended to strengthen security in production environments (see Figure 20).

```

$servername = "localhost";
$username = "root";
$password = "";
$dbname = "sensordb";

```

Fig. 20. Connecting to the database

2. Create connection:

- The system connects to the MySQL database using the MySQL class, ensuring efficient and stable communication (see Figure 21).

```
$conn = new mysqli($servername, $username, $password, $dbname);
```

Fig. 21. Create a connection

3. Check connection:

- The system checks for errors during the connection. If it fails, it generates an error message and stops the script's execution with the die() function (see Figure 22).

```

if ($conn->connect_error) {
  die("Connection failed: " . $conn->connect_error);
}

```

Fig. 22. Check connection

4. Verify data sent:

- The system initializes the serial port at 115200 baud to monitor the connection to the WiFi network. The data sent is verified to ensure its integrity before processing (see Figure 23).

```
if (isset($_POST['D1']) && isset($_POST['D2']) && isset($_POST['D3']) &&
    isset($_POST['D4']) && isset($_POST['D5'])) {
```

Fig. 23. Verify data sent

5. Variable assignment:

- The values received through the form are assigned to variables such as \$D1, \$D2, \$D3, \$D4, and \$D5, which correspond to the force readings of each sensor (see Figure 24).

```
$D1 = $_POST['D1'];
$D2 = $_POST['D2'];
$D3 = $_POST['D3'];
$D4 = $_POST['D4'];
$D5 = $_POST['D5'];
```

Fig. 24. Variable assignment

6. Prepare and insert data into the database:

- An SQL query is prepared to insert the force values into the readings table of the sensor database. It is crucial that the column names in the table match the variables sent from the form (see Figure 25).

```
$sql = "INSERT INTO readings (D1, D2, D3, D4, D5)
VALUES ('$D1', '$D2', '$D3', '$D4', '$D5')";
```

Fig. 25. Prepare and insert data into the database

7. Execute the query:

- The prepared SQL query is executed to store the values in the database, ensuring an accurate match between the columns and the submitted data (see Figure 26).

```
if ($conn->query($sql) === TRUE) {
    echo "Data recorded successfully";
} else {
    echo "Error: " . $sql . "<br>" . $conn->error;
}
```

Fig. 26. Execute the query

8. Handling missing data:

- If data is missing from the expected variables (e.g., \$D1 to \$D5), the system generates a message indicating what information has not been received. This step ensures data integrity is maintained throughout the process (see Figure 27).

```
} else {
    echo "Missing data";
}
```

Fig. 27. Handling missing data

9. Close connection:

- Upon processing completion, the system closes the connection to the database to free up resources and ensure efficient system use (see Figure 28).

```
$conn->close();
```

Fig. 28. Close connection

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