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RESEARCH ARTICLE

# Design of a Therapeutic Device for Drop Hand Patienst

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**Abstract**

Drop hand is a condition where a person's wrist or fingers experience difficulty and weakness in performing extension and flexion movements. This paper reports on the design and development of a therapeutic device for individuals with drop hand, capable of performing passive training movements, electrical stimulation, and monitoring muscle strength. The device includes a servo motor (MG995) for passive training movements, an IC NE555 for stimulation, and a Myoware muscle sensor to monitor muscle strength in the hands of individuals with drop hand. Additionally, the device is equipped with a Nodemcu ESP8266 microcontroller that can connect to a WiFi network, allowing muscle sensor readings to be stored in Google Sheets. Initial tests showed that the device could lift weights up to 1 kg, generate electrical stimulation frequencies ranging from 2.94 Hz to 18.5 Hz, and monitor muscle strength in real time.

**Keywords:** Drop hand, Passive Exercise, Electrical Stimulation, Myoware Muscle Sensor

## 1. Introduction

One of the causes of skeletal movement disorders is injury to the radial nerve in the arm, particularly in the case of fractures [1]. Radial nerve injuries can result from blunt force trauma, electrical burns, cuts from sharp objects, explosions [2], fractures, muscle damage, or denervation [3]. Injury to the radial nerve can lead to a lack of motor muscles control to flex the forearm, loss of wrist mobility, and inability to flex the fingers, or weakness in the hand area commonly referred to as drop hand [4]. Individuals with drop hand usually experience difficulty moving the extensor muscle group in the wrist and performing extension movements of the fingers and wrist [5]. To restore normal wrist and finger movement, passive training movements and electrical stimulation are required [6]. Passive training movements are exercises generated by the force of another person or device without direct muscle contraction [7]. Electrical stimulation is a neurological technique that can influence the motor and sensory systems by applying electrical currents through the skin to stimulate nerves or muscle tissue [8].

The goal of passive exercise is to prevent dysfunction and to improve, develop, restore, and maintain muscle strength, balance, coordination, and functional capacity. Simultaneously, electrical stimulation helps preserve muscle physiology and prevent muscle atrophy in patients [9]. Electrical stimulation involves placing two electrodes placed on the skin surface.

The positive electrode is placed proximal to the origin point of the extensor carpi radialis, while the negative electrode is placed on the distal part of the tendon. The frequency of sessions, duration of intervention, and intensity of the current used can be adjusted based on the severity of the injury and the patient's sensitivity [10].

Passive exercise and electrical stimulation are commonly used modalities for the rehabilitation and healing of drop hand. The effectiveness of rehabilitation interventions for drop hand typically includes passive exercises such as straightening, bending, stretching, pressing, and rotating the fingers, as well as rotating the wrist. Additionally, electrical stimulation can help reduce pain in drop hand patients [11] [12] [13].

So far, research on developing therapeutic devices for drop hand patients utilizing passive exercise, electrical stimulation, and muscle strength monitoring has been extensively conducted. Table 1 shows several research findings and commercially produced devices

However, as far as the author knows, a device capable of simultaneously performing passive exercise, electrical stimulation, and muscle strength measurement using electromyography techniques has not yet been developed in Indonesia. Therefore, this research is developing a therapeutic device for drop hand patients that can perform passive exercise, electrical stimulation, and muscle strength measurement. The device facilitates passive exercise through a servo motor's rotational movements, enabling flexion, extension, and hyperextension exercises. Electrical stimulation within the device is used to stimulate nerves with pulses that can be adjusted according to the patient's needs. The Myoware muscle sensor integrated into the device allows for precise muscle strength measurement. Muscle strength data can be displayed on an LCD screen and stored in Google Spreadsheets. With further development, it is envisioned that this designed device will evolve into an advanced and user-friendly tool for rehabilitating drop hand patients.

**Table 1.** Comparison of Researched and Commercially Available Devices

| Functional | Title | Characteristics | Reference | Year |
|---|---|---|---|---|
| Passive Exercise | Design of a Power-Grip Exoskeleton as a Rehabilitation Aid for Post-Stroke Patients. | The device does not include options for movement levels and is only designed for adult hands. | [14] | 2018 |
| | Hand Extension Robot Orthosis (HERO) Glove | The strength for flexion and extension movements of the fingers is still considered inadequate. | [15] | 2019 |
| | Robotic Exoskeleton for Finger Rehabilitation | Successfully created a passive exercise device capable of reaching almost the maximum finger flexion angle of 160° for adults, with a force of 68.4 N for a normal hand. | [16] | 2022 |
| | Hand Rehabilitation Robot Glove HF1002 | This device has been commercialized with features including flexible finger movement, adjustable training time, and lightweight design. | [17] | 2017 |
| Electrical Stimulation | Integrated Design of Functional Electrical Stimulator and Transcutaneous Electrical Nerve Stimulator on a Single Prototype | Uses an Arduino Uno microcontroller to control the frequency and pulse width of the device. The frequency range produced by the device is 10 Hz to 60 Hz. | [18] | 2021 |
| | Design of Functional Electrical Stimulator for Foot Drop Rehabilitation | Uses the STM32F103 microprocessor, which can generate a current intensity range of 0-100 mA and a frequency of 17-40 Hz. | [19] | 2021 |

| Functional | Title | Characteristics | Reference | Year |
|---|---|---|---|---|
| Electrical Stimulation | Design of Transcutaneous Electrical Nerve Stimulating Machine Using 555 Timer and 7555 Timer | Utilizes the NE555 IC and 7555 IC timer for TENS production with a high frequency range of 90 - 130 Hz. | [20] | 2022 |
| | SaeboStim Pro V4 | This device has been commercialized with a frequency range of 1 Hz to 125 Hz, adjustable to the user's needs. | [21] | 2017 |
| Electromyography Measurement | The Effectiveness of Electromyographic Biofeedback as Part of a Meniscal Repair Rehabilitation Programme Mihaela | Evaluates the effectiveness of using electromyography biofeedback in the initial stages of rehabilitation after meniscal repair. Measures electrical potential in contraction, contraction speed, and muscle relaxation. | [22] | 2013 |
| | Application of Surface Electromyography in Exercise Fatigue | Electromyography is effectively performed during sports fatigue and reduces the risk of injury during exercise. | [23] | 2022 |
| | A Prototype of Myoware (Electromyography Muscle Sensor) for Measuring People's Muscle Strengths | Uses the Myoware 1.0 muscle sensor for electromyography techniques. This sensor has potential in hand movement recognition and is useful in various medical rehabilitation applications. | [24] | 2023 |
| | Muscle Stimulator KM530 | Uses a combination of biofeedback and electrical stimulation. | [21] | 2020 |

## 2. Materials and Methods

Before developing the device, initial stages involve consulting with therapists and drop hand patients. Based on the outcomes of these consultations, the design and development of the therapeutic device are initiated. The process of creating and testing the device undergoes three iterative cycles to achieve desired outcomes. Each iteration involves gathering feedback from users and medical personnel, collecting data, testing prototypes, and refining them.

The design phase of the device starts with Solidworks software to shape its structure. Various designs are explored, including a hand pad designed for user comfort during device use, and finger caps to secure fingers to the device. The hand pad measures 8 cm in length, 7 cm in width, and 6 cm in height. Finger caps have diameters ranging from 2.5 cm to 1.3 cm, suitable for adult fingers. Design outcomes are illustrated in Figure 1.

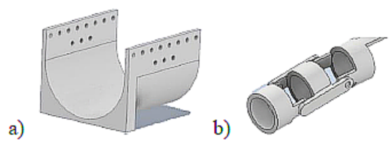



**Figure 1.** a) Hand pad of the device and b) finger cap

In the subsequent stage, the component configuration of the therapeutic device was designed using Fritzing software. The device incorporates an ESP8266 microcontroller capable of WiFi connectivity and command processing for multiple integrated components. These components comprise a Myoware muscle sensor for muscle strength measurement, a servo motor for passive exercise movements, a relay for microcontroller connection to the electrical stimulation circuit, and a Nextion LCD for the user interface.

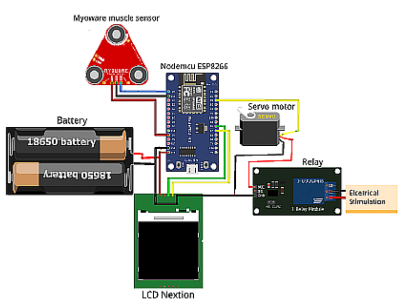



**Figure 2.** Configuration of the therapeutic device for drop hand patients

Figure 2 shows the design of the component configuration of the therapeutic device. After the device configuration is completed, the creation of the electrical stimulation follows. The schematic design of the electrical stimulation circuit is created using Eagle software. The schematic results of the electrical stimulation can be seen in Figure 3.

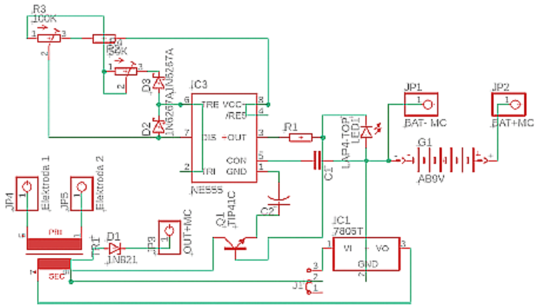


**Figure 3.** Schematic of the electrical stimulation circuit

Following the completion of the schematic design, the subsequent step involved assembling the components onto a dot matrix PCB as per the schematic. The NE555 IC was specifically chosen for the electrical stimulation circuit due to its ability to regulate the frequency and pulse duration of the electrical stimulation.

The program design for the device utilizes Arduino IDE software. The source code was developed to enable the Nodemcu ESP8266 to read the Myoware muscle sensor data and connect to the nearest WiFi network via a smartphone, storing the readings in Google Spreadsheet. Additionally, the source code was created to control the MG995 servo motor and electrical stimulation. The Nodemcu is also connected to the Nextion LCD, serving as the user interface. The program design was initially written in the form of a flowchart, as shown in Figure 4.

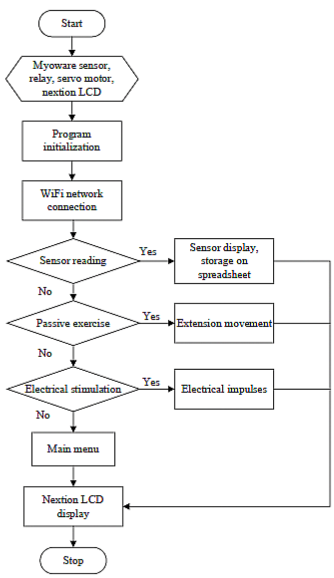



**Figure 4.** System flowchart of the device

## 3. Results and Discussion

The developed device underwent testing with drop hand patients to validate its effectiveness and usability. Subsequently, PLA+ filament material was 3D printed using a Creality Ender 3 V2 printer in the next stage. The outcomes of this process are illustrated in Figure 5.

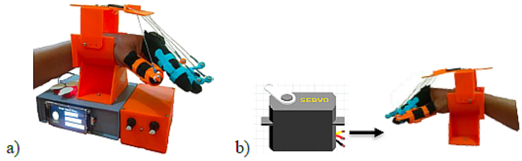



**Figure 5.** a) Device design results and b) servo motor for moving the hand

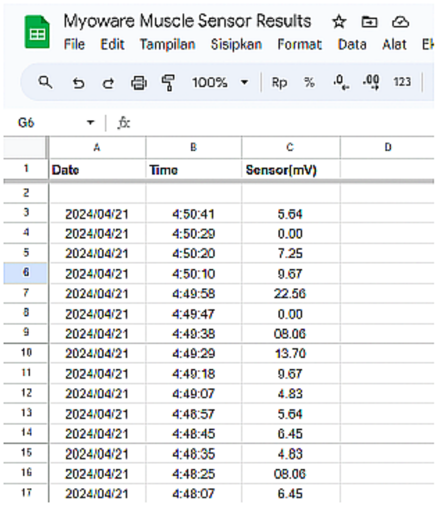
The MG995 servo motor is utilized to facilitate passive exercise movements by pulling the hand. It is connected to the finger cap using a 0.5 mm diameter sling wire capable of lifting up to 17 kg. In this design, the servo motor operates within a variable voltage range of 4.8 V to 6 V, producing a torque ranging from 9.4 kg/cm to 11 kg/cm. At a torque of 9.4 kg/cm, it takes 0.17 seconds to achieve a 60-degree angle increment, whereas at 11 kg/cm, this time reduces to 0.13 seconds. Based on these specifications, the maximum load that the servo motor can handle can be calculated for a sling length of 10 cm and a torque of 11 kg/cm:

$$Load = \frac{11\ kg/cm}{10\ cm} = 1,1\ kg \tag{1}$$

Based on the calculations, it is shown that the device is capable of performing passive exercise on the hand of drop hand syndrome patients, which accounts for approximately 0.575% of the total body weight [25]. As an illustration, for a body weight of 100 kg, the weight of the hand would be around 575 grams. For instance, an individual weighing 100 kg would have a hand weight of approximately 575 grams.


**Figure 6.** LCD nextion display

In this design, users are facilitated to easily select therapy modalities. Figure 6 shows the Nextion LCD interface for modalities selection. Subsequently, Myoware muscle sensor testing was conducted to determine muscle strength values by operating the device on volunteers with drop hand syndrome. The sensor was attached to the lower arm using three electrodes. Disposable H124SG electrodes were used and placed on the skin surface. When users connect the device to the nearest WiFi network, it automatically stores Myoware muscle sensor reading data in a Google Spreadsheet. The display of muscle strength readings using the Myoware sensor stored in the Google Spreadsheet can be seen in Figure 7.




| | A | B | C | D |
|---|---|---|---|---|
| 1 | Date | Time | Sensor(mV) | |
| 2 | | | | |
| 3 | 2024/04/21 | 4:50:41 | 5.64 | |
| 4 | 2024/04/21 | 4:50:29 | 0.00 | |
| 5 | 2024/04/21 | 4:50:20 | 7.25 | |
| 6 | 2024/04/21 | 4:50:10 | 9.67 | |
| 7 | 2024/04/21 | 4:49:58 | 22.56 | |
| 8 | 2024/04/21 | 4:49:47 | 0.00 | |
| 9 | 2024/04/21 | 4:49:38 | 08.06 | |
| 10 | 2024/04/21 | 4:49:29 | 13.70 | |
| 11 | 2024/04/21 | 4:49:18 | 9.67 | |
| 12 | 2024/04/21 | 4:49:07 | 4.83 | |
| 13 | 2024/04/21 | 4:48:57 | 5.64 | |
| 14 | 2024/04/21 | 4:48:45 | 6.45 | |
| 15 | 2024/04/21 | 4:48:35 | 4.83 | |
| 16 | 2024/04/21 | 4:48:25 | 08.06 | |
| 17 | 2024/04/21 | 4:48:07 | 6.45 | |

**Figure 7.** Display on Google Spreadsheet

The subsequent stage involved testing the range of electrical stimulation frequencies. In this device, a 50 kΩ potentiometer is connected to pin 5, and a 10 kΩ potentiometer is connected to pin 7 of the NE555 IC. Pin 5 regulates the control voltage, while pin 7 manages the discharge voltage. This configuration enables adjustment of the voltage and frequency of the generated electrical stimulation signal. The results of the electrical stimulation frequency measurements are depicted in Figure 8.

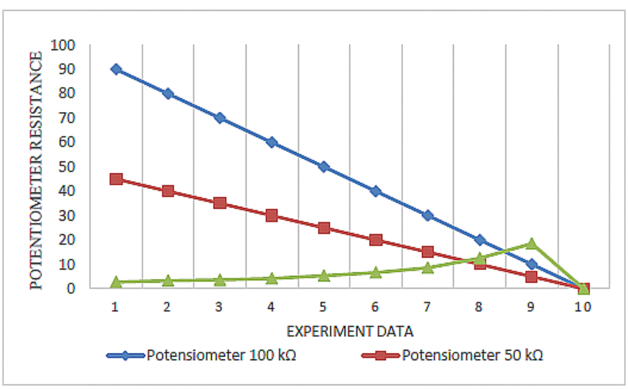



**Figure 8.** Frequency measurement of electrical stimulation for various potentiometer resistance values

The frequency measurements obtained from 10 tests ranged from 2.94 Hz to 18.5 Hz, depending on variations in potentiometer resistance values of both 100 kΩ and 50 kΩ. The resistance of the 100 kΩ potentiometer was reduced in increments of 10 kΩ, while the 50 kΩ potentiometer was adjusted in increments of 5 kΩ. Lower potentiometer resistance values resulted in higher frequencies. The test results demonstrated that the achieved frequency range is adequate to induce the release of endorphins, promoting relaxation, reducing contractures, and facilitating muscle contractions. This frequency range is suitable for wrist and finger extension [26] [27] [28] [29], comparable to commercially available devices such as the Saebostim Pro Neuromuscular and ODFS Pace XL.

## 4. Conclusion

Based on the results of the research and discussions conducted, it can be concluded that the developed device meets the requirements of users with drop hand conditions. The servo motor used in the device, with a torque ranging from 9.4 kg/cm to 11 kg/cm, effectively supports the lifting of hand loads. This device facilitates passive exercise movements and provides a frequency range of electrical stimulation from 2.94 Hz to 18.5 Hz, inducing a relaxation effect. Muscle strength readings can be displayed on the Nextion LCD and stored in Google Sheets when the device is connected to a nearby WiFi network. Further advancements are anticipated to enhance this device for potential commercial production.

## References

[1] Osama Deif, Amr Madkour, and Mohammed Agamy. "Nerve transfer of median nerve to radial nerve in high radial nerve injury". In: *Pan Arab Journal of Neurosurgery* 18.1 (2023), pp. 37–41.

[2] A. Disawal and S. Srivastava. "Sensory outcomes after repair of median and ulnar nerve with nerve graft". In: *International Surgery Journal* 8.3 (2021), p. 874.

[3] A. Noufal. "A case report of surgical treatment of traumatic drop hand by quadruple tendons transfer". In: *International Journal of Surgery Case Reports* 92.January (2022), p. 106880.

[4] T. J. Latef et al. "Injury of the Radial Nerve in the Arm: A Review". In: *Cureus* (2018).

[5] A. A. Amin et al. "Pengaruh Infra Red, Electrical Stimulation Dan Terapi Latihan Pada Drop Hand Et Causa Post Operasi Fraktur Humerus". In: *Jurnal Fisioterapi dan Rehabilitasi* 2.1 (2018), pp. 69–76.

[6] D. A. Nugraha, N. A. Hamidah, and N. D. Rachmawati. "Electrical Stimulation Dan Passive Exercise Efektif Dalam Meningkatkan Kekuatan Otot Pasien Lesi Nervus Radialis". In: *Physiotherapy Health Science* 3.2 (2021), pp. 74–77.

[7] Agusrianto and N. Rantesigi. "Penerapan latihan range of motion (ROM) pasif terhadap peningkatan kekuatan otot ekstermitas pada pasien dengan kasus stroke". In: *Jurnal Ilmiah Kesehatan* 2.2 (2020), pp. 61–66.

[8] A. D. Pratama and E. Williati. "Efektivitas Neuromuscular Electrical Stimulation Pada Penderita Anterior Cruciate Ligament Reconstruction Untuk Meningkatkan Kekuatan Otot: Studi Literatur". In: *Jurnal Sosial dan Humaniora Teraputik* 5.2 (2023).

[9] Arini. "Penatalaksanaan Fisioterapi Pada Kasus Drop Hand Sinistra Dengan Modalitas Infra Red, Electrical Stimulation, Dan Terapi Latihan Di Rsal Dr. Ramelan Surabaya". In: (2018).

[10] D. Craciun et al. "Physiotherapeutic management in the injuries of the extensor muscles tendons of the hand". In: *2019 7th E-Health and Bioengineering Conference (EHB)*. doi: 10.1109/EHB47216.2019.8969878, 2019, pp. 3–6.

[11] Z. Edger-Lacoursière, E. Deziel, and B. Nedelec. “Rehabilitation interventions after hand burn injury in adults: A systematic review”. In: *Burns* 49.3 (2023), pp. 516–553.

[12] B. Liu et al. “Effect of passive finger exercises on grip strength and the ability to perform activities of daily living for older people with dementia: A 12-week randomized controlled trial”. In: *Clinical Interventions in Aging* 13 (2018), pp. 2169–2177.

[13] P. L. Anggiat. “Penggunaan Terapi Elektrofisis Pada Satu Rumah Sakit Umum Swasta Di Jakarta”. In: *Oktober* 20 (2020), p. 40.

[14] P. Mahardhika. *Desain Power-Grip Eksoskeleton sebagai Alat Bantu Rehabilitasi Pasien Pasca-Strok*. http://repository.its.ac.id/id/eprint/59432. 2018.

[15] A. Yurkewich et al. “Hand extension robot orthosis (hero) glove: Development and testing with stroke survivors with severe hand impairment”. In: *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 27.5 (2019), pp. 916–926.

[16] Y. Dai et al. “A Novel Robotic Exoskeleton for Finger Rehabilitation: Kinematics Analysis”. In: *Applied Bionics and Biomechanics* 2022 (2022).

[17] U. Manual. *Soft Rehabilitation Glove*. http://siyizn.com. 2021.

[18] A. Khan, K. Li, and N. Wei. “Integrated design of functional electrical stimulator and transcutaneous electrical nerve stimulator on a single prototype”. In: *2021 6th IEEE International Conference on Advanced Robotics and Mechatronics (ICARM)*. doi: 10.1109/ICARM52023.2021.9536149, 2021, pp. 453–458.

[19] J. Wang and Y. Zhang. “Design of functional electrical stimulator for foot drop rehabilitation”. In: *Journal of Physics: Conference Series* 1885.5 (2021).

[20] S. Sarkar. “Design of Transcutaneous Electrical Nerve Stimulating Machine Using 555 Timer and 7555 Timer”. In: *International Journal of Science and Research* 5.12 (2016), pp. 1043–1049.

[21] I. Manual. *Stim Pro*. www.saebo.com. 2018.

[22] M. Oravitan and C. Avram. “The effectiveness of electromyographic biofeedback as part of a meniscal repair rehabilitation programme”. In: *Journal of Sports Science and Medicine* 12.3 (2013), pp. 526–532.

[23] J. Sun et al. “Application of Surface Electromyography in Exercise Fatigue: A Review”. In: *Frontiers in Systems Neuroscience* 16.August (2022), pp. 1–8.

[24] A. Rahagiyanto et al. “Prototype of MyoWare (Electromyography Muscle Sensor) for Measuring People’s Muscle Strengths”. In: *International Journal of Health Information Systems* 1.1 (2023), pp. 19–26.

[25] F. Buccino et al. “Mechanical Design Optimization of Prosthetic Hand’s Fingers: Novel Solutions towards Weight Reduction”. In: *Materials (Basel)* 15.7 (2022).

[26] E. L. Utari, I. Buyung, and I. M. G. G. Putra. “Simulasi Alat Elektrostimulator Akupuntur Berbasis Mikrokontroler Atmega16”. In: *Teknoin* 23.1 (2017), pp. 29–42.

[27] C. F. Nugroho, E. Yulianto, and S. Sumber. “Pengukuran Arus dan Frekuensi pada Alat Elektrostimulator”. In: *Jurnal Teknokes* 13.1 (2020), pp. 8–13.

[28] E. L. Nussbaum et al. “Neuromuscular electrical stimulation for treatment of muscle impairment: Critical review and recommendations for clinical practice”. In: *Physiotherapy Canada* 69.5 Special Issue (2017), pp. 1–76.

[29] D. Teoli and J. An. *Transcutaneous Electrical Nerve Stimulation*. Treasure Island (FL), 2024.