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REHABILITATION THROUGH SERVO MOTOR BASED ROBOTIC HAND GLOVE TO A SPINAL-CORD INJURED PATIENT

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Abstract: A spinal cord injury (SCI) can severely affect hand function. It is becoming more common to use passive and active assistive devices to improve lost hand strength and dexterity. In approaching the design of the prototype, a holistic mechatronic viewpoint was embraced in an attempt to effectively and efficiently integrate the mechanical and electronic aspects of the plan. This design philosophy has resulted in a prototype that meets and exceeds the requirements. Robotic Glove assistive devices enable a human-robot interaction facilitated by compact and lightweight structures. This study examined whether a servo motor-based robotic glove can effectively perform Rehabilitation of impaired hands of patients affected by spinal cord injury. This research work was administered to a Patient with C4-C5-C6 spinal cord injuries to assess the functionality of the robotic glove. The test included Rehabilitation of impaired hands and measuring their Activities of Daily Living (ADL). The test was administered to the Patient up to the period of eighteen months in duration; once a day up to six months, twice a day in the next six months, and thrice a day during the last six months while wearing the assistive glove. The impaired hands were rehabilitated, and effects were evaluated, including interaction effects of variables such as frequency & duration of Rehabilitation per day. The soft robotic glove is conducive to the Rehabilitation of impaired hands and observed minimal Capability of performing grasp and release, picking and holding, pressing to object through impaired hands after a long time and more numbers of time rehabilitation by this device in spinal injured Patient. The results gathered in this study are our Servo motor-based robotic glove as an effective device for Patients who have suffered upper limb, i.e., hands paralysis following a spinal cord injury. It helped the Patient in taking Rehabilitation without assistance from the therapist.

Keywords: Robotic glove, Servo motor-based robot, Spinal cord injury, Activities of Daily Living.

1. INTRODUCTION: About 12,500 Americans survive spinal cord injuries (SCI) each year [1], World Health Organization report of 19 November 2013, every year around the world, 250,000-5,000,000 people suffer spinal cord injuries [9]. Those living with cervical-level spinal cord injury have a severe disability in their upper extremities, particularly the hands and arms, impacting patients' independence and quality of life (2, 1). Daily living activities (ADLs) such as eating, dressing, and grooming become more difficult without normal hand function, which leaves the individual reliant on caregiver assistance for even the most basic task. However, few treatments are available to aid in hand function recovery after SCI [4]

1.1 BACKGROUND OF DEVICE**:** Several assistive and Rehabilitation devices have been designed to assist with ADL in a home in people with chronic SCI [10]. However, many complex devices incorporate giant exoskeletons [11-17]. A Servo Motor Based robotic hand glove was designed to actuate fingers movement with a cable secured to a robotic glove via plastic pipe guides. The wires are attached to the fingertips on the glove on one end and servomotors on the other end. The servomotors hold the carpal bones of the hand, which reels the cable line to bend the fingers in either flexion or extension controlled with an ARDUINO programming. The actuating of wrist movement carried out through servo motor attached with the glove through "L" shaped metal clamps and servo motor firmly tighten over Wrist with the help of elastic wrist splint. The position and force at which the wrist spin can be controlled with an ARDUINO programming. Control methods for the glove were implemented through the switch and vocal program.

1.2. PATIENT HISTORY**:** This robotic glove was used on the impaired hands of a Patient, aged 43 years, who were meeting in a road accident about 11 years ago. The condition of his hand's Fingers & Wrist as per OCCUPATIONAL THERAPY REPORT(dated 11-09-2012) of Indian Spinal Injuries Centre (ISIC), Vasant Kunj, New Delhi, reported MMT, as under:-

Table No.1 OCCUPATIONAL THERAPY REPORT

Upper Limb	Left Hand	Right Hand
Wrist		
D. Flexor	0	0
P.Extensor	0	0
Fingers		
Flexors	0	0
Extensor	0	0
Addiction	0	0
Indicator	0	0

This study aims to demonstrate that a Servo motor-based robotic hand glove, which is portable, bidirectional (enabling both opening and closing of the hand), offers an assistance solution for the above Patient with extremely limited hand strength and dexterity. This study evaluated the effectiveness of the assistive glove by administering a test to assess the grasp and release, pick and hold, press to object function of the Patient with impaired hand due to SCI with the regular and long period Rehabilitation provided by a servo motor-based robotic hand glove.

Using this device, you can detect grip or manipulation intentions through regular and continuous Rehabilitation of impaired hands through this device. This device's orthotic effect was assessed in a study among aging individuals with impaired hand function [18]. Because of its neuroplasticity [19, 20], its use could potentially contribute to motor learning

Using the servo motor-based hand glove, the study investigated whether self-administered home-based hand therapy using the servo motor-based hand glove may improve hand function, leading to improved ability to perform ADL.

2. METHODS

2.1 PARTICIPANT:

A patient of 43 years old who has met with a road accident about 11 years ago and suffered from spinal cord injury with a neurological level between C4, C5 & C6. He has extremely limited sensation in fingers and the Wrist of his hands. Such Patient was recruited for this study. The Spine condition of the participant is at a chronic stage. Therefore, it is not expected to have spontaneous recovery. Obtained consent for participation in an experiment from such Patient.

2.2. DEVICE:

It is a portable and cheaper device, especially meeting the posture & conditions of the above Patient was designed and developed for Rehabilitation of his impaired hands. It was designed and developed using mechatronics concepts. The device was developed using servo motors and other flexible materials in soft robotic gloves, which allows the device to actuate the fingers and Wrist of impaired hands. The inclusion of a servo motor-based, robotic glove into the design resulted in a significantly lighter and cheaper device, as shown in Fig. No. 1.

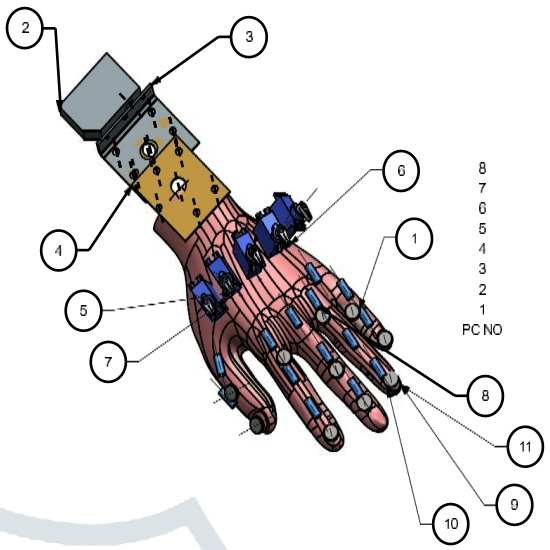

Fig.No. 1: Prototype 3- D Model

2.1.1. COMPONENTS:

The components used for assembling of prototype model are shown below. All Components used in making this device are readily available in the market. None of the components of this device was required to fabricate precisely. The device is very simple and involves a low cost. It was made with an aim to the approach of people of all categories in society.

Table No.2: COMPONENTS OF DEVICE

Component No.	Name of Component	Qty.
1.	VIBRATOR	10
2.	MOTOR2	1
3.	STRIP A	1
4.	STRIP B	1
5.	MOTOR CAM	5
6.	MOTOR SG90	1
7.	MOTOR ASSEMBLY	5
8.	SLEEVE	14

9.	GLOVE	1
10.	HAND	1
11.	GLOVE ASSEMBLY	1

2.3 SETTING:

This study was conducted at the Patient's residence because the Patient's current condition did not permit him. The Patient is on the job; therefore, conditions did not allow him to go for this experiment study out of his native place for such a long period. Therefore, all possible required facilities for rehabilitations and conducting tests were developed in his residence to experiment smoothly.

2.4 STUDY DESIGN:

The study follows the interventional longitudinal design described below in detail; the Patient was asked to wear the Servo Motor-based hand glove for executing Rehabilitation. The Rehabilitation of fingers and Wrists of impaired hands was conducted through wearing the Servo Motor Based robotic hand glove. In experimenting, we framed the plan of experimental design.

The Rehabilitation with the device was carried out in the house of the Patient. The outcome of this study in the hands of the Patient was measured through the "Capabilities of Upper Extremity Questionnaire (CUE) "method.

Experimental Design: The study on the Patient follows the following interventional longitudinal experimental parameters.

a. Rehabilitation Motion.

b. Rehabilitation Frequency.

c. Observation & Analysis

2.4.1. REHABILITATION MOTION:

A. FINGERS: The experiment was conducted to provide the Extension and Flexion motion to fingers of the Patient's hand. It was administered during Rehabilitation through Servo Motor Based Robotic Hand Glove. The working of the device on the patients' hand is shown as in Fig. No. 2 and Fig. No. 3

- Flexion of Fingers - 60-degree motion

Fig.No.2: Finger Flexion Motion during Rehabilitation through Servo Motor Based Robotic Hand Glove

- Extension of Fingers- 180-degree motion

Fig.No.3: Finger Extension Motion during Rehabilitation through Servo Motor Based Robotic Hand Glove

B. WRIST: The motion to the Wrist of the Patient's hands was administered during Rehabilitation through this device. The angle of abduction and adduction motion provided to the Patient's Wrist while conducting the experiment is mentioned below. The motion of the hand's Wrist being performed through this device was as shown in Fig. No. 4.

Abduction - 75-degree motion (left)

Adduction -35 degree motion (right)

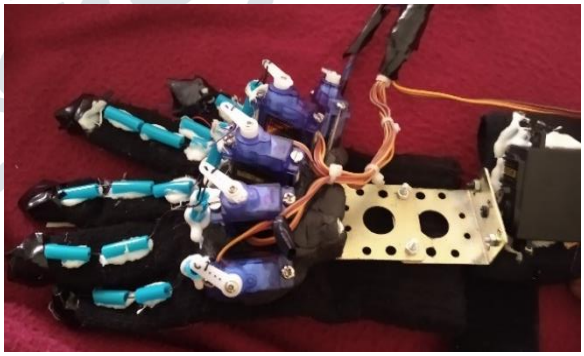

Fig. No. 4:- Abduction and Adduction Motion Of Wrist

2.4.2. REHABILITATION FREQUENCY:

The participant was provided the Rehabilitation at home for a minimum of 45 minutes per shift a day. The Patient was scheduled to attend three assessment sessions named initial first six months, next six months, and last six months in different frequencies. The Patient was maintained a basic diary to ensure protocol adherence and to record ADI. The design time schedule with different frequencies for Rehabilitation to the Patient was designed, which is as under:

Table No.3. TIME SCHEDULE OF REHABILITATION

1st Six months	2nd Six Months	3rd Six months
One shift per Day	Two Shift per Day	Three shift per Day

2.4.3 OBSERVATIONS & ANALYSIS

Observations: The Patient was asked to accomplish a set of tasks each day through impaired hands like grasping, Picking, holding, and pressing to object after Rehabilitation. During assessment sessions, the performance of impact through Rehabilitation was assessed using various Scales. The assessment tool "Capabilities of Upper Extremity (CUE) questionnaire" was used. Assessment of impact on Fingers and Wrist of the Patient was measured at the interval of a month. This practice was kept continued for the entire period scheduled for this study.

Analysis: Observations data were analyzed at the interval of every three months with the patient initial test report of ISIC. The performance through this device was continuously recorded and analyzed till the study was carried out.

2.5 DATA COLLECTION:

Capabilities of Upper Extremity (CUE) questionnaire is a test that is designed to find out how well a patient can use their fingers and Wrist. In this test number of actions are designed which are to perform by spinal cord injury patients. Questions asked on the action of the specific part of the body, an answer of each question puts the score at 7 as best and 1 as worst.

The Patient was given Rehabilitation through this device regularly and continuously for eighteen months. However, there become a break of six months after completing Rehabilitation of one year due to Covid-19. Tests were conducted in accordance with the Experimental Design described above, and test results were analyzed quarterly basis.

Spinal cord injury is the cause of this Patient's disability; therefore, there was not much expectation of getting encouraging results. This device was used on impaired parts of hands for a long time, i.e., 18 months, and at various frequencies. Observations were taken monthly basis and recorded in a table. Data were compiled quarterly basis, results obtained are satisfactory according to the condition of the Patient, and the outcome of the result is shown as below in Table no.4.

Question result on Scale: Totally Limited (1) Extremely Limited (2) Very Limited (3) Moderately Limited (4)

Table No.4: REGAIN OBSERVATIONS THROUGH THE "CUE" TEST.

S.No.	QUESTION	LEFT ARM Result on scale	RIGHT ARM Result on Scale
1.	Picking of a small object with tip of the thumb and first two fingers	2	2
2.	Picking and holding an object between thumb and side of the index	2	2
3.	Grasping Large object (Jar) with tip of finger and open Lid	1	1
4.	Using fingers and manipulate object	1	1
5.	Pressing something with tip of Index finger	1	1

3. RESULTS & DISCUSSIONS:

It is observed from the above table that limited significant effects were observed through Rehabilitation being a spinal injured Patient; however, the improvement was noticed on picking off a small object between thumb and first two fingers and picking and holding an object between thumb and side of the index. This device has become very helpful to the Patient in doing Rehabilitation of fingers and Wrist of impaired hands. He did not require any assistance from a physiotherapist.

According to the "CUE" Test, Rehabilitation through this device has had a favorable impact on the impaired hand of the Patient and observed in him to hold the object with partial assistance.

4. CONCLUSION

1. Rehabilitation through this device has impacted the impaired hand of the Patient to pick and lift the object with partial assistance.

2. The device helped the Patient take Rehabilitation without assistance from the therapist because of provided vocal operational command.

3. This device could help the patient restore function, improve mobility, relieve pain, and prevent or limit permanent physical disabilities of impaired parts suffering from injuries or disease.

4. Size of The device for the hand exoskeleton of the Patient is compact, handy, and small in size.

5. Weight is a lightweight device due to its slim mechanism design, actuators reduction, and used compact size of the actuators. The device weighed about 340 g on the human hand.

6. Portability will allow the system to be portable since it will no longer require the additional equipment of rehabilitation units.

7. Safety device's design limits the ROM for each finger and Wrist to natural ranges to prevent unsafe bending. Safety precautions in the design are included to prevent any body parts from injuring the Patient.

8. The Device is simple in design, compact, lightweight, and easy to use by Patients, and it is user-friendly.

9. It is a low-cost rehabilitation device for the Rehabilitation of fingers and Wrist of spinal injured patients. The hardware component of Mechanical and Electronic coasted about Rs. 7500.

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