Design and Development of Exoskeleton Hand for Paraplegic (SCI) Patients Using Composite Materials

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Abstract - Paraplegia is a condition that results from spinal cord injury and accomplishes the deficiency of sensation and engine cutoff in both upper and lower farthest core interests. The use of exoskeletons has been proposed as a potential solution for SCI patients to regain some of their mobility. This article discusses the sketch and evolution of an exoskeleton for paraplegic SCI patients made from composite materials. The exoskeleton was intended to be soft and lightweight, and offer the client with the support individuals to stand, walk, hold objects, and write. The use of mechanical devices in nerve medicines, demands the availability of lightweight, user-friendly, cost effective, and adaptable designs. These objectives have been built into Exo-Hand in case they become essential. It is a hand exoskeleton that is especially helpful for those who have finger spasticity. Therefore it's simple to place in the hand and allows for similar finger improvement via both flexion and an actuation plan. The mechanical strategy, the sequence of events, and the incorporation of the device's kinematic model are the primary elements of this work. The design process involved the use of solidworks software, finite element analysis (FEA), and rapid prototyping techniques. The final design was tested on a paraplegic patient with positive results.

Keywords - Exoskeleton, Spinal Cord Injury, Composite Materials, Mobility Aids, Assistive Technology, Prosthetics and Orthopedics.

I. INTRODUCTION

A bunch of people around the globe are impacted by the terrible state termed as spinal cord injury (SCI), that tends to result a variety of physical symptoms and psychological impairments. An exoskeleton hand is a wearable contraption that is worn over the client's hand and is expected to mirror the customary improvements of the hand. The contraption is consistently compelled by the client's own muscle advancements, and can give assistance with finishing many activities. These devices are particularly useful for individuals with SCI, as they can provide additional support and assistance in carrying out daily activities, such as grasping objects, typing, and even driving. Exoskeletons, on the other hand, have emerged as a promising technology that can potentially provide a more complete and natural solution to mobility impairment caused by paraplegia. An exoskeleton is an external structure that can be worn like a suit and powered by motors or various means to build the client's turns of events. Exoskeletons can give assistance with holding, making, and various activities, in this way growing adaptability and opportunity. [1][2][3] The use of composite materials in the arrangement and headway of exoskeletons has obtained basic thought recently on account of their transcendent mechanical properties, lightweight, and durability. Composite materials are made of two or more materials with different properties, such as carbon fibers and epoxy resins, which are combined to create a material with enhanced performance characteristics. Composite materials have been widely used in aerospace, automotive, and other industries, but their application in the field of assistive technology is still relatively new. Designing and developing an exoskeleton for paraplegics using composite materials presents several challenges and opportunities. The exoskeleton must be lightweight, comfortable, and durable, while also providing the necessary assistance to the user.[4][5][6] The design must also take into consideration the user's body shape and size, as well as the specific needs of individuals with paraplegia. Additionally, the exoskeleton must be intuitive to operate, allowing the user to control its movements easily and naturally. The development of an exoskeleton for paraplegics using composite materials requires an interdisciplinary approach, bringing together experts in biomechanics, materials science, robotics, and rehabilitation engineering. The exoskeleton was designed to be lightweight, comfortable, and provide the necessary support for the user to stand, walk, hold and write. Robotized equipment is increasingly utilized as neuro-recovery medicines, which requires the adaptation of lightweight, convenient, financially able, and flexible frameworks. These objectives have been facilitated as required by Exo-Hand. It is a hand exoskeleton which is particularly suitable for those who have stiffness in their fingers. Since it is simple to install and enables for both flexion and strengthening of the fingers from a design that is underactuated. This work provides the important key credits, the mechanical course of action, the turn of events, and the foundation of the kinematic model of the equipment, which has been obviously tied up contemplating and handles pieces of cutoff and flourishing key in this kind of material. [7-10] The usage of the solid works programme was required for the design process, finite element analysis (FEA), and rapid prototyping techniques. The final design was tested on a paraplegic patient with positive results. Collaboration between researchers, clinicians, and making sure the exoskeleton meets the needs of its users, especially paraplegics, is essential. Strategy and improvement of an exoskeleton for paraplegics using composite materials is a promising area of assessment that could perhaps change the presences of individuals with paraplegia. The usage of composite materials in exoskeleton design presents an expected opportunity to make a lightweight, solid, and first in class execution assistive improvement that can give customary and normal versatility help. Through interdisciplinary joint exertion and client centered plan, the advancement of such an exoskeleton could perhaps change the field of assistive development and work on the particular fulfillment for endless people with paraplegia.

Spinal Cord Injury

The intricate structure of cells and neurons that carries information from the cerebral lobe to and from the rest of the body is damaged by a spinal cord injury. At the level of the lower back, the spinal cord and the base of the frontal brain are in interaction. Direct trauma to the spinal cord itself can produce SCI, and also cause malicious damage to the vertebrae and surrounding tissue. This damage may cause temporary or extremely unexpected changes in sensation, growth, strength, and physical restrictions near to the injury. The amount of slightness depends on where in the spinal cord the lesion occurs and how severe it is.

Changes in the hands and feet, such as deadness or shivering.

- Head, neck, or back pressure or torture.
- Lack of progress.
- The lack of weakness to move any part of the body.
- Issues with walking.
- Breathing issues.
- An unnatural spine or head alignment.
- The spinal cord wounds are coordinated into two sorts:
- Complete
- Insufficient

There being no nerve connection underneath the injured location is a whole genuine concern. This implies that the site's major and engine capacity is destroyed, but a separated damage suggests that the spinal cord is already prepared to send or receive two or three signals. Those with inadequate wounds possess some substantial capacity and may be able to manage the development of their muscles underneath the damage location. The leading causes of SCI are collisions with moving objects and fatal falls (spinal rope injury). [11-17] The remaining cases are brought on by violent acts (frequently assaults and gunshot wounds), sports injuries, medical errors, recent catastrophes, ailments and diseases that can injure the spinal column, and other, far more astounding causes. A risk factor for falls includes age (between the ages of 15 and 30, or after the age of 66 for serious falls), alcohol use, certain disorders, and the lack of real equipment, such as a seat belt or careful sports equipment.

Rehabilitation

The central season of recovery is twirled around recuperating social limits and leg and arm strength. For express people, adaptability may be conceivable with assistive or adaptable contraptions, for example, a walker, leg stays aware of, or a wheelchair. Social endpoints like synthesis, making, and merging the phone may correspondingly require versatile contraptions for those with tetraplegia. [18-20] Flexible contraptions could assist individuals with spinal line injury to recuperate a section and further attract solace and individual satisfaction. Reliant upon the genuineness of the injury, individuals could require a wheelchair, electronic triggers, helped sorting out with strolling, frontal cortex prosthetics (assistive contraptions that could brace the nerves to reestablish lost limits), PC blends, and other PC helped improvement.

II. EXOSKELETON

Exoskeletons are outer coverings that provide support and protection to the body of an organism. Exoskeletons for humans has acquired more attention in recent years, particularly for the arms and limbs.Considering the potential to enhance human strength, endurance, and mobility, these exoskeletons were suitable in a wide range of applications from the military and industrial to medical and restorative. Exoskeletons are not an original idea. Animals like insects and crustaceans have actually employed exoskeletons for millions of years. However, developing exoskeletons for humans is a relatively recent development. The first exoskeleton designed for human use was developed in the 1960s by General Electric. This exoskeleton was designed to help workers lift heavy objects, but it was not very practical or comfortable to wear. Recent developments in materials science, robotics, and control systems have allowed for the creation of exoskeletons that are comfortable and light yet still being able to offer the user a substantial amount of help.Exoskeletons of many kinds, such as full-body orthosis, lower-body prosthetic limbs, and topmost prosthetic limbs, are currently being developed for use by humans. [21-30] Exoskeletons for the arms and limbs have recently been developed, which seems fascinating because they may considerably improve human endurance and physical fitness. For example, an exoskeleton for the arms could allow a person to lift heavy objects with ease, while an exoskeleton for the legs could allow a person to walk or run for longer distances without getting tired. One of the main challenges in developing exoskeletons for the arms and legs is designing a system that is comfortable and easy to wear. Exoskeletons can be quite bulky and heavy, which can make them uncomfortable to wear for extended periods of time. Additionally, exoskeletons can be difficult to control, especially if they are providing a significant amount of assistance to the user. To overcome these challenges, researchers are exploring a variety of different designs and control systems. Some exoskeletons use pneumatic systems, which use air pressure to provide assistance to the user. Others use electric motors or hydraulic systems, which can provide more precise control over the movement of the exoskeleton. Some exoskeletons are designed to be worn over clothing, however others are made to be applied straight to the skin. The topic of rehabilitation is one of the most exciting areas for exoskeletons for the arms and limbs. Exoskeletons can aid in the recovery of strength and movement in those who have experienced a stroke or other neurological impairment. In this case, a person grant's the ability to perform everyday tasks like feeding themselves or brushing their teeth with the use of an arm exoskeleton. Similar to this, a leg exoskeleton might aid someone in regaining their ability to walk or navigate stairs. Exoskeletons can also be useful for people who have lost a limb. For example, an exoskeleton for the arms could be used to help a person who has lost an arm regain some of their functionality. Similarly, an exoskeleton for the legs could be used to help a person who has lost a leg regain the ability to walk. Another potential application for exoskeletons for the arms and limbs is in the military. Exoskeletons could be used to help soldiers carry heavy equipment over long distances or to help them perform tasks that require significant strength and endurance. Exoskeletons could also be used to help soldiers who have been injured in combat regain their mobility and strength.

Exoskeleton Hand

The goal of hand prosthetic limbs, which are portable robotized devices, is to help the fingers on the human hand reach their full range of motion , increase power, restore function, restore hands that have been injured, or in a continuously developing society, offer more haptic feedback for virtual or motion control applications. Exoskeleton is a term that appropriately defines the hard exterior that many species have as their support and defence mechanism. Inside each person's body are integrated endoskeletons. As a result, robotic devices up until this point were made to be attached to the hand's palm, dorsum, or a comparable side. There are specific needs that must be taken into account while developing an exoskeleton, regardless of whether it is used for assistive, rehabilitative, augmentative, or haptic purposes. Every kind of exoskeleton has historically portrayed a set of specifications that meet its inspirations. The two types of hand exoskeletons that are created over a lengthy period of time are unyielding and sensitive exoskeletons, or a mix of the two. Constant exoskeletons are machines that use a mechanical design to supply power to the major joints. To ensure that the exoskeleton joints and the finger joints (often on the same side of the fingers) are in accord, the mechanical game plan should ideally line up with each joint. In this instance, the most typical framework for arrangement should be evident, but because the size is constrained by the space between the fingers, special fittings are sometimes required. This strategy is known universally as the matched turn plan. The phalanges of this structure, which is typically affixed to the dorsal side of the fingers, provide electricity to the joints. The round, exquisite joints and parallelogram pieces are joined by the bar tools. Hand exoskeletons are wearable robotized devices that enable the human hand's fingers to move to their full range of motion (ROM), continue to strengthen, recover movement in paralyzed hands, and give haptic feedback for virtual or motion control applications. The word "exoskeleton" really refers to the robust outer covering most animals utilize to sustain and safeguard their body. People have internal endoskeletons with a defined structure. Therefore, the mechanical devices up to this point were intended to be connected to the palmar, dorsal, or analogous side of the hand or fingers.

III. METHODOLOGY

Design

It is spoken about how the exoskeleton for the hands has developed. Backstage, a linkage connected the thumb and fingers to the palm. The finger was ergonomically coordinated using the finger development path. The design allowed independent mobility of the thumb, the four fingers, in addition to lateral bending, taking, and palm-backward motion for the thumb. The thumb was pushed by two direct actuators, and each finger was pushed by a short actuator. Solidworks was utilized to coordinate and manage the design process, and 3D printing was used to produce it. The thermoplastic materials used to construct the palm back shell that covered the wrist and back of the hand. The obvious was first demonstrated, and after that it was broken free by hot water and fitted to the clients' hands. The exoskeleton is useful to wear, weighs 500 g, and was attached to the palm back shell. The exoskeleton was driven by six straight actuators that matched their corresponding control sheets. Voltages requires the low actuators' working distance. Directional steering is available for the rapid actuator, with a length of 102 mm and a weight of 40 g. Three shells make up each finger, and a linkage bar links them. The linkage bar offers a breaking point to the finger shells as soon as the rapid actuator reacts, producing an advancement for getting/adduction. The exoskeleton fingers were coordinated with human fingers' anatomical features. The truly coordinated exoskeleton adopted a more flexible thumb development that can operate with the thumb for inner turn, sorting, and seizing since the thumb has greater DOFs than the fingers. Clearly, the actuator's force can return to the metacarpophalangeal joint or the carpometacarpal joint (CMC) (MCP). Undoubtedly, the wrist and palm joints move first when the CMC joint receives power again. As the CMC joint makes contact with the object, the CMC joint's movement may be impeded, which limits the versatility of the control over the tip of the thumb. The thumb's flexibility might be increased precisely when the power returns to the MCP joint, however this strategy is invalid for resolving much more obvious issues. The coordinated exoskeleton had stopped doing any of these things lately. After accounting for everything, the force of the new exoskeleton is once more applied to the thumb's MCP and PIP joints. The collapse of the sliding path of action served as the catalyst for CMC's collective advancement. The MCP ROMs, in contrast to PIP joints, will surely take all necessary precautions to prevent turning the item that has been given a handle. The CMC joint can be propelled ahead when the sliding game plan is in motion till it becomes confused by the sorting out issue. The MCP and PIP joints are then subjected to a buildup of force from the straight actuator. The linkage structure's sliding component expands the thumb's range of motion. To enable the thumb to complete a circumduction, two straight actuators were utilized to govern the thumb's movement in the vertical planes. The design of the exoskeleton's control framework. By using the mirror treatment rule and sEMG of the non-paretic lower arm and hand, this exoskeleton may be encouraged. We established a testing group to review the introduction of the hand exoskeleton, the classifiers, and the predictable control (not totally for all time laid out in appraisal for hand exoskeleton execution to assessment for constant control of an exoskeleton). The design of an whole part of an exoskeleton hand is represented in **Fig 1.** Shows 3D Model Exoskeleton Hand using Solid works.

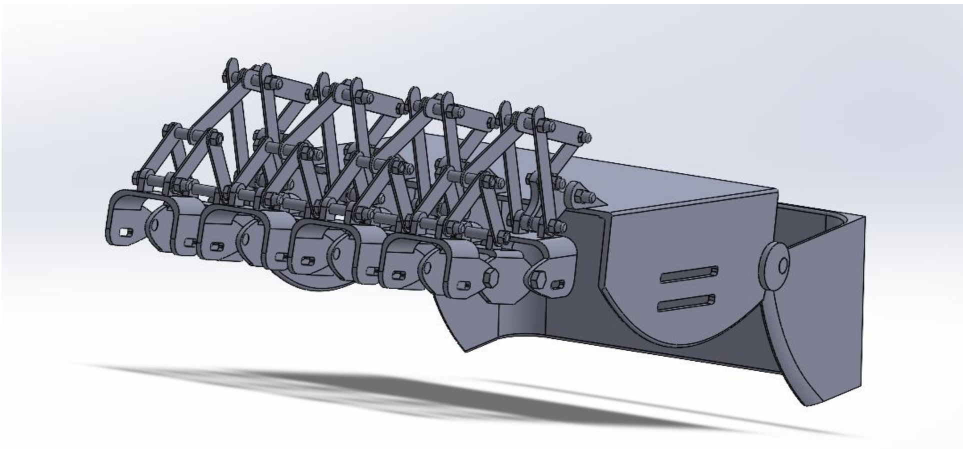

Fig 1. 3D Model Exoskeleton Hand using Solid works.

Conceptual Design

The conceptual design of an exoskeleton hand involves several key considerations, such as the materials to be used, the type of actuation, and the control system. The determination of materials is vital in arranging an exoskeleton hand. The materials should be strong, lightweight, and tough. Regularly used materials integrate carbon fiber, titanium, and aluminum mixes. These materials are used for the exoskeleton structure, which is expected to fit over the client's hand. The incitation course of action of the exoskeleton hand is responsible for providing the significant ability to build the client's hand improvements. There are a couple of sorts of actuators that can be used, similar to electric motors, pressure driven structures, and pneumatic systems. Each kind of actuator partakes in its advantages and weights. Electric motors are the most usually elaborate actuators as they are more modest, useful, and have a high capacity to-weight extent. The control plan of the exoskeleton hand is responsible for unraveling the client's hand improvements and making an understanding of them into the advancements of the exoskeleton. The control structure can be either electromechanical or myoelectric. The electromechanical control system uses sensors to perceive the client's hand advancements and makes an understanding of them into improvements of the exoskeleton. The myoelectric control system uses sensors that are associated with the client's skin and perceive the electrical signs made by the muscles in the hand. The design of the exoskeleton hand should take into account that user's hand size and shape to ensure a comfortable fit. A full motion range, including flexion, expansion, inclination, range of motion, and rotation, should be provided by the exoskeleton. The exoskeleton should also be designed to be modular, allowing for easy replacement of parts and customization to fit the needs of the user.Security is a fundamental idea in the arrangement of the exoskeleton hand. The exoskeleton should be expected to prevent injury to the client, as well as to people in the enveloping district. With everything taken into account, the sensible arrangement of an exoskeleton hand requires mindful idea of the materials, initiation structure, control system, plan, and prosperity. By taking into account these components, originators can make a contraption that further develops the client's hand strength, skill, and determination, while in like manner ensuring security and comfort. With extra creative work, exoskeleton hands might potentially change the field of prosthetics and update human limits in various applications.

Structural Design

The structural design of an exoskeleton hand ordinarily comprises of three sections: the hand exoskeleton structure, the activation framework, and the control framework. The hand exoskeleton structure is for offering help and strength to the client's hand. It is intended to mirror the shape and development of the human hand, with joints and ligaments that permit the fingers to twist and flex. The material utilized for the exoskeleton construction is to be lightweight, sturdy, and adaptable to guarantee most extreme solace and ease of use. The activation framework is liable for giving the vital power to move the exoskeleton hand. It comprises of engines and links that force and delivery the ligaments in the hand exoskeleton structure, empowering the fingers to move. The activation framework is to be minimized and lightweight to decrease the general load of the exoskeleton hand, making it easier for the client to wear and utilize. The control framework is liable for handling and deciphering the client's developments and making an interpretation of them into activities for the exoskeleton hand. It comprises of sensors, microcontrollers, and programming that empower the exoskeleton hand to answer the client's developments progressively. The control framework should be intended to be natural and simple to utilize, permitting the client to work the exoskeleton hand with negligible exertion. One of the difficulties in planning an exoskeleton hand is accomplishing a harmony among usefulness and convenience. The exoskeleton hand should have the option to impersonate the developments of the human hand precisely, while additionally being not difficult to wear and utilize. To accomplish this, fashioners frequently utilize a secluded plan approach, where the exoskeleton hand is partitioned into more modest parts that can be effectively supplanted or overhauled on case basis. This considers adaptability on the plan and makes it more straightforward to redo the exoskeleton hand to the particular requirements of the client. Another test is guaranteeing that the exoskeleton hand is agreeable to wear for broadened periods. This is particularly significant for clients who will be wearing the exoskeleton hand for extensive stretches over the course of the day. To address this, fashioners utilize ergonomic game plan standards, for example, orchestrating the exoskeleton hand to the client's limb and hand's conditions. The materials utilized in the plan ought to be delicate, adaptable, and breathable to forestall distress and disturbance. The underlying model of an exoskeleton hand is basic in accomplishing its motivation of reestablishing hand usefulness to people with hand wounds or loss of motion. The plan ought to be lightweight, solid, and adaptable, with a secluded methodology that considers customization and updates. The exoskeleton hand ought to likewise be agreeable to wear, with an ergonomic plan that fits the forms of the client's arm and hand. By tending to these plan contemplations, creators can make exoskeleton hands that are utilitarian, simple to utilize, and agreeable for clients to wear for expanded periods.

CAM Sheet Metal Bending

The process of CAM sheet metal bending of an exoskeleton hand is a critical part of manufacturing such a complex device. For those with impairments or those who undertake repetitive activities, an exoskeleton hand is a wearable robotic device that is intended to increase the strength and dexterity of a human hand. The exoskeleton hand is made from various parts, including the packaging or skeleton, sensors, and actuators that control the improvement of the fingers and hand. One of the essential pieces of the exoskeleton hand is the skeleton frame. This frame is typically made from sheet metal, which is cut and bent into the required shape using a variety of manufacturing techniques. CAM sheet metal bending is one such technique that is commonly used in the production of exoskeleton hands.A cam mechanism is used in the precision manufacturing process known as computer-aided manufacturing (CAM) sheet metal bending to bend sheet metal into intricate designs. Each bend is accurate and uniform since the process is computer-controlled. The cam mechanism is made to exert just the right amount of pressure on the sheet metal to produce a precise bend angle. The first step in CAM sheet metal bending is to create a 3D model of the exoskeleton hand's skeleton frame. This model is then brought into the PC maintained assembling (CAM) programming, which makes a ton of rules for the bowing machine.These instructions include the precise dimensions of the sheet metal, the location of the bends, and the angle of each bend.Once the instructions are generated, the sheet metal is loaded into the bending machine, which is equipped with a set of specialized tools, including the cam mechanism. The machine uses these tools to clamp the sheet metal in place and apply the necessary force to create the bends. The CAM mechanism ensures that each bend is precise and consistent, resulting in a high-quality finished product.CAM sheet metal bending is very helpful for producing intricate forms and curves that are challenging to accomplish with regular bending methods. This makes it an ideal choice for manufacturing exoskeleton hands, which require a high degree of precision and accuracy. CAM sheet metal bowing is an exactness manufacturing strategy that is extensively used in the formation of exoskeleton hands. The process involves the use of a computer-controlled cam mechanism to bend sheet metal into complex shapes with a high degree of accuracy and consistency. This method enables producers to produce exoskeleton hands that are both attractive and useful, giving those with impairments or those who undertake repetitive chores more capabilities.

Kinematic Model

The hand is a complex reliable breaking point that contains more than 30 muscles and 20 joints and allows you to do a wide range of activities with greater accuracy. The core of hand work is kinetics. This encourages a fundamental all-out to keep in mind that, in order to ensure client success, human-exoskeleton kinematic closeness should be ensured both in the approach stage and before attempting more mild phases. On the off chance that this closeness isn't achieved, appalling joint effort cutoff points could appear, for the most part due to the misalignment between the exoskeleton likewise, very far, whose effect couldn't be reimbursed by the actuators for machines. A kinematic model was developed by showing physically sealed circles in various conditions. They offer logical increases for each finger's MCP and PIP joints as a cutoff again for straight actuator's stroke augmentation. Each finger is modeled as a planar bar-linkage framework to get the analytical model. Near the motor, which is a striking or longitudinal joint, all joints between the various elements are assumed to be rotating joints in this modification. The focal points and separations for this section are chosen with the location of the place where the halfway piece and the back help stage cross as the starting point of the heading structure. Grubler's Method was used to determine the number of degrees of freedom, by using the following equation:

$DoF = 3 (N - 1) - 2R1 - R2$

Where:

- N: in standard number of relationship in the planar bar-linkage part.

In our part N=7+1. There are 7 affiliations and the ground.

- R1: number of one-DOF kinematic matches (joints). In our instrument R1 = 10.
- R2: number of two-DOF kinematic matches (joints). In our instrument R2 = 0.

By condition (1) we get DoF = 1, for the planar bar-linkage instrument of one finger. The lineal furthest shows up at that portray a planar bar-linkage instrument . The most fundamental are:

- Human finger limits: L2, L3, L4 and L8, where L4 addresses

MCP — PIP distance. L8 is the PIP-Plunge distance, close to for the thumb, where L8 is the length of the distal phalanx.

- Bar lengths: L7 (distal) and L11 (proximal).
- Moderate part limits: L12, L13, L14, and L15.
- d: stroke expansion of the straight actuator. It is the distance two or three spot in the level of P12 and R23.
- Lmotor: shut length of the lineal actuator
- Leq: L motor + d

L2, L3, L4, and L8 are the numerical limitations that represent the finger in the planar bar graphs of one finger. L2 and L3 are the level (X direction) and vertical (Y coordinate) distances, respectively, between the MCP joint and the moderate piece's turn point. The device combines 30 mm straight stroke Actuonix L12 direct actuators. RobHand's mechanical properties make it astonishingly feasible for the value of the variable "d" to respect a few positions between 0 and 30 mm; however, the minimum range between the points P12 and R23 will be 16.5 mm and the greatest way beyond ridiculous 39.7 mm. Two mechanical shut circles that reflect the straight and significant Exo-Hand restrictions have been used to accomplish the kinetic study under a variety of vector parameters. Defining the kinetic constraints of the device is the key step in choosing a kinematic model. So, to show the human finger, it is crucial to supply the suitable rises of the numerical furthest arrivals (L2, L3, L4 and L8). The size of a person's hand fingers varies according to their age, occupational status, and body type. In order to close master part points of view, the fingers perspectives rely on data obtained from, including an anthropometric evaluation of the hand for a thorough local area primer of 500 individuals. Precisely when the actually alluded to values have been good to go, the kinematic model registers the normal increments of shafts length, proximal L7 additionally, distal L11. Then, at that point, considering that the straight actuator plays out a way di, I = 16.5, . . . , 39.7 mm, with $\Delta d = 0.5$ mm, the kinematic model works out MCP and PIP joint focuses (αi, βi focuses, exclusively), as well as the normal augmentations headings of PIP and Plunge centers. Finally, all settled attributes are managed to be used in the kinematic model help. However the kinematic model has actually been presented for the pointer, it is proper to all fingers since it is parameterizable. The particular human credits of the thumb, that simply has two phalanges, wants to authoritatively deciphered. The course of the PIP besides, Plunge joints of the fingers interact with the headings of the IP joint and fingertip of the thumb [3]. The kinematic model of the finger exoskeleton is illustrated on the **Fig 2** shows Manipulating Link to actuate the single finger.

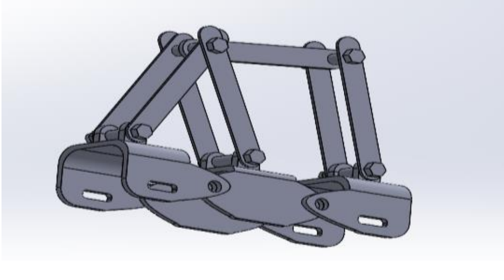

Fig 2. Manipulating Link to Actuate the Single Finger.

IV. PROBLEM IDENTIFICATION

As of now a days people are defying critical injuries in which maybe of the most essential injury looked by the more number of social classes are spinal line injury. In view of this people lost their transportability of holding, forming, walking and a piece of their proactive undertakings too. People who are encountering spinal line injury and lost their flexibility are searching for individual associates for approaching their genuine obligations. To diminish these kind of issue expert are incorporate the field of making accomplice contraptions which will help the SCI patients to deal with a couple of their obligations without need of others with having an effect. In such a way to help the SCI patients the improvement of exoskeleton is proposed. Exoskeletons are wearable mechanical contraptions that give controlled help to the wearer's turns of events. They have been made to assist individuals with spinal line wounds (SCI) to stand up and walk. Exoskeletons have been shown to enjoy basic benefits for individuals with SCI, including additionally created adaptability. The upsides of extended independence, further created hand capacity, and reduced danger of discretionary complexities make exoskeletons an astounding area of imaginative work, extended bone thickness, further created stream, and diminished muscle rot. One explicit locale where exoskeletons have been used with unprecedented accomplishment is for hand recuperation. SCI patients every now and again experience the evil impacts of loss of movement of the hand, which can essentially limit their independence and individual fulfillment. Exoskeletons for the hand offer a response for this issue by aiding the client's fingers and wrist improvements. The use of exoskeletons for hand recuperation has been shown to additionally foster hand ability, hold strength, and fine organized developments. This can incite extended opportunity and a more significant capacity to perform exercises of everyday living. Likewise, using an exoskeleton can help with lessening the bet of discretionary hardships, for instance, carpal section issue and tendonitis, which are typical in individuals with SCI. Considering everything, exoskeletons for hand recuperation might conceivably chip away at the individual fulfillment for individuals affected by SCI.

V. MATERIALS AND METHODS

Materials For Exoskeleton Hand

Exoskeleton hands are customarily made of lightweight and tough materials. These materials should have the choice to persevere through the powers applied on them by the human hand and should be pleasing to wear for extended time spans. Four distinct blends that are by and large used for exoskeleton hands are titanium, aluminum, steel, and magnesium.

Titanium

Titanium is a lightweight and strong metal that is generally used in the flying and clinical ventures. It has a high-fortitude to-weight extent, which makes it an ideal material for exoskeleton hands. Titanium is in like manner biocompatible, and that suggests that it isn't perilous to the human body. This makes it a fair choice for clinical applications where the exoskeleton hand could come into contact with the skin.

Aluminum

Aluminum is one more lightweight metal that is ordinarily utilized in the aviation and car enterprises. It is likewise a decent decision for exoskeleton hands since it is lightweight and solid. Aluminum is likewise consumption safe, which goes with it a decent decision for open air applications.

Steel

Steel is a robust and hard metal that is usually employed in the construction industry. It is also a fine choice for exoskeleton hands because it's able to withstand the stress that a human hand might impose on it. Steel is also relatively inexpensive compared to other materials, which makes it a good choice for low-cost applications.

Magnesium

Magnesium is a lightweight metal that is used often in the car and aerospace sectors. It is also a good choice for exoskeleton hands because it is lightweight and strong. Magnesium is also biocompatible, which makes it a good choice for medical applications. The part of finger exoskeleton is represented in **Fig 3**.

VI. METHODS FOR EXOSKELETON HAND

The methods used to create exoskeleton hands vary depending on the materials used and the application of the exoskeleton hand. The following are methods used to create exoskeleton hands.

Fiber Blade Laser Cutting

A sort of laser cutting that has grown in popularity recently is fibre blade laser cutting, often known as laser cutting employing a fibre optic cable. With this technology, the laser beam is delivered to the material being cut via a fibre optic connection, enabling finer cuts and better control. The ability to cut a variety of materials is one of the best aspects about fibre blade laser cutting. Metals like steel, aluminium, and copper are just a few of the common materials that are frequently cut with this technique. Even very thin or delicate materials can be safely sliced with fibre blade laser cutting because it provides for such fine control over the light beam.

CNC Bending

CNC press brakes, commonly referred to as CNC brake presses, are manufacturing equipment that perform computer numerically controlled (CNC) bending. The largest industrial machines can bend sheet metal into portions that are many metres long or just a few millimetres across. In order to do down forming, CNC press brakes either feature a fixed bottom bed with the V block tooling fastened in place or a top beam that moves while being forced by the V blade tools. An up-forming machine, on the other hand, has a fixed top beam and a movable bottom bend. There are no constraints on the design of your component to fit either machine, or both process methods will result in the same sheet metal components. The length of the CNC press brake bed obviously determines the maximum length of the sheet metal component that can be bent up, but the thickness of the material depends on the tensile strength of the material and the amount of tonnage available from the machine to form the sheet metal. The greater the sheet metal gauge that can be bent for the same tonnage, the larger the bottom V block aperture. However, the internal radius of the bend in the sheet metal work increases as the V block opening does.

TIG Welding

The heat produced by an electric arc formed between a non-consumable tungsten electrode and the work piece during tungsten inert gas (TIG) welding is used to melt the metal in the joint area. The weld pool and the non-consumable electrode are shielded from the arc area by an inert or reducing gas. It is possible to run the process autogenously, i.e. without filler, or to add filler by introducing a consumable wire or rod into the already-formed weld pool. TIG makes welds of extremely high quality on a variety of materials with thicknesses as high as 8 or 10 mm. It works very well with sheet material.

VII. LIGHT WEIGHT EXOSKELETON

The exoskeletons present now a day are exorbitantly profound; conceivably it may be lower member exoskeleton or upper extremity exoskeleton. In view of the critical weight of an exoskeletons, patients are feeling trouble to wear the contraption for their recuperation cycle. Consequently by pondering this issue, it is a head to diminish the substantialness of the exoskeleton parts which are worn on hands that makes adverse consequence for patient in view of tremendous powers and powers. Researchers see that the general heap of the exoskeleton is 400 to 500 grams. The exoskeleton is progressed to be in an extent of 200-250 grams of weigh. The weight of the exoskeleton is lessened by using kinematic setup considering the underactuation thought. The light weight exoskeletons are made by using carbon fiber or plastic and are expected to be worn down on the ground. The exoskeleton hand could use sensors, motors or a blend of both to recognize the client's turns of events and proposition help where required. For example, if the wearer encounters issues getting a handle on things, the exoskeleton hand could apply capacity to the fingers to help them with closing around the article. An exoskeleton hands may moreover have the choice to give real analysis to the client, giving them a sensation of touch and helping them with bettering control objects. Additionally, lightweight exoskeletons have the potential to be more cost-effective compared to their heavier counterparts. The adoption of lighter materials can help to lower production and maintenance costs, increasing the accessibility of these devices for a wider variety of people in need.

VIII. FABRICATION

Comparison Of Pneumatic Exoskeleton and Hydraulic Exoskeleton

Exoskeletons are wearable robotic devices designed to augment human physical capabilities. They have become increasing popularly in latest days due to various possible application in a variety of industries, such as military operations, industrial manufacture, and rehabilitation .Two of the most common types of exoskeletons are pneumatic and hydraulic exoskeletons. In this article, we will compare these two types of exoskeletons and examine their strengths and weaknesses.Pneumatic exoskeletons use compressed air to power their movements. They are relatively lightweight and flexible; they are therefore perfect for applications that need a high level of mobility. Furthermore less costly than hydraulic exoskeletons, pneumatic exoskeletons are a more practical choice for researchers and developers. The high power-to-weight ratio of pneumatic exoskeletons is one of its key advantages. They can create a lot of force without being overly heavy since they use compressed air. This makes them perfect for activities like running and jumping that call for a high level of agility and speed**. Fig 3** shows Fabricated Light weight Exoskeleton using Sheet metal.

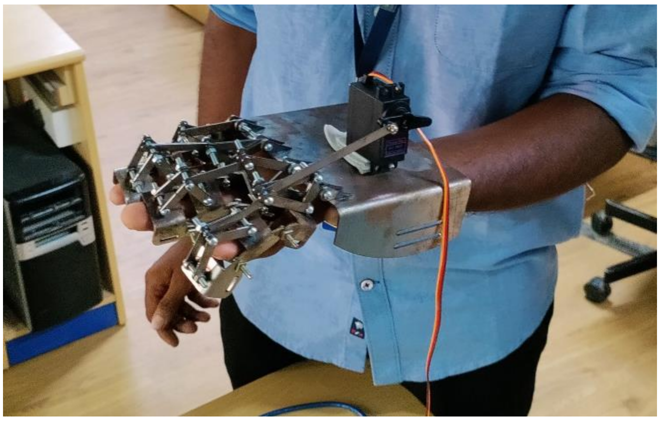

Fig 3. Fabricated Light Weight Exoskeleton Using Sheet Metal.

Another advantage of pneumatic exoskeletons is their simplicity. They require less maintenance than hydraulic exoskeletons and are less prone to leaks and other malfunctions. Pneumatic exoskeletons are also easier to control, as they do not require complex electronic or hydraulic systems.However, there are also some disadvantages to pneumatic exoskeletons. One of the main issues is that they require a constant supply of compressed air, which can be difficult to maintain in certain environments. They may not be suitable for applications which call for a lot of force because they also have a limited power output. Hydraulic exoskeletons, on the other hand, use pressurized fluid to power their movements. They are typically larger and heavier than pneumatic exoskeletons, but they also have a higher power output. Hydraulic exoskeletons are often used in industrial settings, where they can be used to lift heavy objects or perform other physically demanding tasks.The important objective of hydraulic exoskeletons is their greater power output. Because they use pressurized fluid, they can generate a lot of force, making them ideal for applications that require heavy lifting or pushing. They are also more durable than pneumatic exoskeletons, as they are less prone to leaks and other malfunctions.Another advantage of hydraulic exoskeletons is their ability to operate in extreme environments. They can function in high or low temperatures and are less affected by changes in altitude or atmospheric pressure. This makes them suitable for use in space or deep sea exploration.However, there are also some disadvantages to hydraulic exoskeletons. They are typically more expensive than pneumatic exoskeletons and require more maintenance. They are also more complex to control, as they require sophisticated electronic and hydraulic systems.Researchers also conclude that both pneumatic and hydraulic exoskeletons have their strengths and weaknesses. Pneumatic exoskeletons are lightweight, flexible, and easy to control, but they have limited power output and require a constant supply of compressed air. Hydraulic exoskeletons are more powerful, durable, and can operate in extreme environments, but they are more expensive and complex to control. The choice between pneumatic and hydraulic exoskeletons ultimately depends on the specific application and environment in which they will be used. Researchers and developers should carefully consider the requirements of their project before choosing which type of exoskeleton to use.

Features

Exoskeleton hand is a mechanical hand that is expected to duplicate the human hand concerning artfulness and improvement. A contraption is worn over the client's hand, outfitting them with the ability to perform tasks that would some way or another be completely impossible for them to do. The exoskeleton hand has a couple of components that make it an extraordinary and adaptable contraption. One of the fundamental components of the exoskeleton hand is its ability. The hand is planned to move in a way that resembles the human hand. It has different degrees of chance, thinking about a large number of improvements. This artfulness makes it doable for the client to perform complex tasks with precision, such as getting little articles or controlling devices. The exoskeleton hand is in like manner planned to serious solid areas for be. It is prepared for lifting significant articles that would be completely impossible for a human hand to lift. This strength causes it significant for tasks that to require a great deal of force, such as moving huge gear or lifting objects in a stockroom. Another component of the exoskeleton hand is its versatility. The contraption is planned to be worn over the client's hand, and that suggests that it will in general be changed as per fit different hand sizes. This flexibility makes it open to numerous clients, consolidating those with inadequacies or wounds. Exoskeleton hands are outstandingly customizable. The device can be adjusted to fit the client's specific prerequisites and tendencies. This suggests that different clients can have different arrangements, dependent upon their necessities. For example, a client who needs more strength in their grip could have a contraption that is planned to give more power, while a more client perfection could have a device that is expected to give more noticeable exactness. The exoskeleton hand is suitable with a large number of gadgets and stuff. This suggests that it will in general be used in various endeavors, including collecting, improvement, and clinical benefits. The contraption can be used to work device, hold instruments, or help with activities. Another huge part of the exoskeleton hand is its material analysis. The device is expected to provide the client with a sensation of touch and info, which helps them with performing tasks with more conspicuous exactness. This info can in like manner help the client with avoiding injury, as they can feel when the contraption is pushing toward its limits. Finally, the exoskeleton hand is planned to be flexible. The contraption is lightweight and easy to transport, and that infers that it will in general be acknowledged to different regions dependent upon the situation. This convenience makes it significant for a large number of uses, including emergency response and catastrophe help. The exoskeleton hand is an adaptable and solid contraption that has a couple of huge features. Its mastery, strength, flexibility, versatility, similitude, unmistakable analysis, and minimization make it a huge gadget in a considerable number of organizations and applications. As advancement continues to push, more than likely, the exoskeleton hand will end up being impressively additionally evolved and important in the years to come.

IX. FUTURE SCOPE

The design and creation of a paraplegic exoskeleton for spinal cord injury patients utilizing composite materials is a remarkable accomplishment with significant life-changing effects. This innovative device has the potential to transform mobility support and greatly raise the standard of living for those with paraplegia. The use of composite materials in the design of the exoskeleton offers a range of advantages that make it an ideal choice for this application. Composites are known for their exceptional strength-to-weight ratio, making them lightweight yet durable. This characteristic is particularly crucial for an exoskeleton, as it allows for ease of movement without compromising on safety. The ability to minimize the burden on the wearer's body composite material provides the perfect solution by combining strength, flexibility, and lightweight properties.

X. CONCLUSION

The design considerations for the exoskeleton have been meticulously tailored to address the specific needs of paraplegic individuals. Extensive research and collaboration between engineers, designers, and medical professionals have resulted in in ergonomic designs that optimize user experience. The exoskeleton has designed to mimic natural movement patterns and seamlessly integrate with the wearer's body, promoting a sense of comfort and facilitating intuitive control. The integration of cutting-edge technologies, such as sensors and actuators, has been crucial in improving the exoskeleton's performance. These wereallowing for real time feedback and enable precise control of the exoskeleton's movements. By incorporating intelligent sensors, the exoskeleton can adapt to the user's motion and provide personalized support. The level of responsiveness promotes an organic connection between the wearer and the exoskeleton while simultaneously ensuring safety. Moreover in this development process embraces a multidisciplinary approach, involving design, electrical, material science and medicine. This approach has enabled a comprehensive understanding of the challenges faced by the paraplegic individuals,an driven the innovation solution. The impact of the exoskeleton on the lives of the paraplegic individual cannot be overstated. By restoring mobility and independence, it offers a new lease on life for those affected by spinal cord injuries. The ability to stand, walk, and navigate their environment not only provides physical benefits but also has significant psychological and social implications. Paraplegic individuals can regain a sense of agency and control over the lives, fostering a positive self-image and enhancing their overall well-being. As further advancements are made, the potential for broader adoption and integration technology holds the promise of a future where mobility is no longer restricted by physical impairments, empowering individuals to reach new heights and embrace a life of possibilities.

References

[1]. S. Gowtham et al., "A Survey on Additively Manufactured Nanocomposite Biomaterial for Orthopaedic Applications," Journal of Nanomaterials, vol. 2022, pp. 1–7, Jun. 2022, doi: 10.1155/2022/8998451.

[2]. P. R. Ong and N. T. Bugtai, "A bio-inspired design of a hand robotic exoskeleton for rehabilitation," AIP Conference Proceedings, 2018, doi: 10.1063/1.5023978.

[3]. V. Moreno-SanJuan, A. Cisnal, J.-C. Fraile, J. Pérez-Turiel, and E. de-la-Fuente, "Design and characterization of a lightweight underactuated RACA hand exoskeleton for neurorehabilitation," Robotics and Autonomous Systems, vol. 143, p. 103828, Sep. 2021, doi: 10.1016/j.robot.2021.103828.

[4]. M. Haghshenas-Jaryani, R. M. Patterson, N. Bugnariu, and M. B. J. Wijesundara, "A pilot study on the design and validation of a hybrid exoskeleton robotic device for hand rehabilitation," Journal of Hand Therapy, vol. 33, no. 2, pp. 198–208, Apr. 2020, doi: 10.1016/j.jht.2020.03.024.

[5]. T. Ableitner, S. Soekadar, C. Strobbe, A. Schilling, and G. Zimmermann, "Interaction techniques for a neural-guided hand exoskeleton," Procedia Computer Science, vol. 141, pp. 442–446, 2018, doi: 10.1016/j.procs.2018.10.164.

[6]. M. Pan et al., "Soft Actuators and Robotic Devices for Rehabilitation and Assistance ," Sep. 2021, doi: 10.22541/au.163250264.44358700/v1.

[7]. Aaron Yurkewich, Sara Ortega , Jose Sanchez, Rosalie H Wang and Etienne Burdet (2021), Integrating hand exoskeletons into goal-oriented clinic and home stroke and spinal cord injury rehabilitation, https://doi.org/10.1177/20556683221130970.

[8]. Noronha and D. Accoto, "Exoskeletal Devices for Hand Assistance and Rehabilitation: A Comprehensive Analysis of State-of-the-Art Technologies," IEEE Transactions on Medical Robotics and Bionics, vol. 3, no. 2, pp. 525–538, May 2021, doi: 10.1109/tmrb.2021.3064412.

[9]. M. Li et al., "An Attention-Controlled Hand Exoskeleton for the Rehabilitation of Finger Extension and Flexion Using a Rigid-Soft Combined Mechanism," Frontiers in Neurorobotics, vol. 13, May 2019, doi: 10.3389/fnbot.2019.00034

[10]. K. Xia et al., "Hand Exoskeleton Design and Human–Machine Interaction Strategies for Rehabilitation," Bioengineering, vol. 9, no. 11, p. 682, Nov. 2022, doi: 10.3390/bioengineering9110682.

[11]. M. Bianchi,a, M. Cempinib, R. Contia, E. Melia, A. Ridolfia, N. Vitiellob,c, B. Allottaa,c(2018), Design of a series elastic transmission for hand exoskeletons, https://doi.org/10.1016/j.mechatronics.2018.02.010.

[12]. M. Dragusanu, D. Troisi, A. Villani, D. Prattichizzo, and M. Malvezzi, "Design and Prototyping of an Underactuated Hand Exoskeleton With Fingers Coupled by a Gear-Based Differential," Frontiers in Robotics and AI, vol. 9, Mar. 2022, doi: 10.3389/frobt.2022.862340.

[13]. Yu Li1,a, Xingyu Gao1, Bin Liao, YanhuaPeng, YuJing Chen (2021), Research progress of exoskeleton for hand rehabilitation following stroke, https://doi.org/10.1088/1742-6596/1820/1/012076.

[14]. Daniele Esposito 1, Jessica Centracchio1, Emilio Andreozzi1, Sergio Savino2, Gaetano D. Gargiulo3, Ganesh R. Naik4 and Paolo Bifulco1 (2022), Design of a 3D-printed hand exoskeleton based on force-myography control for assistance and rehabilitation, https://doi.org/10.3390/machines10010057.

[15]. Tiaan du Plessis 1, KarimDjouani2,3 and ChristiaanOosthuizen 1 (2021), A review of active hand exoskeletons for rehabilitation and assistance, https://doi.org/10.3390/robotics10010040.

[16]. C.-Y. Chu and R. M. Patterson, "Soft robotic devices for hand rehabilitation and assistance: a narrative review," Journal of NeuroEngineering and Rehabilitation, vol. 15, no. 1, Feb. 2018, doi: 10.1186/s12984-018-0350-6.

[17]. TommasoProietti, Nathanael Jarrass ¨e, Agn ´ es Roby-Brami, and Guillaume Morel (2019), Adaptive control of a robotic exoskeleton for neurorehabilitation.

[18]. Oscar Sandoval-Gonzalez1, Juan Jacinto-Villegas2, Ignacio Herrera-Aguilar1, Otniel Portillo-Rodiguez3, Paolo Tripicchio2, Miguel Hernandez-Ramos1, Agustín Flores-Cuautle1,4 and Carlo Avizzano2 (2016), Design and development of a hand exoskeleton robot for active and passive rehabilitation, https://doi.org/10.5772/62404.

[19]. Yong Dai, 1JunhongJi, 2GuocaiYang, 2and Yu Yang 1 (2022), A novel robotic exoskeleton for finger rehabilitation: kinematics analysis, https://doi.org/10.1155/2022/1751460.

[20]. FL. BIROUAS, FL. AVRAM, AR. NILGESZ, VL. MIHALCA (2018), A review regarding hand exoskeleton technologies for rehabilitation, https://doi.org/10.17667/riim.2018.1/9.

[21]. Ke Li 1, Zhengzhen Li 1, Haibin Zeng2 and Na Wei 3 (2021), Control of newly-designed wearable robotic hand exoskeleton based on surface electromyography signals, https://doi.org/10.3389/fnbot.2021.711047.

[22]. Xinyu Guan, LinhongJi and Rencheng Wang (2016), Development of exoskeletons and applications on rehabilitation, https://doi.org/10.1051/matecconf/20164002004.

[23]. F. Molteni, G. Gasperini, G. Cannaviello, and E. Guanziroli, “Exoskeleton and End-Effector Robots for Upper and Lower Limbs Rehabilitation: Narrative Review,” PM&R, vol. 10, no. 9S2, Sep. 2018, doi: 10.1016/j.pmrj.2018.06.005..

[24]. Neha Singh1, Megha Saini1, Nand Kumar2, M. V. Padma Srivastava3 and Amit Mehndiratta1, 4 (2021), Evidence of neuroplasticity with robotic hand exoskeleton for post-stroke rehabilitation: a randomized controlled trial, https://doi.org/10.1186/s12984-021-00867-7.

[25]. Feiyun Xiao a,b, Liang Gua, Wenzhang Ma a, Yanhe Zhu c, Zhen Zhang d, Yong Wang a ,b, Real time motion intention recognition method with limited number of surface electromyography sensors for A 7-DOF hand/wrist rehabilitation exoskeleton, https://doi.org/10.1016/j.mechatronics.2021.102642.

[26]. Lince, N. Celadon, A. Battezzato, A. Favetto, S. Appendino, P. Ariano,M. Paleari, Design and testing of an under-actuated surface EMG-driven hand exoskeleton, in: 2017 Int. Conf. Rehabil. Robot. IEEE, 2017, https://doi.org/10.1109/ICORR.2017.8009325.

[27]. M.O. Ajayi, K. Djouani, Y. Hamam, Interaction control for human-exoskeletons, J. Control Sci. Eng. 2020 (2020) https://doi.org/10.1155/2020/8472510.

[28]. M. Sarac, M. Solazzi, and A. Frisoli, “Design Requirements of Generic Hand Exoskeletons and Survey of Hand Exoskeletons for Rehabilitation, Assistive, or Haptic Use,” IEEE Transactions on Haptics, vol. 12, no. 4, pp. 400–413, Oct. 2019, doi: 10.1109/toh.2019. 2924881..

[29]. H. Kawasaki, S. Ueki, S. Ito, and T. Mouri, “Design and Control of a Hand-Assist Robot with Multiple Degrees of Freedom for Rehabilitation Therapy,” Robotic Systems, pp. 838–873, 2020, doi: 10.4018/978-1-7998-1754-3.ch043.

[30]. R. J. Varghese, D. Freer, F. Deligianni, J. Liu, and G.-Z. Yang, “Wearable Robotics for Upper-Limb Rehabilitation and Assistance,” Wearable Technology in Medicine and Health Care, pp. 23–69, 2018, doi: 10.1016/b978-0-12-811810-8.00003-8.