Investigation and Development Prospect of Hand Exoskeleton Comfort

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Abstract. Stroke is a major problem in medical health, patients will have a lot of sequelae after cure. The purpose of this article is to review the results of previous articles and experiments on the comfort of different hand exoskeletons, aiming to improve the comfort of users. We analyzed the materials, wearing methods and binding methods of skin contact parts of various exoskeletons, and searched the corresponding keywords in Google Academic website to find the appropriate articles. Then the different ways of wearing exoskeletons were compared according to the test results. Then the comfort of each exoskeleton is concluded. The goal is to better explain and summarize the comfort of today's hand exoskeletons. Finally, the comfort characteristics of different methods are obtained according to several papers. Comfort is very important for patients, and the comfort of flexible exoskeletons is better than that of rigid exoskeletons.

Keywords: Exoskeleton; Comfort; Hand Injury.

1. Introduction

Around the world, 40 million people suffer from spinal cord injury (SCI) each year, mainly adults between the ages of 25 and 30, and boys are more likely to suffer from SCI than girls. These injuries usually come from gunshot wounds, traffic accidents, falls, knife wounds, sports injuries, etc. Spinal cord injury can cause damage to the nerves in the spinal canal, resulting in impairment or loss of motor and sensory functions in the body. The typical injury is arm dysfunction caused by quadriplegia [1], and spinal cord injury will also lead to the failure and loss of function of many organs, such as kidney problems [2]. There are many levels of spinal cord injury. These include grades C1-8, T11-12 and L1-5. At the C5 level, for example, the patient's body is strong enough to support the flexion and extension of the hand and elbow. But sometimes patients can't control themselves well enough to cause elbow flexion and other symptoms, and they can't control their fingers. This leads to the need for hand exoskeletons to assist them in daily life [1].

Hands play an important role in human life, but due to the invasion of spinal cord injury, stroke and other diseases, people cannot control their hands well. As hand function requires high complexity and accuracy, hand rehabilitation is much slower than other parts [3]. This will cause a great burden to People's Daily life [4]. In order to alleviate this problem, people have developed some auxiliary facilities -- machine therapy. They can provide movement AIDS and facilitation for patients. There are two main categories: end-point machines and exoskeletons. In contrast, the advantage of exoskeleton is that it can allow patients to better control the posture of their limbs [5, 6].

Exoskeletons have been used as auxiliary rehabilitation tools to help patients complete a series of functions such as hand opening and closing in the past two decades [7, 8]. In this paper, we will focus on the comfort of the exoskeleton. This is because the exoskeleton not only needs to assist the patient to live and other functions, but also needs to make the patient feel comfortable, without discomfort. That's what makes a good exoskeleton. So far, many kinds of exoskeletons have been developed. They also dress differently. These include exoskeletons, which are worn like gloves and tied to the corresponding parts with straps. Comfort is an important part of the user experience. Comfort includes but is not limited to the way of binding, whether it is easy to carry and whether it will cause other damage. This is because the user will need to wear the device during operation. Therefore, the kinematic and ergonomic design of the device must minimize or eliminate user discomfort, fatigue and pain [9]. Most patients need to wear exoskeletons for a long time to carry out rehabilitation exercises, so comfort design becomes particularly important.

2. Structural Adaptability

2.1 Requirements

Since exoskeleton is a wearable device that provides force support and feedback to users through the transmission of force on a series of mechanical components, exoskeleton must meet people's different needs and characteristics.

2.2 Features

It needs to be adapted to the structure of the hand, and each finger has different degrees of freedom: MCP, PIP, DIP. Exoskeletons need to adapt to different degrees of flexibility. At the same time, the exoskeleton needs to be safe for its users. Each moving place needs to be adapted to the natural size of the hand joint [16]. A suitable structure is needed to ensure that the user will not have any fatigue and discomfort. In addition, the exoskeleton needs to have high enough efficiency and effective delivery, so that sufficient and appropriate force can be delivered to the joint, avoiding pain and other injuries to the hand. Finally, the hand exoskeleton needs to be affordable to ensure that patients can afford the rehabilitation process of using the device while using the exoskeleton.

2.3 Adaptability

The exoskeleton needs to be practical enough. There are many criteria for this practical, including but not limited to, wearability and the ability to interact with everyday objects (not only with regular objects, but also with irregular objects in the real world).

In terms of wearability, the exoskeleton should not be extremely specific to wear. Instead, there should be a variety of non-fixed wear methods, which can be convenient for the patient.

In addition, the exoskeleton needs to be able to cope with different objects, which is previously the ability to interact with life's endless. Each mechanical joint needs to be capable of performing complex tasks together. Such as grasping and picking [17].

2.4 Special

Each exoskeleton has a different purpose, from providing daily assistance to speeding up recovery. And that's just on the medical side. The assisted exoskeleton is usually used in daily life, where the patient recovers after leaving use. The category of use is usually used at home by recovering patients. This is because at home, they need to make contact with the objects in their lives, so the exoskeleton needs to be considered practical and portable. Portability is not necessarily what a rehabilitative exoskeleton requires. The exoskeleton focuses more on the comfort of the patient and whether it has enough capacity to help the patient regain the function of the hand.

Of course, among these, there is a more special kind. This exoskeleton can be used by a normal person, and requires the output of power to be controlled according to the characteristics of the normal person, as opposed to a rehabilitative exoskeleton. Make sure the force is used where it is strong (meaning to provide the right amount of force to help, but not as coercive as a rehabilitative exoskeleton).

3. Rigid Exoskeleton Wearing Mode

3.1 Velcro

This is one of the more common wear methods in which patients attach a mechanical exoskeleton to their hand by using Velcro. This way of wearing is more solid. But the method requires a complex series of movements with the wearer's other hand to secure it. This series of fixed movements can be very difficult for a patient with hand muscle weakness. So, this method is not suitable for patients to wear alone. The way Velcro is worn can also cause a loss of touch and pressure in the hands. This is because Velcro strips the wearer's fingers away from the feeling.

3.2 Thin Active Fixing Device

The wearer uses a fixator consisting of a memory alloy and an air cushion, which reduces the time spent on and off. Memory alloy (SMA) creates a force to hold it in place and, because it's a cushion of air, it weighs only one gram. It's also thin and doesn't interfere with hand movement. [10] The chamber is made of polypropylene sheets hot-welded. The deflating chamber is soft and can be deformed freely. The expanded air chamber stiffens and deforms into a cylindrical shape. The air pressure to the air chamber is 0.15mpa. The fixator is mounted on the scaffold of the exoskeleton. Can maintain enough force to grasp objects. According to the study, it can take up to 75 percent less time than Velcro [11].

4. Wearing Mode of Flexible Exoskeleton

Use soft, tendin-based guide wires to run along the sides of your fingers and palms to accomplish a series of stretches. This type of traction is very lightweight and can greatly reduce the load on the hands. But the disadvantage is that it is difficult to control the direction, so there are potential risks. This problem can be mitigated by a soft-starting actuator.

At the same time, because the exoskeleton is a soft air cushion structure, it is lighter and softer than the conventional rigid structure, which can greatly reduce the discomfort of the user. In this exoskeleton, there are different ways to wear it [12- 14].

1) Tie a band on each finger and keep the palm bare. This can ensure that the user can get sensory feedback in the process of use, and can also reduce the pressure on the hand.

2) Use Velcro to cover the whole glove, which will be very convenient to wear, but it will lose feeling because of covering the palm.

3) The last method is to cover only part of the finger, so as to maintain the comfort of the hand and ensure stability at the same time [15].

5. Conclusion

In general, there are a lot of things that go into making a good hand exoskeleton. These include the factors of the human body itself and the challenges that the outside world will bring to the exoskeleton. But the exoskeleton itself can bring benefits to people who are unable to live independently or have difficulty living.

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