

Chapter 35

Hybrid Exoskeletons for Upper Limb Stroke Rehabilitation

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ABSTRACT

Hybrid exoskeletons are a recent development, combining electrically controlled actuation with functional electrical stimulation, which potentially offers great benefits for muscular rehabilitation. This chapter presents a review on the state of the art of upper-limb hybrid exoskeletons with a particular focus on stroke rehabilitation. The current needs of the stroke rehabilitation field are discussed and the ability of hybrid exoskeletons to provide a solution to some of the gaps in this field is explored. Due to the early stage of development which most hybrid exoskeletons are in, little research has yet been done in control methods used for them. In particular, more investigation is needed with regards to the potential benefit of hybrid exoskeletons as a patient-monitoring and rehabilitation assist-as-need tool.

INTRODUCTION

Stroke is the second largest cause of disability worldwide after dementia (World Heart Federation, 2015). Each year the costs of stroke on society are considerable, both financially and with regards to the wellbeing of the affected individual, their families, and their friends. Approximately 1 in 6 people will suffer a stroke during their lives and these numbers are only likely to increase as the number of elderly

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increase (World Stroke Campaign, 2015). Effective rehabilitation after a stroke is important if the costs of stroke on society are to be minimised.

A stroke can cause many impairments which interfere with a person's ability to perform tasks with their affected limbs. These will be described in the next few paragraphs. Temporary hemiparesis is common among stroke survivors. Regaining strength and movement in the affected side takes time and can be improved with the use of rehabilitation therapy involving repetitive and function-specific tasks (Senelick, 2010). Patients who undergo stroke rehabilitation generally have a few sessions a week with a physiotherapist where they undertake various exercises. Many patients, particularly the external patients, will also be assigned exercises to complete outside of their regular sessions with the physiotherapist.

The abilities of stroke patients can vary quite considerably. While it is more common for a patient to regain strength in their shoulder before the elbow and fingers respectively there are also many exceptions. The rate at which patients improve and the joints with which they struggle with can vary significantly from patient to patient. Muscle atrophy is one of the most common issues that occurs after a stroke. Muscle atrophy is the wasting away of the muscles which leads to a loss in the size and strength of the muscle. For each day a patient is in hospital lying in bed with minimal activity approximately 13% of muscular strength is lost (Ellis, Jackson, Liu, Molloy, & Paterson, 2013). Regaining muscle strength and motor control are very important if a patient is to regain independence in their day to day life. Muscle atrophy can only be prevented by physically working the muscles either through the patient's own volition or the use of Functional Electrical Stimulation (FES).

Problems that patients have after a stroke are not just limited to lack of strength in the affected limbs. Some patients can be very capable of movement but lack sensation. This makes it difficult for a patient to know how much force to apply when manipulating objects such as holding a glass of water. It can also make it difficult for a patient to perform movements with their limb without observing where the limb is. This increases the mental energy required to undertake everyday tasks and can even pose a danger to the patient's limb as they are not always aware of where it is. Other problems include muscle spasticity. Pharmacological and non-pharmacological treatments can combat spasticity.

A lack of control or strength in one joint may affect the ability of a patient to perform movements with another joint. For example, lack of control or strength at the wrist may make performing exercises with the hand difficult as the forearm may not be in the ideal position to allow a strong grip. Some patients may adopt compensatory patterns of movement due to their impairments. Over a longer period, these compensatory patterns can lead to long term issues such as pain. Some patients experience involuntary movements where the limb will move unpredictably without the patient intending it to. This can cause damage to the limb and may be embarrassing for some people. In addition, patients can often also suffer from reduced mental cognition and increased mental fatigue.

There are many different types of training strategies and devices which can be employed as tools to help combat the problems which stroke patients face. Despite all the interventions available however, there remain several gaps in the field of stroke rehabilitation. The current tools and rehabilitation methods used, as well as the gaps in the stroke rehabilitation field, will be described in the background section of this chapter. Following on from this the potential of hybrid exoskeletons to help fill some of these gaps will be discussed, an evaluation of the state of research with regards to upper limb hybrid exoskeletons will be undertaken, and future directions suggested.

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