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Development of Robotic Rehabilitation Device for Spasticity Treatment of Acute Spinal Cord Injury Patients

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ABSTRACT

As spasticity is a major cause of illness in patients that suffer from spinal cord injury (SCI), there are several limitations in the present robotic-based therapy for the treatment of acute SCI patients. A large literature is present for the use of full body exoskeletons, but due to their limitations such as uneasiness due to repetitive motion, does not meet the anthropometric range. As manual therapy is tiresome, a need for ankle-foot therapy exoskeleton was felt and Ankle-Foot Orthosis was developed. This paper presents an ankle-foot therapy exoskeleton device for spasticity treatment of acute SCI patients to reduce the manual efforts of physiotherapists. The proposed device has one Degree of Freedom (DOF) in the sagittal plane in ankle joint. This paper analyses the control design of the prototype and clinical trial results on SCI patients, which show that the proposed prototype is viable in improving the range of ankle motion alleviating the spasticity with $p = 0.000365$.

KEYWORDS

Ankle-foot exoskeleton; Degree of Freedom (DOF); dorsiflexion; goniometer; range of motion (ROM); spinal cord injury

1. INTRODUCTION

According to World Health Organization (WHO), all over the world, people in the range between 2,50,000 and 5,00,000 suffer from Spinal Code Injury (SCI) yearly [1]. Mortality rate is highest in the initial years after injury and remains high, surpassing all the major factors of disability and death [2,3]. Given the current U.S. population size of 327 million people, a current approximation showed that the annual incidence of SCI is approximately 54 cases per one million people in the United States, or about 17,700 new SCI cases every year. New SCI cases do not comprise those who die at the location of the incident that caused the SCI [4]. SCI is defined as a motor disorder, which is characterized by velocity-dependent increase in the muscle tone and unrestrained repetitive involuntary inconsistencies of the skeletal muscle as the component of the upper motor neuron syndrome [5]. The general occurrence of spasticity for multiple sclerosis patients is 60%, which increases to 75% if the disease is prevailing for more than 15 years [6]. In a study of North American Research Committee on MS (NARCOMS) cross-sectional data of 21000 patients were acquired and it was deduced that 50% of the patients suffer from mild spasticity [7]. With the oral treatment procedure, 41% of physicians and 36% of the patients do not find satisfactory [8].

Rehabilitation of the spastic foot can be done by consistent therapy which can be done either manually or with the aid of robot-rehabilitation. Manual therapy has some limitations, such as non-uniformity in therapy; it's tiresome and monotonous for physiotherapist. As for acute SCI patients, therapy worked when patient is treated in his/her early stages of spasticity. Due to the lack of one-to-one ratio of physiotherapist to patient, robot-rehabilitation is preferred over conventional therapy. Knee Ankle Foot Orthosis (KAFO) [9], wearable ankle-knee exoskeleton [10], Robotic Gait Trainer (RGT) [11] and Yonsei-AAFO [12] are some of the earlier AFOs developed for the lower limb rehabilitation. Different efficient controlling techniques like Pneumatic Muscle Actuator are also used to reduce the work of therapists[13]. AFO, developed for the patients suffering from hemiplegia, has given much better results for the treatment of foot drop and toe drag during walking than the conventional AFOs [14,15]. Dhule *et al.* used a microcontroller to measure the force by Force Sensitive Resistor (FSR) and position control [16]. This AFO is proficient in accomplishing variation of functional tasks in daily life as it is battery powered and light in weight.

Numerous studies have shown that the AFO is helpful for improving Dorsiflexion (DF) and Plantarflexion