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Effectiveness of robo-assisted lower limb rehabilitation for spastic patients: A systematic review

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ABSTRACT

Background: Though many rehabilitative treatments are available for treatment of spasticity, thus the effectiveness of different robo-rehabilitative devices needs to be evaluated through a systematic review.
Objective: The objective of this study is to focuses on the efficacy of Robot assistive rehabilitation device for the removal of spasticity from the lower limb of Spastic patients.
Data Sourcessources: PubMed, Web of Sciences, EMBASE (Excerpta Medical database), CDSR (Cochrane database of systematic reviews), Scopus, IEEE Xplore, Wiley online library, MEDLINE (OvidSP), Science Direct, Springer Link were from January 1980 to September 2017
Data Extractionextraction: Seventy-one publications from eleven databases published were selected using keywords Ankle foot, spasticity, robotic rehabilitation, efficacy of robotics and Ankle foot rehabilitation. The review is narrowed down to twenty-six articles which were selected for they focused on effects of Robot assistive rehabilitation device quantitatively.
Result: A quantitative study from analyzing 26 studies comprising of 786 subjects is carried out. The major outcome of the effectiveness of the robot assistive therapy for the movement of ankle and functioning of gait is deduced. As the used protocols and treatment procedures vary, made comparative study complex or impracticable.
Conclusion: Robo-rehabilitation possesses an ability to provide unified therapy protocols with greater ease in comparison to conventional therapies. They continuously prove to be irreplaceable assistant devices when it comes to providing excellent treatment in terms of improvement from this study. Though many mechatronic devices are available but the devices for treatment of early stage rehabilitation of stroke patients is very limited.

1. Introduction

Spasticity is a condition in which there is a continuous contraction of muscle resulting in inability to control the muscle. Generally, occurrence of Spasticity is due to disorders of the CNS which are affecting the motor neurons. Spasticity occurs when there is an imbalance in the excitatory and inhibitory input signal which is caused due to injury of spinal cord and CNS including stroke.

Spasticity occurs due to disorders of the CNS affecting the motor neuron and it has affected more than 12 million people worldwide. About 4/5 of patients suffering with cerebral palsy (CP) and multiple sclerosis have varying degree of spasticity. Spasticity also occurs in the state when the brain and/or spinal cord fail to develop normally or are damaged and it may include Traumatic Brain Injury (TBI), Brain damage due to insufficient oxygen, Spinal cord injury (SCI), Meningitis and Stroke (Bose et al., 2015).

Due to stroke, there is an alteration in the net inhibition and excitation required in the affected region. This results in the increased depolarized state of neuron cell membrane (Hui et al., 2015). So, the threshold of action potential of neuron decreases which result in immobilized spastic muscle. According to WHO, Stroke is the "rapid developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 h or longer or leading to death, with no apparent cause other than of vascular origin" (Guilbert, 2003).

Today stroke is the major reason for disability in adults in Western Countries (Carolei et al., 2002), and the most common cause of death in the world (World Health Organization, 2008) and in this 80% are first event and rest are relapses. The report also states the data of some European countries. Italy has annual stoke incidence of approx. 200,000 patients and it is the third major cause of death behind

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Fig. 1. Phases of Rehabilitation.rehabilitation.

cardiovascular diseases and neoplasia. Incidence also increases with age progressively with 75% of stroke affected people are over 65 years of age. The rehabilitation consist of three phases (Chan et al., 2006; Pandian et al., 2012; Schmidt et al., 2007) as shown in Fig. 1.

With mild to moderate impaired spastic muscle, exercises are the best method for treatment by a professional therapist. The traditional rehabilitation process was uneconomical as it was a labor-intensive process as for rehabilitation at least 3 therapists were needed. Furthermore ageing, shortage of healthcare personnel, and the need of higher quality healthcare increases the average cost of rehabilitation. These factors are responsible for innovation in the domain of rehabilitation so that it can be made affordable and increase its availability to more patients for a longer time period (Gelderblom et al., 2009). Moreover, the use of drugs have aftereffects that should be avoided (Guohua et al., 2017). The need for a portable and cheap assistive device compel the researchers for the development of new rehabilitative device (Hui et al., 2016; Ji et al., 2017).

This systematic review aims at updating of the reviews done in the past and amalgamates the latest corroboration for effectiveness of robotic rehabilitation in the treatment of spasticity.

2. Methods

2.1. Search approach

This systematic review is done according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Moher et al., 2009) searching articles (i.e. journal articles, magazine articles, proceedings of conferences (international and national) and extended abstracts published from January 1980 to September 2017 in the databases recommended like pubMed, Web of Sciences, EMBASE (Excerpta Medical database), CDSR (Cochrane database of systematic reviews), Scopus, IEEE Xplore, Wiley online library, MEDLINE (OvidSP),ScienceDirect, Springer Link) with the search terms as Ankle Foot, Spasticity, Rehabilitation, Robotic rehabilitation and Effectiveness of robotics. Even though a wide range of devices for curing spastic patients is available but the most effective control technique still remains vague.

2.2. Selection Criteria

Based on the titles and the abstracts the screening is done by two authors (DS and NK). The entire texts of the articles screened were examined for the following queries. (1) Is the study for lower limb spasticity? (2) Is robotic rehabilitation used for therapy? (3) Is the robot rehabilitation effective? (4) What measurement procedure is used to measure improvement in spasticity? (4) Is bio signal visual feedback effective?

Depending on the screening process a baseline and intergroup comparison was made and the outcomes were reported. The point which are focused are whether the spasticity is related with lower limb spasticity or not, the study done in the article includes based on robo-rehabilitation or not, the effectiveness of robot rehabilitation is included in the article or not, the assessment method used in the study and the effectiveness of bio signal based visual feedback is discussed or not. By keeping these factors in mind and selecting the papers based on the keywords described in Fig. 2, studies are selected for review.

2.3. Exclusion Criteria

Spasticity is used as the only keyword for the search of publications but existence of paper with different names is also a possibility. The inclusion criteria were only confined to lower limb and the studies with upper limb is not used for reviewing the study. The therapies focused are of robo-rehabilitation and the effectiveness of manual therapies is not argued. Bias is created as studies published in English language are considered. Effective validation is not done due to limitation of subjects in the study.

2.4. Data extraction and assessment of methodological quality

Three reviewers (LM, NK and CK) studied the articles and the following information is extracted: Design of device, Specialty of device/study, Number of subjects involved, Gender (percentage of male subjects), Duration of study, Disease, Measured parameters, Improvement and Outcomes of study (Table 1).

3. Results

3.1. Study Selection

This systematic review identified 929 articles. Removal of 186 repeated publications reduced the articles of study to 743. Segregation with the keywords ‘Ankle foot’, ‘spasticity’ and ‘robotic rehabilitation’ in title and abstract narrowed down the study to 78 publications. 165 publications were selected from the references of selected publication based on title and abstract. In the abstract screening stage 61 publications were determined which qualified selection criteria for manuscript (Fig. 2).

A total of 61 publications were identified for different type of robo-assisted devices for the rehabilitation of lower limb. These were separated into nine categories: 5 assessments with EMG for AFO, 9 EMG employed AFO 4 ankle gait orthosis, 30 actuated AFO, 2 intelligent rehabilitation, 1 CPM, 3 dynamic AFO, 3 electrical simulation and 4 foot splint as shown in bar chart in Fig. 3.

3.2. Study Characteristics

Out of 786 subjects, 140 subjects are used as control group in the study while 646 subjects are used as experimental group in the 26 studies used in Table 1. Study includes all type of spasticity of lower limb and the efficacy of robot rehabilitation over other therapies is deduced. Table 2 and Fig. 5 are all about the quantitative effectiveness of robo- assisted therapy using Statistical Analysis (Wang et al., 2017).

3.3. Various Treatment methods of Spasticity

To treat spasticity a wide range of methods have been done in recent past and the application of the process depend on the severity of spasticity. As a consequence the better understanding of muscle may recommend the therapist which process to use (Picelli et al., 2017). To treat spasticity current available practices are as follows: Preventive measures; Neuro-rehabilitative approaches and physical modalities, Oral medications; injectable neurolytic medications; Positioning techniques/orthotics (Camerota et al., 2017; Noseworthy et al., 2000).

The ankle knee movement is always complex because of its intricate bone structure (Sui et al., 2009). The complete motion of ankle comprises of

- Dorsi Flexion or Plantar Flexion,
- Inversion or Eversion,
- Abduction or Adduction and
- Pronation or Supination.

The high training cost of the therapist can be replaced by Robotic rehabilitation giving more intensive reiterative action and performing the therapeutic exercises at relatively low cost and accessing the motor