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Review

Lower limb co-contraction during walking in subjects with stroke: A systematic review

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ABSTRACT

Purpose: The aim of this paper was to identify and synthesise existing evidence on lower limb muscle co-contraction (MCo) during walking in subjects with stroke.
Methods: An electronic literature search on Web of Science, PubMed and B-on was conducted. Studies from 1999 to 2012 which analysed lower limb MCo during walking in subjects with stroke, were included.
Results: Eight articles met the inclusion criteria: 3 studied MCo in acute stage of stroke, 3 in the chronic stage and 2 at both stages. Seven were observational and 1 had a pretest–posttest interventional design. The methodological quality was "fair to good" to "high" quality (only 1 study). Different methodologies to assess walking and quantify MCo were used. There is some controversy in MCo results, however subjects with stroke tended towards longer MCo in both lower limbs in both the acute and chronic stages, when compared with healthy controls. A higher level of post-stroke walking ability (speed; level of independence) was correlated with longer thigh MCo in the non-affected limb. One study demonstrated significant improvements in walking ability over time without significant changes in MCo patterns.
Conclusions: Subjects with stroke commonly present longer MCo during walking, probably in an attempt to improve walking ability. However, to ensure recommendations for clinical practice, further research with standardized methodologies is needed.

Contents

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1. Introduction

Stroke is defined by the World Health Organization as a focal or global neurological impairment of cerebrovascular cause (Lamontagne et al., 2000; Truelsen et al., 2007). It is one of the most chronic disabling diseases (Olesen and Leonardi, 2003) and the major cause of persistent motor impairments on one side of the body, which interfere with arm function and the ability to sit up, stand and walk (Staines et al., 2009).

Walking ability is severely impaired in 25% of people with stroke (Hendricks et al., 2002; Jang, 2010), limiting functional independence and leading to reduced quality of life (Lord et al., 2004). Walking impairment may result from a combination of deficits in perception, muscle strength, sensation, muscle tone and motor control (Yavuzer, 2006; Patterson et al., 2007). A deficit in motor control is one of the most common walking deficits following stroke (Roerdink et al., 2007). Motor control is the process by which the Central Nervous System (CNS) generates purposeful and coordinated movements whilst the body interacts with the environment (Latash et al., 2010). This process depends on precisely timed and appropriately modulated synergies between muscles, including synergies between functionally opposite muscles (agonist and antagonist muscles) (Latash et al., 2010).

Muscle co-contraction is the simultaneous activity of agonist and antagonist muscles crossing the same joint (MCo) (Busse et al., 2005). When agonist/antagonist muscles work synergistically, the antagonist muscle acts as stabiliser during agonist muscle contraction (Busse et al., 2005). This synergy is important for providing optimal joint stability, good movement accuracy and energy efficiency during functional activities, such walking (Milner, 2002; Arias et al., 2012; Knarr et al., 2012). MCo can be estimated using temporal or magnitude dimensions of electromyographic (EMG) recordings from the muscles involved (Criswell, 2007). Temporal MCo is defined as the time during which opposing muscles are simultaneously active and is usually classified using terms such normal, longer or shorter MCo duration. Magnitude of MCo is defined as the relative magnitude of simultaneous contraction between opposing muscles (Hortobágyi et al., 2009) and is classified using terms such normal, high or reduced magnitude of MCo (Criswell, 2007).

Some differences have been found in MCo patterns between subjects with CNS disorders (Hesse et al., 2000; Lamontagne et al., 2000, 2002; Busse et al., 2005) and healthy subjects (Den Otter et al., 2004; Prosser et al., 2010) during walking. In healthy subjects, MCo is at a maximum around the knee in the loading period of gait (e.g., vastus lateralis/medial hamstrings) to provide increased knee stability (Fonseca et al., 2006) and around the ankle in mid-stance (e.g., tibialis anterior/soleus) to generate an efficient plantarflexor moment necessary to move the limb forward efficiently (Fonseca et al., 2006; Sasaki et al., 2009). MCo increases in healthy and impaired participants whilst learning a new skill (Vereijken et al., 1992) or in the presence of instability (Nakazawa et al., 2004). However, adverse effects of this increased MCo have been reported, such as the increase in compressive joint loading and decreased movement flexibility, resulting in decreased movement adaptability (Busse et al., 2005).

Busse et al. (2005) conducted a systematic review of MCo patterns in subjects with CNS disorders during upper and lower limb tasks, concluding that the most successful rehabilitation outputs were found in people with MCo patterns similar to those found in healthy subjects. However, only two studies included in their review assessed MCo during walking in subjects with stroke. These studies reported increases in inter-subject variability and duration and magnitude of MCo in subjects with stroke.

This research therefore systematically identified and synthesised evidence on lower limb MCo during walking in subjects with stroke.

2. Methods

2.1. Research question

The two main research questions in this study were:

1. Which MCo patterns characterise the affected and non-affected lower limbs during the acute and chronic stages of stroke recovery?
2. How do MCo patterns relate to walking ability?

2.2. Search strategy

The electronic literature search was performed in April 2013 on the following databases: Web of Science (1970-date), MEDLINE via PubMed (1948-date) and B-on Knowledge Library (1999–2013). The following search terms were applied: "co-contraction" OR "coactivation" AND "gait" OR "locomotion" OR "walking" AND "stroke" OR "cerebrovascular disease". The search was limited to titles and abstracts. Articles were included if they: (i) studied people with walking impairment due to stroke and (ii) analysed lower limb MCo with surface electromyography (sEMG) during walking. Articles clearly unrelated to the theme (e.g., did not include subjects with stroke, assessed activities other than walking), written in languages other than English or Portuguese and unpublished studies were excluded. Review papers, abstracts of communications or meetings, papers on conference proceedings, editorials, commentaries to articles and study protocols were not considered suitable for this review. Nevertheless, their reference lists, in addition to the reference lists of all included studies, were scanned to find other potentially eligible articles.

This systematic review was reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) guidelines (Moher et al., 2009). The PRISMA guidelines consist