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Review

Methodologies to assess muscle co-contraction during gait in people with neurological impairment – A systematic literature review

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ABSTRACT

Purpose: To review the methodologies used to assess muscle co-contraction (MCo) with surface electromyography (sEMG) during gait in people with neurological impairment.
Methods: The Scopus (1995–2013), Web of Science (1970–2013), PubMed (1948-2013) and B-on (1999–2013) databases were searched. Articles were included when sEMG was used to assess MCo during gait in people with impairment due to central nervous system disorders (CNS).
Results: Nineteen articles met the inclusion criteria and most studied people with cerebral palsy and stroke. No consensus was identified for gait assessment protocols (surfaces, speed, distance), sEMG acquisition (electrodes position), analysis of sEMG data (filters, normalisation techniques) and quantification of MCo (agonist-antagonist linear envelopes overlapping or agonist-antagonist overlapping periods of muscles activity, onset delimited).
Conclusion: Given the wide range of methodologies employed, it is not possible to recommend the most appropriate for assessing MCo. Researchers should adopt recognized standards in future work. This is needed before consensus about the role that MCo plays in gait impairment in neurological diseases and its potential as a target for gait rehabilitation can be determined.

Contents

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1. Introduction

Gait patterns are usually impaired in people with dysfunction of the Central Nervous System (CNS), such as stroke (Knutsson and Richards, 1979), traumatic brain injury (Chow et al., 2012), cerebral palsy (Hesse et al., 2000) or Parkinson's disease (Dietz et al., 1981). Walking is a very complex function involving multiple interactions between muscle groups which can be adapted to enable walking at different speeds or on different surfaces (Winter, 2009). Neurological impairments can generate many deviations in muscle activity and gait kinematics from those seen in healthy individuals and reduce the ability to adapt gait appropriately to different environmental conditions. Gait patterns in people with neurological impairment have been characterized by abnormal muscle co-contraction, especially when postural stability is challenged (Lamontagne et al., 2000).

Muscle Co-contraction (MCo) is the mechanism that regulates simultaneous activity of agonist and antagonist muscles crossing the same joint (Busse et al. 2005). There is no consensus about the role that MCo plays in the various stages of recovery after CNS disease. However as MCo has been demonstrated to be important for providing adequate joint stability, movement accuracy and energy efficiency (Higginson et al. 2006) and adapting to environmental demands (Darainy and Ostry, 2008), its importance in neurological recovery is worthy of consideration.

Accurate determination of the impact of neurological impairment on MCo during gait requires robust measurement techniques which take careful consideration of the environmental conditions under which gait is assessed (Den Otter et al. 2004). For instance, walking on a ground surface instead of on a treadmill, walking at different speeds and for longer distances/duration would increase MCo recruitment and the variability between subjects (Parvataneni et al. 2009; Knarr et al. 2012). The first research question addressed by this review therefore is:

What are the main characteristics of the gait assessment protocols particularly, the surfaces where people walked, the speed, distance and time spent walking? Which muscles have been assessed?

All measurement techniques, including sEMG, are liable to measurement error which can reduce validity and reliability and confound interpretation of the findings. MCo assessment during functional movements, such as walking, requires the analysis of the relative variations in agonist and antagonist contraction over time using surface electromyography (sEMG) equipment (Fonseca et al. 2001; Fonseca et al. 2004). Standards have been developed for reporting sEMG signals in different processing stages, such as the signal acquisition (Surface Electromyography for the Non-Invasive Assessment Muscles (SENIAM) guidelines), and analogue and digital analysis (International Society of Electrophysiology and Kinesiology (ISEK) guidelines) (Merletti 1999), but the implementation of these is variable. Despite these guidelines, controversies remain about the most appropriate techniques of sEMG signal analysis; (e.g., selection of normalisation technique) leading to inconsistencies across studies (Burden et al., 2003). Therefore, the second research question this review sought to answer is:

What are the main steps in the acquisition and analysis of the sEMG signals and which parameters have been considered when quantifying MCo?

A single definition of MCo would also be facilitate interpretation of MCo outcomes during walking. However MCo has been defined in different ways: the magnitude; the time; or a ratio between the magnitude and time of simultaneous activation of opposite muscles (Fonseca et al. 2001). As a result of different definitions, different formulas or computational approaches to quantify MCo have been employed (Fonseca et al. 2001). All these methodological differences limit the comparison of data across studies and the understanding of the mechanisms of MCo. The third research question for this review is therefore:

Which formulas or computational approaches have been used to quantify MCo?

This paper addresses the need to systematically review, synthesize and critique the methodologies used in this field, contributing to a better understanding of the mechanisms underpinning MCo and of its role in gait in people with CNS disease.

2. Methods

2.1. Variable of interest

The variable of interest in this study was MCo during gait, presented as the time and/or the magnitude of simultaneous contraction between opposite muscles (Fonseca et al. 2001).

2.2. Search strategy

The literature search was performed from date of inception until end of November 2012 on the following databases: Scopus (1995–2013), Web of Science (1970–2013), PubMed (1948–2013) and B-on (1999–2013). B-on includes the Academic Search Complete (EBSCO), Annual Reviews, Elsevier-Science Direct, Nature, Springer Link (Springer/Kluwer), Taylor &Francis and Wiley Online Library (Wiley). Weekly updates were performed until October 2013.

The following search term (free text words) combinations were used in PubMed database: co-contraction AND gait, co-contraction AND locomotion, co-contraction AND Walking; co-activation AND gait; co-activation AND locomotion, co-activation AND walking. Search strategies in the other databases were derived from PubMed. The search terms were limited to titles and abstracts. The reference lists of all studies were also scanned to identify other potentially eligible articles.

The study was conducted using the systematic review method proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Moher et al. 2009), as shown in Fig. 1.

Full papers, written in English or Portuguese that met the following criteria were included if they: (i) studied gait impairment due to neurological diseases, such as stroke, Parkinsońs disease, cerebral palsy, traumatic brain injury and other CNS dysfunctions; and ii) analysed MCo during gait of the lower or upper limb or trunk using sEMG. All articles were independently reviewed by two reviewers for relevance and quality using PRISMA (Moher et al. 2009). Any discrepancies were resolved through discussion.

3. Results

Fig. 1 portrays the number of articles identified, the numbers and reasons for exclusion and the total number of studies included in the final review A descriptive analysis of the methodologies (study design; sample; data collection protocol; sEMG data acquisition and analysis and quantification of MCo) of the included studies is presented in Table 1.

3.1. Study design and sample

Most studies included in this review had observational designs, with the exception of two experimental studies (Hesse et al. 2000; Massaad et al. 2010). The observational studies assessed MCo during gait with no intervention or program. From those studies, only