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Full Length Article

# The coordination of shoulder girdle muscles during repetitive arm movements at either slow or fast pace among women with or without neck-shoulder pain

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ABSTRACT

*Purpose:* The aim of this study was to evaluate the coordination of the shoulder girdle muscles among subjects with or without neck-shoulder pain performing repetitive arm movement at either a slow or fast pace. *Methods:* Thirty female adults were allocated to one of two groups—healthy controls or cases with neck-shoulder pain. Surface electromyography (sEMG) signals from the clavicular, acromial, middle and lower trapezius portions and the serratus anterior muscles were recorded during a task performed for 20 min at a slow pace and 20 min at a fast pace. The root mean square (RMS), relative rest time (RRT) and normalised mutual information (NMI, an index of functional connectivity between two muscles in a pair) were computed. *Results:* No significant differences on RMS, RRT and NMI were found between groups. For both groups, the fast movement pace resulted in increased levels of RMS, lower degrees of RRT and higher NMI compared to the slow pace. No interaction between group and movement pace was found. *Conclusions:* This study highlights the change in sEMG activity of muscles to meet the demands of performing a task at fast movement pace. The fast pace imposed a higher muscle demand evidenced by increased sEMG amplitude, low degree of muscle rest and increased functional connectivity for subjects in both the case and control groups. No indication of impaired sEMG activity was found in individuals with neck-shoulder pain.

## 1. Introduction

Repetitive upper limb movements impose a demand on shoulder girdle muscles, particularly on the trapezius (upper, middle and lower portions) and serratus anterior, which act in concert to promote stability and allow the proper movement of the scapula (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Kibler & McMullen, 2003; Mottram, 1997). During repetitive dynamic tasks, the movement pace may play a role in the development of neck-shoulder disorders (Andersen et al., 2003; Arvidsson et al., 2012; Madeleine, 2010; Madeleine, Lundager, Voigt, & Arendt-Nielsen, 2003a; Mathiassen & Winkel, 1996; Veiersted, Westgaard, & Andersen, 1990), especially when associated with alterations on the muscle activation pattern, muscle imbalance, decrease in strength and fatigue (Borstad, Szucs, & Navalgund, 2009; Cools, 2004; Cools, Witvrouw, Mahieu, & Danneels, 2005;

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Langley, 1997). The movement pace also influences the level of discomfort and the performance rate (Bosch, Mathiassen, Visser, de Looze, & van Dieën, 2011; Gerard, Armstrong, Martin, & Rampel, 2002), the distribution of muscle load (Falla & Farina, 2007), the degree of muscle rest (Escorpizo & Moore, 2007) and the variability of movement (Srinivasan, Samani, Mathiassen, & Madeleine, 2015).

The motor strategies used during repetitive dynamic tasks change in the presence of neck-shoulder pain (Falla & Farina, 2005; Falla, Farina, & Graven-Nielsen, 2007; Madeleine, Lundager, Voigt, & Arendt-Nielsen, 1999). An increase in the surface electromyography (sEMG) amplitude of the upper trapezius associated with low degrees of the muscle rest, and inhibited or ineffective muscle activation of the serratus anterior and lower trapezius are reported in subjects with neck-shoulder pain (Chester, Smith, Hooper, & Dixon, 2010; Falla, Bilenkij, & Jull, 2004; Lin et al., 2005). However, in some studies evaluating repetitive tasks this altered pattern is not observed (Larsen, Søgaard, Chreiteh, Holtermann, & Juul-Kristensen, 2013; Sjøgaard et al., 2006).

Most studies to date have focused on isolated muscles and not on muscle coordination (Kawczyński et al., 2015). Computational methods, including normalised mutual information (NMI) and synergy analyses, have been used to investigate muscle coordination (Farina, Merletti, & Enoka, 2014; Madeleine, Samani, Binderup, & Stensdotter, 2011). These methods allow the synergistic activity of the involved muscles in the shoulder girdle region to be evaluated. Synergistic activity of shoulder girdle muscles is responsible for the stabilization and proper movement of the scapula during upper limb movements (Helgadottir, Kristjansson, Einarsson, Karduna, & Jonsson, 2011). Alterations in this synergistic muscle activity can lead to the development of symptoms (Madeleine et al., 2011). For example, a reduced activity of the serratus anterior and lower trapezius combined with an increased activity of upper trapezius has been identified in cases of scapular dyskinesia (Huang, Ying, Ou, & Lin, 2016) and subacromial impingement syndrome (Lin, Hsieh, Cheng, Chen, & Lai, 2011; Struyf et al., 2014).

The NMI enables the quantification of both linear and non-linear dependencies between two biological time series. This method was originally developed to evaluate electroencephalogram signals (Jeong, Gore, & Peterson, 2001; Kojadinovic, 2005). It has subsequently been applied to sEMG signals, providing an index which reflects the functional connectivity between two muscles in a pair by quantifying the coordination patterns between muscles (Madeleine et al., 2011). The NMI has been used in different contexts to evaluate the effects of sex/gender on functional connectivity (Fedorowich, Emery, Gervasi, & Côté, 2013; Johansen, Samani, Antle, Côté, & Madeleine, 2013), functional changes during static and dynamic muscle contractions (Kawczyński et al., 2015; Svendsen, Samani, Mayntzhusen, & Madeleine, 2011), and the effects of lower back or neck-shoulder pain on muscle coordination (Madeleine, Xie, Szeto, & Samani, 2016; Svendsen, Svarrer, Laessoe, Vollenbroek-Hutten, & Madeleine, 2013). Since NMI is a normalized index, the values vary from 0 (no shared information) to 1 (completely shared information) within a given muscle pair (Johansen et al., 2013; Kojadinovic, 2005).

Only a few studies have evaluated musculoskeletal pain effects on functional connectivity. Low NMI values (low functional connectivity) have been reported in the presence of musculoskeletal pain during the performance of activities including computer work, smartphone use, box-lifting tasks or sit-standing tasks (Madeleine et al., 2016; Svendsen et al., 2013). Thus, a low functional connectivity may be associated with musculoskeletal symptoms in the neck-shoulder region (Madeleine et al., 2016). The evaluation of synergistic muscle activity is particularly important when considering repetitive dynamic tasks in a population with neck-shoulder pain.

To the best of our knowledge, no previous study has investigated the role of movement pace during a repetitive assembly task on the coordination of neck-shoulder muscles among subjects with and without neck-shoulder pain. For that purpose, we computed the sEMG amplitude and the degree of muscle rest, derived from sEMG signals, as well as the functional connectivity of the paired muscles during a repetitive dynamic task performed at either a slow pace and or a fast movement pace. Based on previous studies, we hypothesized that (i) subjects with neck-shoulder pain compared with pain-free controls would have lower degrees of muscle rest and lower levels of functional connectivity (Madeleine et al., 2016; Sandsjö, Melin, Rissén, Dohns, & Lundberg, 2000; Svendsen et al., 2013), and (ii) a fast movement pace would lead to increased sEMG amplitude and lower degrees of muscle rest when compared with a slow movement pace (Arvidsson et al., 2012; Mathiassen & Winkel, 1996; Sundelin & Hagberg, 1992).

## 2. Methods

### 2.1. Subjects

Right-handed female college students with and without neck-shoulder pain were recruited to participate in this study. Subjects were allocated into one of two groups based on the results of a self-reported musculoskeletal complaint questionnaire (Kuorinka et al., 1987), a standardized clinical examination (Ohlsson, Attewell, Johnsson, Ahlm, & Skerfving, 1994), and the intensity of reported pain, measured using a visual analog scale (VAS).

Fifteen healthy control (CON) subjects (24.5 ± 2.7 years of age, weight 60.5 ± 8.2 kg and height 164 ± 0.10 cm) and 15 subjects with neck-shoulder pain (NSP) (23.1 ± 2.6 years of age, weight 57.5 ± 5.4 kg and height 164 ± 0.05 cm) were enrolled in this study. Subjects in the CON group had no symptoms or problems in the neck-shoulder region. Subjects in the NSP group reported moderate to severe pain (intensity > 4 cm on a 0–10 cm scale) in the neck-shoulder region (Larsson et al., 2008), and had a diagnosis of neck tension syndrome or cervical syndrome according to a clinical examination conducted by an experienced physiotherapist (Sjörs, Larsson, Dahlman, Falkmer, & Gerdle, 2009). Within the NSP group, the pain intensity was 6.5 cm ± 2.0 cm. Of the 15 NSP subjects, 88.2% were diagnosed with neck tension syndrome and 11.8% were diagnosed with both neck tension syndrome and cervical syndrome. None were diagnosed with cervical syndrome only.

Subjects who reported any systemic diseases with rheumatic, circulatory or inflammatory characteristics, with experience in