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Sequencing of superficial trunk muscle activation during range-of-motion tasks

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ABSTRACT

Altered lumbo-pelvic activation sequences have been identified in individuals with low back pain. However, an analysis of activation sequences within different levels of the trunk musculature has yet to be conducted. This study identified the activation sequences characteristic of the trunk musculature during upright standing and range-of-motion tasks. Surface electromyography was recorded for eight trunk muscles bilaterally during trunk range-of-motion movement tasks in 30 participants. Cross-correlation was performed on 48 pairings of muscles, consisting of one lower- and one mid-level muscle, or one mid-level and one upper muscle. Time lags of the maximum cross-correlation coefficient were extracted and defined as a top-down or bottom-up activation sequence, or similar activation timing. Pairings that demonstrated a specific activation sequence in 50% or more of participants were then identified. Similar activation timing was consistently identified between muscle pairings for upright standing. Top-down sequences and similar timing were identified for abdominal – mid-level pairings in maximum flexion and slumped standing, respectively, while both tasks were characterized by bottom-up sequences when considering the lumbar and lower-thoracic erector spinae. Sequences were more variable across muscle pairings for lateral bend and axial twist tasks. These results provide insight into the synergy of the trunk musculature for movements in the three planes of motion. These findings can be used for comparison to low back pain populations, as altered activation sequences in these individuals may contribute to maladaptive loading patterns and consequently the development or exacerbation of low back pain.

1. Introduction

Studies employing surface electromyography (EMG) to evaluate trunk muscle function are numerous throughout the literature. Various techniques may be employed during data collection and processing to examine different characteristics of the EMG signal, such as activation timing and sequencing (Nelson-Wong et al., 2013), changes with fatigue (Beneck, Baker, & Kulig, 2013), and the relationships to muscle forces and spine loading (Cholewicki & McGill, 1996; Granata & Marras, 2000). Further, it has been established that EMG variables can be used to distinguish between healthy individuals and individuals with low back pain (Nelson-Wong & Callaghan, 2010; Watson, Booker, Main, & Chen, 1997). For example, different activation

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sequences have been identified in individuals with low back pain, compared to healthy individuals (Nelson-Wong, Alex, Csepe, Lancaster, & Callaghan, 2012; Nelson-Wong et al., 2013). As a result of the insight provided by these characteristics of the EMG signal into various physiological processes (De Luca, 1997), and the potential relationships to injury in the lumbar spine, the lumbar musculature has been extensively researched with respect to these characteristics.

With the traditional focus on the lumbar musculature in spine biomechanics research, there is a relative paucity of work relating to muscle activation patterns and levels in the thoracic spine, as well as the interactions of the musculature amongst the different levels of the spine. While the musculature of the thoracic spine has been somewhat neglected due to the lower incidence of injury relative to the lumbar spine, the median prevalence of thoracic spine pain has been documented to be approximately 30% in the general working population (Briggs, Bragge, Smith, Govil, & Straker, 2009). These findings suggest that thoracic spine pain is a substantial occupational health problem, and therefore a detailed examination of muscle activation within this region is warranted. Further, the thoracic spine may exert substantial influence on postures and motion patterns in the whole spine and in the cervical and lumbar spine regions (Edmondston & Singer, 1997). Lumbar spine posture has also been shown to influence the motion that can subsequently be achieved in the thoracic spine (Nairn & Drake, 2014). Given the mutual influence of the lumbar and thoracic spine regions on each other with respect to posture and movement, a detailed examination of the patterns by which the muscles activate along the spine during trunk movements is warranted to better understand neuromuscular control of the trunk.

Past work has documented activation levels in several muscles in the thoracic spine, such as the lower-thoracic erector spinae (ES) (Drake, Fischer, Brown, & Callaghan, 2006; McGill, 1991; Nelson-Wong & Callaghan, 2010) and latissimus dorsi (Drake et al., 2006; McGill, 1991), both characterized at the T_9 level. These muscles are often examined in relation to lumbar spine mechanics. Conversely, for studies with a focus on the mechanics of the cervical or cervico-thoracic spine, activation levels have been recorded for the thoracic ES musculature at the T_4 level (Burnett et al., 2009; Caneiro et al., 2010; Edmondston, Sharp, Symes, Alhabib, & Allison, 2011), and for the trapezius muscle between the C_7 spinous process and the acromion (Burnett et al., 2009; Caneiro et al., 2010). The majority of studies incorporating the thoracic musculature have focused on one to two of these four muscles, with little work done to integrate multiple muscles within the thoracic musculature itself, or across the thoracic and lumbar spine regions. Nairn, Azar, and Drake (2013), Nairn, Chisholm, and Drake (2013), and Schinkel-Ivy, Nairn, and Drake (2013) presented three such studies, investigating activation levels of the surface trunk musculature during short-duration slumped sitting (Nairn, Chisholm, et al., 2013) and prolonged sitting (Nairn, Azar, et al., 2013), and co-contraction between the various muscles of the trunk during prolonged sitting (Schinkel-Ivy et al., 2013). In these studies, the bilateral upper-thoracic ES (T_4), lower-thoracic ES (T_9), and latissimus dorsi (T_9) activation levels were measured along with the lumbar ES (L_3), rectus abdominis, external oblique, and internal oblique muscles. However, an examination of the interactions between these muscles during trunk range-of-motion (ROM) tasks has yet to be undertaken.

Nelson-Wong and Callaghan (2010), Nelson-Wong, Gregory, Winter, and Callaghan (2008), and Nelson-Wong et al. (2012, 2013) have conducted a series of studies investigating the sequences of muscle activation within the lumbo-pelvic region, focusing on the relationships between selected trunk muscles and the gluteus medius (Nelson-Wong & Callaghan, 2010), and between the bilateral gluteus medius (Nelson-Wong et al., 2008) during prolonged standing; between the thoracic ES, lumbar ES, and gluteus maximus during trunk flexion (Nelson-Wong et al., 2012); and between selected trunk muscles and either rectus femoris or gluteus maximus during two commonly used clinical assessments for lumbo-pelvic control (Nelson-Wong et al., 2013). These works used cross-correlation to identify the sequencing of activation between trunk and pelvic muscles, for the purposes of better understanding lumbo-pelvic control. However, the understanding of activation sequences and patterns within the muscles of the trunk specifically during trunk motion is lacking; work of this nature would provide insight into the means by which trunk movement is accomplished in healthy individuals. Therefore, the purpose of this study was to identify the activation sequences characteristic of the trunk musculature during upright standing and trunk ROM tasks.

2. Methods

2.1. Participants

Thirty individuals (15 male/15 female) participated in the study, with mean (SD) age, height, and weight, respectively, of 25.0 years (3.8), 1.80 m (0.05), and 79.64 kg (8.75) for the males and 22.8 years (2.7), 1.66 m (0.05), and 59.12 kg (6.38) for the females. All participants were right-hand dominant and asymptomatic for low back pain in that none had sought treatment for back pain, nor missed any days of school or work due to back pain, for twelve months prior to collection. All procedures were approved by York University's Office of Research Ethics, and written informed consent was obtained from all participants prior to collection. Data were collected as part of a larger study investigating trunk muscle activation and three-dimensional motion.

2.2. Instrumentation

Pairs of Ag/Ag–Cl electrodes (Ambu® Blue Sensor N, Ambu A/S, Denmark) were applied over the bellies of the muscles of interest (Fig. 1): external oblique (McGill, 1991; Mirka & Marras, 1993), internal oblique (McGill, 1991), latissimus