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Full Length Article

Arm position influences the activation patterns of trunk muscles during trunk range-of-motion movements

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ABSTRACT

To understand the activation patterns of the trunk musculature, it is also important to consider the implications of adjacent structures such as the upper limbs, and the muscles that act to move the arms. This study investigated the effects of arm positions on the activation patterns and co-activation of the trunk musculature and muscles that move the arm during trunk range-of-motion movements (maximum trunk axial twist, flexion, and lateral bend). Fifteen males and fifteen females, asymptomatic for low back pain, performed maximum trunk range-of-motion movements, with three arm positions for axial twist (loose, crossed, abducted) and two positions for flexion and lateral bend (loose, crossed). Electromyographical data were collected for eight muscles bilaterally, and activation signals were cross-correlated between trunk muscles and the muscles that move the arms (upper trapezius, latissimus dorsi). Results revealed consistently greater muscle co-activation (higher cross-correlation coefficients) between the trunk muscles and upper trapezius for the abducted arm position during maximum trunk axial twist, while results for the latissimus dorsi-trunk pairings were more dependent on the specific trunk muscles (either abdominal or back) and latissimus dorsi muscle (either right or left side), as well as the range-of-motion movement. The findings of this study contribute to the understanding of interactions between the upper limbs and trunk, and highlight the influence of arm positions on the trunk musculature. In addition, the comparison of the present results to those of individuals with back or shoulder conditions may ultimately aid in elucidating underlying mechanisms or contributing factors to those conditions.

1. Introduction

There is an extensive body of literature regarding spine mechanics in terms of motion characteristics and the muscle activation that produces that motion. The muscles responsible for spinal motion in each plane (flexion-extension, lateral bend, and axial twist) have been identified, based upon physiological cross-sectional area and lines of action of each muscle (McGill, Santaguida, & Stevens, 1993). For example, flexion and extension movements occur through activation of the abdominal and erector spinae muscle groups (Floyd & Silver, 1955), respectively. Lateral bending is primarily accomplished by the intertransversarii and oblique muscles (Lavender, Chen, Trafimow, & Andersson, 1995) while axial twisting is

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accomplished by the rotatores and oblique muscles (Pope, Andersson, Broman, Svensson, & Zetterberg, 1986). McGill (1991) also identified the latissimus dorsi and erector spinae as contributing to trunk axial twist. However, the muscle activation characteristics of the trunk, and interactions between trunk muscles to produce motion, are not as clearly understood as trunk motion patterns.

Muscle activation plays an important role in regulating spinal stiffness, and consequently spinal stability. The stiffness of the spine represents the amount of translational or rotational deformation a spinal segment may undergo when exposed to an applied force (White & Panjabi, 1978). Activation of the musculature acts to increase the stiffness of the spine (Brown & McGill, 2005, 2008; Lee, Rogers, & Granata, 2006), thereby contributing to stability and preventing buckling of the spine during loading, static postures, and motion (McGill, Grenier, Kavcic, & Cholewicki, 2003). Activation that is either insufficient or excessive to maintain stability may result in spinal buckling or increased compression forces, respectively, increasing the risk of injury in both scenarios (Cholewicki & McGill, 1996). The coordinated activation of the collective trunk musculature is necessary to maintain sufficient spinal stiffness and stability, as the inappropriate activation of a single muscle may facilitate spinal instability (McGill et al., 2003). Therefore, an understanding of activation patterns within the trunk is essential to better understand injury risk in the spine.

There is also clinical relevance for muscle activation characteristics. Cross-correlation has been used previously to quantify patterns of activation between two muscles (Nelson-Wong, Alex, Csepe, Lancaster, & Callaghan, 2012; Nelson-Wong & Callaghan, 2010; Nelson-Wong, Gregory, Winter, & Callaghan, 2008; Nelson-Wong et al., 2013; Schinkel-Ivy & Drake, 2015a), with altered activation patterns identified in individuals with transient or chronic LBP relative to healthy individuals (Nelson-Wong & Callaghan, 2010; Nelson-Wong et al., 2008, 2012, 2013). To further emphasize the potential of evaluating activation patterns as a diagnostic tool for LBP, differences in low back activation patterns during trunk flexion have been documented based on LBP status (Colloca & Hinrichs, 2005; Floyd & Silver, 1955; Watson, Booker, Main, & Chen, 1997). These findings underscore the importance of trunk muscle activation patterns in determining the mechanisms and effects of LBP.

The majority of studies regarding activation patterns focus exclusively on the trunk musculature (Shan et al., 2014) or relationships within the lumbopelvic musculature (Nelson-Wong et al., 2013) and between the lumbopelvic and thigh musculature (Nelson-Wong et al., 2012). However, it is important to consider more superior components of the musculoskeletal system such as the arms because they may also influence the activation patterns of the trunk musculature. Past work has investigated and highlighted the possible implications of arm movement on the trunk. For example, in walking with and without arm swing movements, increased activation of the trunk musculature was reported with restricted arm swing (Callaghan, Patla, & McGill, 1999). With arm movements at varying speeds, Hodges and Richardson (1999) showed differences in trunk musculature recruitment in individuals with LBP. In functional tasks such as lifting, Crosbie, Kilbreath, and Dylke (2010) reported coordinated kinematic movement patterns between the scapulae and spine. Additionally, Schinkel-Ivy, Pardisnia, and Drake (2014) identified differences in trunk range of motion during maximum trunk flexion, lateral bend, and axial twist with different arm positions. However, work addressing the effects of arm position and trunk movement on muscle activation patterns, and relationships in activation patterns of the muscles that move the trunk and arms, is currently limited. Providing a more in-depth understanding of the relationships between the trunk and arm musculature will contribute to the study of LBP, as activation characteristics of the trunk have been related to both pain (Nelson-Wong, Howarth, & Callaghan, 2010; Nelson-Wong et al., 2012, 2013) and injury (Cholewicki & McGill, 1996; McGill, 1992; McGill et al., 2003) development. This study aimed to investigate the effects of arm position on the activation patterns (specifically co-activation) of the trunk musculature and muscles that move the arm during trunk range-of-motion movements (maximum trunk axial twist, flexion, and lateral bend).

2. Methods

2.1. Participants

Thirty right-handed individuals, 15 males (mean (SD) age, 25.0 (3.8) y; height, 1.80 (0.05) m; weight, 79.64 (8.75) kg) and 15 females (mean (SD) age, 22.8 (2.7) y; height, 1.66 (0.05) m; weight, 59.12 (6.38) kg), participated in this study. All participants were asymptomatic for back pain, defined as not having sought treatment or missed any days of school or work due to back pain for 12 months. This study was approved by York University's Office of Research Ethics, and written informed consent was obtained prior to collection.

2.2. Instrumentation

Electromyography (EMG) data were collected, differentially amplified (frequency response 10–1000 Hz, common mode rejection 115 dB at 60 Hz, input impedance 10 GΩ; AMT-8, Bortec, Calgary, Canada), and sampled at 2400 Hz (Vicon MX, Vicon Systems Ltd., Oxford, UK). Sixteen pairs of disposable Ag/Ag-Cl electrodes (Ambu® Blue Sensor N, Ambu A/S, Denmark) were applied over eight muscles bilaterally (Schinkel-Ivy & Drake, 2015a): external oblique (EO), 15 cm lateral to the umbilicus at a 45° angle (McGill, 1991; Mirka & Marras, 1993); internal oblique (IO), superior to the inguinal ligament below the external oblique electrodes (McGill, 1991); rectus abdominis (RA), 2 cm superior to the umbilicus and 3 cm lateral to the midline (Mirka & Marras, 1993); lumbar erector spinae (lumbar ES), 4 cm from the midline or over the largest muscle mass