Human Movement Science 38 (2014) 262–280

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Age-related changes in trunk neuromuscular activation patterns during a controlled functional transfer task include amplitude and temporal synergies

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ARTICLE INFO

Article history:
Available online 17 November 2014

PsycINFO classification:
2330
2530

Keywords:
Electromyography
Aging differences
Trunk musculature
Temporal patterns
Muscle synergies
Bidirectional moment

ABSTRACT

While healthy aging is associated with physiological changes that can impair control of trunk motion, few studies examine how spinal muscle responses change with increasing age. This study examined whether older (over 65 years) compared to younger (20–45 years) adults had higher overall amplitude and altered temporal recruitment patterns of trunk musculature when performing a functional transfer task. Surface electromyograms from twelve bilateral trunk muscle (24) sites were analyzed using principal component analysis, extracting amplitude and temporal features (PCs) from electromyographic waveforms. Two PCs explained 96% of the waveform variance. Three factor ANOVA models tested main effects (group, muscle and reach) and interactions for PC scores. Significant ($p < .0125$) group interactions were found for all PC scores. Post hoc analysis revealed that relative to younger adults, older adults recruited higher agonist and antagonistic activity, demonstrated continuous activation levels in specific muscle sites despite changing external moments, and had altered temporal synergies within abdominal and back musculature. In summary both older and younger adults recruit highly organized activation patterns in response to changing external moments. Differences in temporal trunk musculature recruitment patterns suggest that older adults experience different dynamic

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http://dx.doi.org/10.1016/j.humov.2014.08.013

spinal stiffness and loading compared to younger adults during a functional lifting task.

1. Introduction

Industrialized nations worldwide are experiencing an aging demographic, with projections that by 2050, one in three individuals will exceed an age of 60 years (United Nations, 2011). While a majority of older adults live and complete activities of daily living independently (Scott, Pearce, & Pengelly, 2005), they have an increased risk of experiencing both falls (Pijnappels, Delbaere, Sturnieks, & Lord, 2010; Scott et al., 2005) and low back pain (Gourmelen et al., 2007; Plouvier, Gourmelen, Chastang, Lanoe, & Leclerc, 2011). The falls literature has focused on lower extremity joint function (Gillespie et al., 2012) although the ability to control trunk motion during both voluntary and unexpected perturbations has implications for maintaining dynamic stability during functional tasks (Doi et al., 2013; Grabiner et al., 2008). The spine is inherently unstable with links made between spinal instability and spinal injury (Cholewicki, Panjabi, & Khachatryan, 1997; Panjabi, 2003). Spine instability is partially explained by its osteoligamentous structures (ligaments, bones, discs, joint capsules, etc.) which contribute to passive stiffness only at end range of motion (Panjabi, 2003). Thus when in neutral spinal postures active stiffness through the interactions among the active force generation (skeletal muscles) and neural control (central and peripheral nervous system) components are needed to maintain stability (Cholewicki et al., 1997; McGill, Grenier, Kavcic, & Cholewicki, 2003). Alterations in one component requires compensation from the others, and this is particularly evident during dynamic tasks where the time varying recruitment of trunk musculature can change dynamic joint stability by altering active spinal stiffness (McGill et al., 2003; Panjabi, 2006).

Relevant to this study is that each component can be modified with increased age including decreases in joint space (de Schepper et al., 2010), muscle strength (Hasue, Fujiwara, & Kikuchi, 1980), contractile speed (D'Antona, Pellegrino, Carlizzi, & Bottinelli, 2007), action potential velocity (Rivner, Swift, & Malik, 2001), joint position sense (Goldberg, Hernandez, & Alexander, 2005), and changes in central nervous system recruitment (Van Impe, Coxon, Goble, Wenderoth, & Swinnen, 2011). These alterations can challenge spinal motion/stability control in older adults mainly in a neutral position where joint space narrowing results in increased neutral zone motion of the vertebra (Sengupta & Fan, 2014) and for dynamic tasks that require neuromuscular integration (de Freitas, Knight, & Barela, 2010). The literature supports an association between trunk function and both balance and fall risk (Davidson, Madigan, Nussbaum, & Wojcik, 2009; Doi et al., 2013; Goldberg et al., 2005; Grabiner et al., 2008; Hicks et al., 2005a; Kell & Bhambhani, 2006) as well older adults with low back disorders have an increased risk of falls (Leveille et al., 2009).

Differences in trunk kinematics and kinetics variables were found between older and younger adults (Burgess, Hillier, Keogh, Kollmitzer, & Oddsson, 2009; Grabiner et al., 2008; McGill, Yingling, & Peach, 1999; Van Emmerik, McDermott, Haddad, & Van Wegen, 2005), but there is limited research comparing trunk muscle responses between older and younger adults. Since motion is partially controlled by the time varying tension generated by multiple trunk muscles (coordination) (Cholewicki et al., 1997; Rashedi, Khalaf, Nassajian, Nasseroleslami, & Parnianpour, 2010), alterations in muscle responses with age would be expected. In general older adults were found to have: (i) increased overall activation of both agonist (Asaka & Wang, 2008; Kuo, Kao, Chen, & Hong, 2011) and antagonist muscles (Asaka & Wang, 2008; McGill et al., 1999), and (ii) delayed onset time to voluntary and involuntary trunk motion (Allum, Carpenter, Honegger, Adkin, & Bloem, 2002; de Freitas et al., 2010; Hwang, Lee, Park, & Kwon, 2008). Two methodological issues exists that limit our understanding of the age-related differences in synergies among the comprehensive trunk musculature and their responsiveness to dynamic forces normally found in activities of daily living. First, most studies only characterize a few (2–4) trunk muscle sites (Allum et al., 2002; Asaka & Wang, 2008; de Freitas et al.,