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Full Length Article

Sex differences in anticipatory postural adjustments during rapid single leg lift

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A R T I C L E I N F O

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A B S T R A C T

The aim of this study was to assess the influence of sex on the kinetic, kinematic and neuromuscular correlates of anticipatory postural adjustments (APAs) during a single leg lift task performed by healthy participants. Fifty healthy age and body mass index matched participants (25 women and 25 men) performed 20 single leg lift task (hip flexion to 90° as quickly as possible) with their dominant and their non-dominant lower limbs. A force plate was used to determine the medial-lateral displacement of the center of pressure (COP_{ML}), and the initiation of weight shift (T_0); kinematics was used to determine leg lift (T_1); and electromyography was used to determine onset times from eight muscles: bilateral external oblique, internal oblique and lumbar multifidus, and unilateral (stance limb) gluteus maximus and biceps femoris. Movement control limb dominance was included in the analysis. Statistically significant interactions between sex and limb dominance ($p < .001$) were observed for T_1, $COP_{ML,}$ and muscle onsets. Also, statistically significant main effect of sex on T_0 was observed. Women showed increased APA time (T_1) and magnitude (COP_{ML}) in their dominant limbs compared to men. Such differences between sexes did not occur in the non-dominant limb. Women recruited proximal muscles later than their man counterparts. Overall, women appear to have a stronger effect of limb dominance on their anticipatory postural control strategy which requires further investigation. The findings of the current study indicate that women and men differ in their anticipatory postural control strategy for rapid single leg lift.

1. Introduction

The prevalence of low back pain (Schneider, Randoll, & Buchner, 2006), and the frequency and duration of musculoskeletal pain (Berkley, 1997; Leveille, Zhang, McMullen, Kelly-Hayes, & Felson, 2005; Unruh, 1996) are greater in women than men. While social and psychological factors appear to play a role in the sex-specific concentrations of musculoskeletal disorders (Wijnhoven, de Vet, & Picavet, 2006), the importance of those factors can only be understood once the contributions of biophysical mechanisms have been established. The biophysical characteristic most commonly linked with low back pain is suboptimal stabilization of the lumbar spine, which has been associated with delayed trunk muscle activation during dynamic stability tasks (Hodges & Richardson, 1996). The activation of trunk muscles to stabilize the spine often occurs in advance of limb or whole-body movements that would otherwise destabilize spinal posture (Bussey & Milosavljevic, 2015; Hungerford, Gilleard, & Hodges, 2003), this phenomenon is an example of

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feed-forward postural control. Impairments of anticipatory trunk muscle actions may therefore be an important factor in the development of low back pain (Moseley, Nicholas, & Hodges, 2004). Despite the higher prevalence of low back pain in women and the association between low back pain and muscular activation delays, sex-specific characteristics are usually not considered in studies exploring feed-forward mechanisms of postural control (Cau et al., 2014; Hall, Brauer, Horak, & Hodges, 2010; Halliday, Winter, Frank, Patla, & Prince, 1998; Maribo, Stengaard-Pedersen, Jensen, Andersen, & Schiøttz-Christensen, 2011; Mehta, Cannella, Smith, & Silfies, 2010). The identification of sex-specific features in postural control strategy during self-initiated perturbations may help us understand the greater vulnerability of women to musculoskeletal disorders in general and low back pain in particular. For example, a greater reliance by women on feedback associated to decreased feed-forward control during static to dynamic balance transitions might expose them to greater risk of injury in the event of sensorial dysfunction induced or pregnancy, aging or other factors.

The ability of the human sensorimotor system to predict and compensate for self-initiated perturbations becomes particularly important during transitions from a standing posture to dynamic activities, such as walking or single leg lift. These actions require a complex cascade of mechanical and neuromuscular events that must be timed to ensure that the transition takes place without loss of balance (Cau et al., 2014; Hungerford et al., 2003). Since the desired changes in limb and body position have consequences for balance, the neuromuscular events necessary to ensure proper postural control and smooth load transfer between lower limbs and spine require motor commands to be delivered both with and without feedback-based regulation (Friedli, Hallett, & Simon, 1984; Krishnan, Aruin, & Latash, 2011; Latash, 2010). Anticipatory postural adjustments (APAs) are automatic actions of the neuromuscular system that occur in order to minimize the destabilizing effect of voluntary movements on limb or whole body posture. To achieve this, APAs must be initiated before sensory feedback is available about segmental motion or postural perturbation (feed-forward control) (Hugon, Massion, & Wiesendanger, 1982). Individuals' knowledge about several factors related to the task, such as the magnitude, direction and type of the perturbation, as well as instructional or mechanical constraints on posture, influence the output from feed-forward and feedback control networks (Ito, Azuma, & Yamashita, 2003; Latash, 2010). Given the association between delays in feed forward control and low back pain (Hodges & Richardson, 1996), APAs generated prior to single leg lifts provide an excellent model for detecting differences in feed forward trunk and pelvic girdle control between men and women.

Unlike many upper limb tasks, self-initiated lower limb tasks typically involve either whole body progression (e.g., during step initiation) or a transitory base of support (e.g., during single hip flexion). As such APAs may not be wholly dedicated to the focal movement but also to the postural chain (Bouisset & Do, 2008; Yiou, Ditcharles, & Le Bozec, 2011). During rapid hip flexion, the APA phase is marked by an initial weight shift toward the swing leg, observed as a posterior lateral shift in the center of pressure (Hass, Waddell, Fleming, Juncos, & Gregor, 2005; Hass et al., 2004). This initial load transfer is considered a postural chain response and the associated trunk muscle activity has been identified as clinically relevant for stabilizing the lumbopelvic complex in preparation for movement (Hodges & Richardson, 1998; Hungerford et al., 2003; Sims & Brauer, 2000; Stokes, Gardner-Morse, & Henry, 2011). Particularly, activity in the multifidus, transverse abdominis, internal and external oblique has been identified as critical to the stability of the lumbopelvic complex prior to and during the load transfer phase of rapid hip flexion movements (Hungerford et al., 2003; Stokes et al., 2011).

The aim of this study was to assess the influence of sex on the kinetic, kinematic and neuromuscular correlates of APAs during a single leg lift task performed by healthy participants. Since women are more susceptible to types of pain associated with suboptimal feed-forward control of trunk and pelvic girdle muscles (P W Hodges & Richardson, 1998; Schneider et al., 2006; Vleeming, Albert, Ostgaard, Sturesson, & Stuge, 2008), we predicted that when women perform a single leg lift task they would demonstrate delays in feed-forward activation of those muscles. Thus, we hypothesized that the initiation of weight shift, leg lift and muscle onsets would occur later in women, as such women would have delayed muscle activation and longer APA duration compared to men.

2. Methods

2.1. Participants

Fifty healthy age and body mass index matched participants (Table 1) gave informed consent to take part in this study (University of Otago Human Ethics Committee #12/188). Participants were excluded from the study if they had history of low back or pelvic girdle pain, a known localized spinal pathology, a history of spinal fracture, disc rupture, spinal surgery, diagnosed spinal deformity or instability, known congenital anomalies of the hip, pelvis or spine, known systemic arthropathy or neuropathy, diagnosed acute disk herniation/prolapse, pregnancy or less than six months postpartum, recent lower limb injury or surgery or the presence of any

Table 1
Participant demographics.

	Men (n = 25)	Women (n = 25)	p-value
Age [years]	27.1 SD 6.6	29.5 SD 9.1	.306
Height [m]	176.1 SD 7.1	166.2 SD 7.5	< .001
Mass [kg]	74.8 SD 9.0	65.0 SD 10.2	< .001
Body mass index [kg/m^2]	24.1 SD 2.2	23.5 SD 3.2	.457
Limb dominance [right/left]	25/0	25/0	n/a