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Full Length Article

The effects of trunk extensor and abdominal muscle fatigue on postural control and trunk proprioception in young, healthy individuals

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ABSTRACT

The purpose of this study was to induce both trunk extensor and abdominal muscle fatigue, on separate occasions, and compare their effects on standing postural control and trunk proprioception, as well as look at the effects of a recovery period on these outcome measures. A total of 20 individuals participated, with 10 (5 males and 5 females) completing either a standing postural control or lumbar axial repositioning protocol. Participants completed their randomly assigned protocol on two occasions, separated by at least 4 days, with either their trunk extensor or abdominal muscles being fatigued on either day. Postural control centre of pressure variables and trunk proprioception errors were compared pre- and post-fatigue. Results showed that both trunk extensor and abdominal muscle fatigue significantly degraded standing postural control immediately post-fatigue, with recovery occurring within 2 min post-fatigue. In general, these degradative effects on postural control appeared to be greater when the trunk extensor muscles were fatigued compared to the abdominal muscles. No statistically significant changes in trunk proprioception were found after either fatigue protocol. The present findings demonstrate our body's ability to quickly adapt and reweight somatosensory information to maintain postural control and trunk proprioception, as well as illustrate the importance of considering the abdominal muscles, along with the trunk extensor muscles, when considering the impact of fatigue on trunk movement and postural control.

1. Introduction

The maintenance of postural control through the proper coordination of muscle and movement patterns requires precise monitoring of trunk and whole-body motion (Horak & Nashner, 1986). As such, any deficit in either trunk muscle and/or proprioceptive function has the potential to degrade the overall quality of control and/or movement. As muscle fatigue is known to alter both sensory and motor control processes (Taylor, Butler, & Gandevia, 2000), many studies have begun investigating the effects of isolated muscle fatigue on quiet upright standing and proprioception. More specifically, it has been suggested that isolated muscle fatigue negatively impacts our sensorimotor systems by decreasing force generating capacity (Taylor et al., 2000) and proprioceptive reliability (Allen & Proske, 2006) through an association with increased muscle spindle discharge and mechanoreceptor thresholds (Boucher, Abboud, & Descarreaux, 2012). This combination of decreased force generating capacity and proprioceptive sensitivity, when in a fatigued state, degrades the ability to control posture and movement (Proske & Gandevia, 2012).

With respect to the trunk extensor muscles in particular, past research has discovered that fatigue degrades quiet standing

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postural control (Davidson, Madigan, & Nussbaum, 2004; Johanson et al., 2011; Lin et al., 2009; Pline, Madigan, & Nussbaum, 2006; Vuillerme, Anziani, & Rougier, 2007; Vuillerme & Pinsault, 2007). As described above, the maintenance of quiet upright standing balance requires proper coordination of muscular activation. Two major postural control strategies focused around the ankle and hip involve significant contributions from trunk extensor and abdominal muscles to maintain balance (Horak & Nashner, 1986). During demanding situations (e.g. standing on small or unstable support surfaces), contributions from the trunk muscles increase as the hip movement strategy becomes the predominant strategy of choice to maintain postural control (Horak, Nashner, & Diener, 1990). In regard to trunk proprioception, past research has shown that healthy individuals are able to reposition their trunk with considerable accuracy in an unfatigued state (Swinkels & Dolan, 1998); however, trunk proprioception decreases when the trunk extensor muscles are fatigued (Boucher et al., 2012; Taimela, Kankaanpää, & Luoto, 1999). Therefore, the combination of degraded postural control and trunk proprioception experienced when the trunk extensor muscles are fatigued indicates that quality of movement in a fatigued state is poor, which could increase the risk of low back or lower limb injury. Although the majority of this research has focused on the trunk extensor muscles, it is also important to consider the effects of abdominal muscle fatigue on postural control and trunk proprioception, as the abdominal muscles play an important role in controlling spine motion (McGill, Grenier, Kavcic, & Cholewicki, 2003) and contribute to the maintenance of standing postural control (Horak & Nashner, 1986).

Another important factor to consider is the recovery time needed to regain function after a fatiguing exercise. Previous researchers have reported that times ranging from as little as 9 min to more than 30 min are necessary to regain function with respect to postural control (Davidson et al., 2004; Lin et al., 2009; Parreira et al., 2013; Pline et al., 2006) and trunk proprioception (Boucher et al., 2012) after a trunk extensor fatiguing exercise. This range in reported recovery times is likely due to the limited number of post-fatigue time points measured across studies, and this uncertainty limits the ability to recommend appropriate rest requirements that will limit injury risk associated with muscle fatigue. Therefore, increasing the number of post-fatigue assessments, similar to the approach of Lin et al. (2009), will provide greater accuracy when measuring the recovery time needed to regain function after a fatiguing exercise. Altogether, understanding how both trunk extensor and abdominal muscles respond to and recover from a fatiguing exercise, specifically regarding postural control and trunk proprioception, is crucial for understanding and limiting injury risk, as the trunk is the centre of the kinetic chain for most human movement.

To the authors' knowledge, the effects of abdominal muscle fatigue on quiet standing postural control and trunk proprioception, both immediately after fatigue and during a recovery period, has yet to be researched. Therefore, the purpose of this study was to induce both trunk extensor and abdominal muscle fatigue, on separate occasions, and compare their effects on postural control and trunk proprioception, as well as look at the effects of a recovery period on these outcome measures. We hypothesized that abdominal muscle fatigue would degrade quiet standing postural control and trunk proprioception similar to what has been seen previously with trunk extensor muscle fatigue. We also hypothesized that postural control and trunk proprioception would return to pre-fatigued values within 10 min of post-fatigue muscle recovery.

2. Methods

2.1. Participants

A total of 20 young, healthy participants were recruited for this study, with 10 randomly selected participants completing the standing postural control protocol and the other 10 participants completing the trunk proprioception protocol (Table 1). Exclusion criteria were any history of recent acute/chronic abdominal or low back pain/injury, musculoskeletal disorders, or skin conditions. All participants completed a health screening questionnaire and signed informed consent. The study was approved by the University Research Ethics Board.

2.2. Fatiguing tasks

Participants completed an isometric fatigue protocol to isolate either their trunk extensor or abdominal muscles on the first collection day; participants were then asked to return to the lab at least 4 days later to perform the same protocol as their first collection, with the opposing muscle group being fatigued (e.g. Collection day 1 – trunk extensor muscle fatigue, Collection day 2 – abdominal muscle fatigue). To fatigue their trunk extensor muscles, participants performed a Biering-Sørensen test, as shown in Fig. 1a (McGill, Childs, & Liebenson, 1999). To fatigue their abdominal muscles, participants held a modified reverse Biering-Sørensen position, in which an experimenter aligned the participant's T12 to the edge of the bench as shown in Fig. 1b. In each fatigue task, participants were asked to hold the isometric position until complete exhaustion.

For participants taking part in the standing postural control task, surface electromyography (sEMG) Al/AgCl electrodes (Ambu Inc, Columbia, MD, USA) were placed bilaterally over three muscles: lumbar erector spinae, external oblique, and rectus abdominis as

Table 1
Mean (± SD) postural control (n = 10) and trunk proprioception (n = 10) group characteristics.

Testing Protocol	Height (cm)	Mass (kg)	Age (years)
Standing postural control (5 males; 5 females)	172 (± 8.9)	69 (± 11.7)	23 (± 2.2)
Trunk proprioception (5 males; 5 females)	177 (± 6.0)	71 (± 7.7)	23 (± 2.9)