Time to Task Failure of the Trunk Extensor Muscles Differ with Load Type

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Introduction
Muscle fatigue is commonly defined as an exercise-induced reduction in maximal voluntary muscle force (Enoka & Stuart, 1992). It arises not only because of peripheral changes at the level of the muscle, but also because the central nervous system fails to drive the motor neurons adequately.

The relative contribution of the neural and muscular mechanisms to muscle fatigue varies with the specificity of the task being performed (Enoka & Duckworth, 2008; Enoka & Stuart, 1992; Hunter, Duckworth, & Enoka, 2004).

Numerous studies of the appendicular muscles have shown that task failure during sustained submaximal contractions is 50% shorter when subjects attempt a position-matching task compared to a force-matching task (Hunter, et al., 2004; Hunter, Youn, Fameltie, Griffin, & Nig, 2008; Maluf & Enoka, 2005; Maluf, Shinohara, Stephenson, & Enoka, 2010; Rudroff, Justice, Matthews, Zuo, & Enoka, 2005). Findings over the last five years strongly suggest that limited duration of position-matching tasks in appendicular muscles may result from spinal mechanisms such as increased excitation of spinal motor neurons.

Fatigability of the trunk extensors is an important predictor of a first time point of low back pain (Alaia, Lustc, Heliovana, & Hur, 1995; Broering, Samuelson, 1984), and a discriminator of those with and without low back pain or a history of low back pain (McGill, et al., 2003; McNeil, Arentzen, & Needham, 2004). This understanding fatigue in the trunk extensors is clinically important.

The purpose of this study was to first determine the effects of load type (i.e., position versus force matching) on time to task failure of the trunk extensor muscles in healthy participants during seated extension tests. The protocol was approved by the Institutional Review Board of Ohio University.

Methods
Eighteen healthy participants (9 males, 9 females) with a mean age of 22.8±5.82 years and no history of low back pain participated in this study. All subjects provided written informed consent before participating in this study. The protocol was approved by the Institutional Review Board of Ohio University.

This experiment consisted of two sessions scheduled at least 72 hours apart. The order of testing (i.e., force versus position matching) was randomized and counterbalanced.

Participants were seated upright in a lumbar extension apparatus (MedX, Ocala, FL) that was modified by inserting a load cell in series with the weight stack to 1) assess maximal isometric voluntary strength and 2) monitor isometric load during the force-matching tasks.

A potentiometer was attached to the trunk resistance arm of the apparatus to monitor trunk position.

Real-time visual feedback of force or position was provided on a flat panel monitor located 1.5 meters in front of the participant using software developed in LabVIEW/NI (National Instruments, Austin, TX).

Gain of the visual feedback provided was 0.5°/cm for position-matching and 5% Target Force/cm for force-matching tasks.

Position-Matching: participants maintained an upright sitting posture against a weight stack loaded to 15% MVIC as long as possible receiving visual and auditory feedback regarding trunk position. Task failure occurred when the participant was unable to match the target position (±1 degree) for greater than 3 seconds.

Force-Matching: participants maintained an extension force of 15% MVIC for as long as possible while receiving visual and auditory feedback. Task failure occurred when the participant was unable to match the target force (±10%) for greater than 3 seconds.

A 2-way mixed-model ANOVA was used to determine the effect of load type and gender on time to task failure.

Steadiness of the contraction was also quantified using the coefficient of variation of force measured at the following time points: 1st 10 sec, 20, 40, 60, 80% of task duration, and last 10 sec.

Results
• Time to task failure for the trunk extensors was significantly longer for the position-matching task (23.6±4.2 mins) when compared to force-matching task (28.8±4.7 mins) (F=9.36, p<.05).
• Time to task failure for the elbow flexors was significantly shorter for the position-matching task (18.7±2.5 mins) when compared to the force-matching task (20.8±4.7 mins) (F=3.93, p<.05).

Conclusions
This study provides the first test of the effect of load type on the time to task failure of the trunk extensor muscles. These data indicate that the time to task failure is approximately 50% longer for position-matching tasks compared to force-matching tasks for the trunk extensors, which is in contrast to that typically observed in appendicular muscle (Hunter, et al., 2008; Maluf & Enoka, 2010; Maluf, et al., 2005; Rudroff, et al.). Additionally, our findings from a subset of our subjects performing force versus position matching tasks with the elbow flexor muscles is consistent with these previous reports on appendicular muscle fatigue (Maluf & Enoka, 2015; Maluf, et al., 2005; Rudroff, et al.). Accordingly, our findings suggest the mechanism of task failure differ between the trunk extensor muscles and those of appendicular muscles.

Future Directions
We seek to determine the underlying mechanisms driving the differences in time to task failure of the trunk extensor muscles. It is unknown if early task failure of the trunk extensors in force-matching tests is due to similar spinal mechanisms reported in the appendicular muscles for position-matching tasks, or if supraspinal mechanisms such as greater alterations in cortical inhibition and facilitation are causal factors of task failure in trunk extensor muscles. Therefore we have added classic neurophysiological techniques to examine the spinal and supraspinal mechanisms contributing to trunk extensor task failure under different load types (position- versus force-matching). We will examine single motor unit recruitment of the multifidus muscles. Short latency afferent reflexes (F2) and cortical excitability using: paired pulse transcranial magnetic stimulation to evaluate motor potentials in the erector spinae muscles.

References

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The time to task failure for the different load types is shown for the trunk extensor muscles (n=18) and for the elbow flexors (n=4) which was from a subset of the larger group. Figure 4 shows for the trunk extensor muscles (n=18) and for the elbow flexors (n=4) which was from a subset of the larger group. The time to task failure for the different load types is shown for the trunk extensor muscles (n=18) and for the elbow flexors (n=4) which was from a subset of the larger group.

Figure 4. The time to task failure for the different load types is shown for the trunk extensor muscles (n=18) and for the elbow flexors (n=4) which was from a subset of the larger group.