Time to Task Failure of the Trunk Extensor Muscles Differs 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 motorneurons adequately.
- The relative contribution of the neural and muscular mechanisms to muscle fatigue varies with the specifics of the task being performed (Enoka & Duchateau, 2008; Enoka & Stuart, 1992; Hunter, Duchateau, & Enoka, 2004).
- Numerous studies of the appendicular muscles have shown that time to task failure during sustained submaximal contractions are 50% shorter when subjects attempt a position-matching task compared to a force-matching task (Hunter, et al., 2004; Hunter, Yoon, Farinella, Griffith, & Ng, 2008; Maluf & Enoka, 2005; Maluf, Shinohara, Stephenson, & Enoka, 2005; Rudroff, Justice, Matthews, Zuo, & Enoka).
- 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 episode of low back pain (Alaranta, Luoto, Heliovaara, & Hurri, 1995; Biering-Sørenson, 1984), and a discriminator of those with and without low back pain or a history of low back pain (McGill, et al., 2003; McKeon, Albert, & Neary, 2006). Thus 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.

Methods

- Eighteen healthy participants (9, males, 9 females) with a mean age of 22.8±0.92 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(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 for as long as possible while 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.

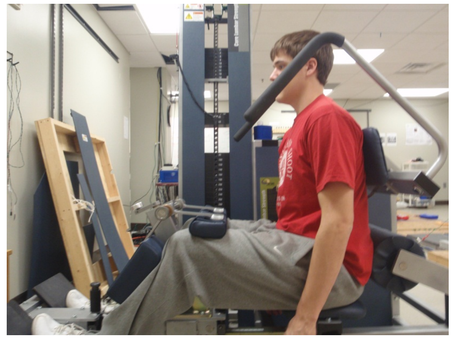

Figure 1. A subject positioned in the MedX Lumbar Extension device.

Figure 2. Screen shot of the visual feedback used for the position- and force-matching tasks is shown.

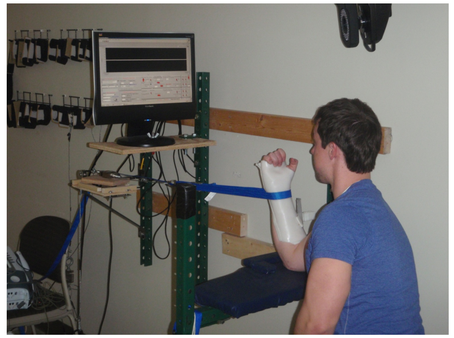

Figure 3. A subject positioned in the Biceps Force vs. Position device.

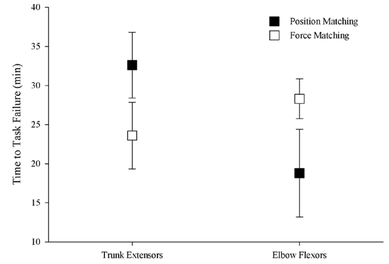

Figure 4. The time to task failure for the different load types is shown for the trunk extensor muscles (n=18) and for the elbow flexors (n=4) which was from a subset of the larger group completing the main experiment. The time to task failure for the trunk muscles were significantly longer for the position matching tasks compared to the force matching tasks while opposite the results were found for the elbow flexors.

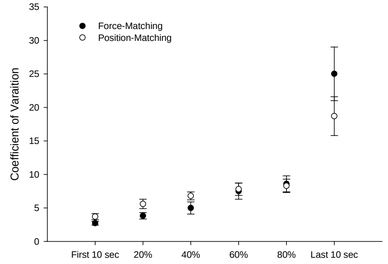

Figure 5. The coefficient of variation is plotted for both force- and position-matching tasks. time to task failure for the different load types is shown for the trunk extensor muscles (n=18) and for the elbow flexors (n=4) which was from a subset of the larger group.

Results

- Time to task failure for the **trunk extensors was significantly longer for the position-matching task** (32.6±5.6 mins) when compared to force-matching task (23.6±4.2 mins) (F=6.34, p<.05).
- Time to task failure for the **elbow flexors was significantly shorter for the position-matching task** (18.7±2.5 min) when compared to the force- matching task (28.8±4.7 mins) (F=9.36, 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 muscles (Hunter, et al., 2008; Maluf & Enoka, 2005; 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, 2005; Maluf, et al., 2005; Rudroff, et al.). Accordingly, our findings suggest that the mechanisms 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 tasks is due to similar spinal mechanisms reported in the appendicular muscles for position-matching tasks, or if supraspinal mechanisms such as greater alterations in intracortical inhibition and facilitation are causal factors of task failure in trunk extensor muscles. Therefore we have adapted 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 spinal reflexes (Fig 6), and cortical excitability using paired pulse transcranial magnetic stimulation to evoke motor potentials in the erector spinae muscles.

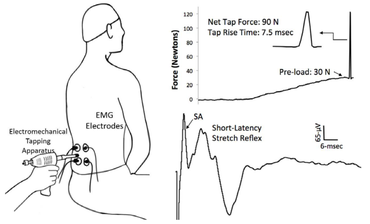

Figure 6. A. The experimental setup for revoking short latency stretch reflexes from the erector spinae muscles. **B.** the tip of the electromechanical tapping apparatus will be gradually pressed into the tissue until a pre-load 30 Newtons is reached and then the device delivers a rapid mechanical tap to the muscle with a net force of 90 Newtons. **C.** Representative examples of a short latency stretch reflex recorded from the erector spinae muscles in response to a mechanical tap.