DISTURBANCES TO INTRINSIC STIFFNESS AND REFLEXIVE MUSCLE RESPONSES FOLLOWING PROLONGED TRUNK FLEXION

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INTRODUCTION

Prolonged trunk flexion is associated with an increased risk of low back disorders (LBDs) [1]. Prolonged trunk flexion reduces passive support of the spine due to creep of viscoelastic structures. Ideally, the neuromuscular system detects such alterations and compensates with appropriate and effective muscle activation. Efficient control of muscle activation (i.e., to achieve equilibrium and stability requirements of the trunk) is imperative for avoiding LBDs. Hence, understanding normal and/or disturbed trunk neuromuscular behavior is needed for prevention, treatment, and rehabilitation of LBDs. The goal of this study was to quantify alterations in trunk neuromuscular behaviors induced by prolonged trunk flexion. More specifically, the effects of angle and duration on trunk stiffness and reflex response were investigated.

METHODS

Twelve healthy young adults with no self-reported history of low back pain participated, after completing an informed consent procedure approved by the local IRB. Participants included six males with mean (SD) age = 23(4) yr, stature = 180.3(6.8) cm, and body mass = 75.3(10.8) kg. Respective values for the six females were 22(3) yr, 166.1(7.9) cm, and 60.1(5.5) kg. Trunk posture was monitored using electromagnetic sensors (Xsens, Los Angeles, CA, USA) over the T10 and S1 spinous processes, and muscle activity (EMG) using bipolar surface electrodes over the bilateral erector spinae, internal obliques, external obliques, and rectus abdominis muscles.

Three replications of slow trunk flexion-extension movements were performed to determine the corresponding lumbar flexion angle at which extensor EMG dropped below 5% of maximum (i.e., flexion-relaxation, or FR angle). Each participant completed six experimental sessions involving exposures to 33, 66, and 100% of FR angle for durations of 2 and 16 min. in a counterbalanced order, during which muscle activity (EMG) was minimized. Mean FR angle was 65.2°, mean treatment levels were 22, 45, and 65°.

During the experiment, participants stood upright in a structure that restrained the pelvis and lower limbs. Static lumbar flexion was achieved by raising the legs with the torso upright (Fig. 1), thereby minimizing movement, muscle activity, and potential muscle fatigue.
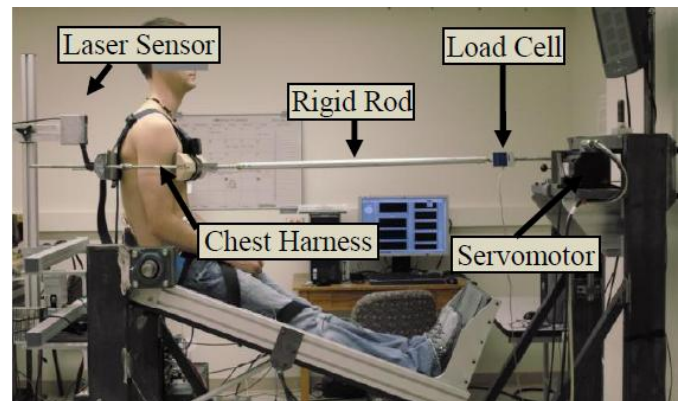
Figure 1: Experimental set-up demonstrating a participant in a 100% (of FR angle) posture.

Prior to and after exposures, a pseudorandom sequence of 12 anterior-posterior position perturbations of ±5mm were applied to the trunk at ~T8 via a servomotor (Kollmorgen, Radford, VA), rigid rod, and chest harness (Fig. 1). During these perturbations, participants maintained an extensor effort of 10% MVC using real-time visual feedback of muscle activity. Trunk displacements (at T8, superior to the chest harness) were measured with a CCD laser displacement sensor (Keyence, Osaka, Japan) and motor encoder. Applied forces were measured using a load cell in-line with the rigid rod (Interface SM2000, Scottsdale, AZ, USA).

Several measures were derived to assess neuromuscular behaviors (during anteriorly-directed perturbations). Reflex response latency was determined as the time delay between displacement onset and the onset of erector spinae muscle reflex response (via EMG) [2]. Intrinsic trunk stiffness was then estimated using a system identification method relating measured trunk kinetics and kinematics during the period prior to reflex response [3]. Reflex response, estimated by subtracting the intrinsic response from measured trunk kinetics, was then related to delayed trunk velocity to estimate reflex gain [4]. Mixed-factor analyses of variance (ANOVA) were used to determine the effects of gender, flexion angle, and duration on these measures ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Mean (SD) muscle reflex delays were similar ($p=0.32$) for males [62(3) ms] and females [64(5) ms], and were unaffected by trunk flexion ($p=0.79$). Though not significant ($p=0.1$), intrinsic trunk stiffness was higher among males than females, at 6075 (1370) and 4916 (1509) N/m, respectively. Intrinsic stiffness decreased significantly ($p<0.01$ with flexion angle (Fig. 2), but was consistent ($p=0.92$) between the two exposure durations. The latter was likely a result of relatively quick (2-3 min) exponential decays in passive stiffness at a given strain. Specifically, ~90% of the moment decrement due to relaxation occurred during the first 2 min. of exposure.

Pre-exposure reflex gains tended ($p=0.075$) to be higher in females [1015(229) Ns/m] than males [926(243) Ns/m]. Trunk reflex gains increased significantly ($p<0.01$) with flexion angle (Fig. 2), but were unaffected by flexion duration ($p=0.41$). There was a gender x duration interaction effect ($p=0.038$) on reflex gain; effects of 2 min. of exposure were similar between genders, though males showed substantially larger increases after 16 min. of exposure. These increased reflex gains are consistent with evidence from animal models in which a hyper-excitable reflex response was found following periods of prolonged ligament stretch [5].

CONCLUSIONS

Despite the roles of intrinsic stiffness and paraspinal reflex responses in spinal stability and neuromuscular control, no prior studies have quantified alterations in these variables following exposure to varying magnitudes and durations of prolonged flexion in humans. Our results (Fig. 2) suggest that increases in trunk reflexive stiffness, at least in healthy individuals, may be a compensation for decreases in passive trunk stiffness (i.e., reflected by predicted intrinsic stiffness) following prolonged trunk flexion.
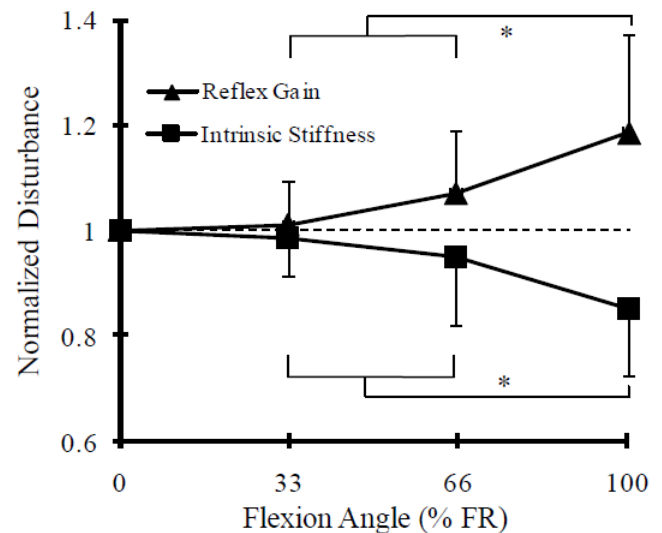
Figure 2: Effects of flexion angle on trunk intrinsic stiffness and reflexive gain (data are normalized to pre-exposure values). Results from post hoc pairwise comparisons are indicated by brackets (* = significant difference).

REFERENCES

1. Kumar S. *Ergonomics* **44**: 17-47, 2001.
2. Granata KP, *et al. J Biomech* **37**: 241-247, 2004.
3. Gardner-Morse MG, et al. *J Biomech* **34**: 457-463, 2001.
4. Moorhouse K, et al. *J Biomech* **40**: 1058-65, 2007.
5. Solomonow M. *J Electromyogr Kinesiol* **14**: 49-60, 2004.

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