EFFECTS OF EXERCISE-INDUCED LOW BACK PAIN ON INTRINSIC TRUNK STIFFNESS

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INTRODUCTION

Low Back Pain (LBP) is the most significant musculoskeletal health problem in industry [1], accounting for 20% of occupational injury and 40% of worker compensation. Impaired neuromuscular control of the lumbar spine is associated with LBP. Fundamental characteristics of this neuromuscular control include passive tissue properties, active muscle stiffness, and reflex behavior. Any impairment in these characteristics could lead to an insufficient response to a spinal disturbance and cause LBP or injury (e.g. excessive stress or strain in tissues).

Fundamental characteristics of neuromuscular control contribute to what are termed “effective” stiffness and damping in response to a perturbation, with effective stiffness being a combined measure of intrinsic stiffness and a reflex contribution. In an effort to understand the characteristics associated with LBP, studies have compared trunk responses between individuals with and without LBP. For example, following sudden trunk load release, individuals with LBP are reported to have greater effective trunk stiffness and lower effective trunk damping [2], as well as delayed reflex latencies [3], compared to healthy individuals.

Since comparisons between those with and without LBP are susceptible to inter-individual differences, additional insight may be provided by collecting repeated measurements from individuals who experience intermittent LBP. Comparing measures of neuromuscular control between known periods of pain and no pain in these individuals could reveal how/if neuromuscular control changes with the presence of pain, as well as how it differs with individuals who do not suffer from LBP. Additionally, since effective stiffness includes a reflex contribution, determining the intrinsic stiffness before reflexes occur could be beneficial for the further understanding of LBP. Therefore, the purpose of this study was to investigate effects of exercise-induced LBP on intrinsic stiffness using sudden trunk flexion position perturbations.

METHODS

Repeated measurements were collected from a local triathlon team, eight males (1.83±4.67 m, 72.9±2.7 kg) who experience exercise-induced LBP and nine males (1.79±3.15 m, 70.8±7.3 kg) who do not experience LBP, during known periods of pain and no pain in the LBP group (i.e. 1-2 days and 4-5 days post strenuous training). Participants were seated in a rigid metal frame (Fig. 1), strapped in at the pelvis, and attached to a servomotor (Kollmorgen AKM53K, Radford, VA, USA) via a rigid harness/rod connection at the T8 level. For two trials, the motor applied 12 anterior-posterior perturbations with amplitudes of 10 mm and peak velocities of 0.357 m/s. Perturbations completed within ~40 ms, less than typical reflex latencies [4].

![Figure 1: Experimental set-up.](image)

During each trial, motor displacement was recorded with a high accuracy encoder on the shaft of the motor. Trunk kinematics were collected with a high accuracy CCD laser displacement sensor (Keyence...
LK-G 150, Osaka, Japan) focused on the midline of the dorsal harness just above the rod height. Forces in the rod connecting the motor to the harness were collected with an in-line load cell (Interface SM2000, Scottsdale, AZ, USA). All data was sampled at 1000 Hz and processed with 7th order, 10 Hz zero-lag low pass Butterworth filters.

Trunk properties were estimated by modeling the trunk and harness/rod connecting device as a 2DOF system (Fig. 2), with each degree of freedom having parameters of stiffness, damping, and mass [5]. Parameters were determined with a least squares MATLAB curve fit routine minimizing the difference between estimated and measured forces and using a system of 2nd order linear differential equations. Trunk damping, assumed as negligible and indistinguishable for such a quick time period [6], was forced to zero in order to greater represent changes in trunk behavior with those in stiffness.

![2DOF linear dynamic model of stiffness](image)

**Figure 2: 2DOF linear dynamic model of stiffness (k), damping (c), and mass (m) for both the harness/rod connection (1) and the trunk (2). Inputs are displacements from the motor (u1) and laser (u2) along with their 1st and 2nd derivatives.**

To isolate the intrinsic portion of the trunk response, curve fits were restricted to the period of force tension in the load cell during anterior trunk flexion perturbations, visually inspected to occur before reflexes. Intrinsic stiffness was the value corresponding to the best curve fit within the 12 anterior perturbations applied per trial.

Pairwise comparisons using student t-tests were conducted within a 2-way ANOVA to compare intrinsic stiffness between repeated measurements for both healthy and LBP individuals as well as between healthy and LBP individuals for each repeated measurement. Statistical analyses were conducted using JMP 8 (SAS Software, Cary, NC, USA) and a significance level of $P \leq 0.05$.

### RESULTS AND DISCUSSION

Trunk stiffness (Fig. 3) was not different ($p=0.702$) between healthy and LBP participants 1-2 days after exercise, when LBP individuals were experiencing pain. However, trunk stiffness was different ($p=0.040$) between healthy (7347±1561 kg/s²) and LBP participants (8728±801 kg/s²) 4-5 days after exercise, when pain had subsided in the LBP individuals. This is consistent with the significant decrease ($p=0.002$) in trunk stiffness in the healthy participants from the first measurement 1-2 days after exercise (9111±1472 kg/s²). Results suggest rested, healthy individuals exhibit lower trunk stiffness than rested individuals who experience exercise-induced LBP. However, trunk stiffness increases for a few days after exercise in healthy individuals only, not in those with exercise-induced LBP. Therefore, increased stiffness in a rested, pain-free state could indicate a characteristic inherent to the LBP individual.

![Intrinsic stiffness](image)

**Figure 3: Intrinsic stiffness. An asterisk represents a group difference within session, and a line represents a session difference within group.**

### REFERENCES


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