INTRODUCTION

Lower extremity injuries and low back pain pervade everyday life. Along with injuries come the unavoidable physical, emotional, and economic costs, along with lost time and normal function [1]. Ankle sprains, anterior cruciate ligament (ACL) injuries, and hamstring muscle strains are the most common sports injuries [2]. Low back pain (LBP) can significantly influence an individual's quality of life and will affect between 60-80% of the population [3]. Additionally, LBP can alter functional ability and increase the risk of lower extremity injury [4]. A volitional preemptive abdominal contraction (VPAC) is commonly used to improve lumbar spine stabilization and reduce pelvic motion in individuals with spine dysfunction. The VPAC influences lower extremity motion control and potentially reduces the risk of injury [5]. Fatigue serves as a major risk for injury that alters muscle shock absorbing capacity and coordination of the locomotor system [6]. The effects of spine stabilization on people with recurrent low back pain are well documented [4]. The purpose of this study was to test the hypothesis that volitional spine stabilization strategies would modulate the effects of lower extremity fatigue on lower extremity and trunk mechanics, as well as neuromuscular control during landing in people with and without recurrent low back pain.

METHODS

Thirty-three healthy and 32 young adults with LBP participated. Three-dimensional kinematics (VICON Nexus) were collected from the lower extremity and lumbar spine at a sampling rate of 100 Hz. Ground reaction force (GRF) and electromyographic (EMG) data from the right side internal oblique (IO), external oblique (EO), and multifidus (Mf) at the first lumbar (L5) spinal level, as well as the right side gluteus maximus (GM), semitendinosus (ST), vastus medialis (VM) and rectus femoris (RF) were sampled at 2000 Hz. Subjects performed twelve DVJ trials: six with and without VPAC and six with and without VPAC in a fatigued state. Fatigue was induced using a submaximal squat protocol. A 2x2x2 mixed ANOVA was used to determine differences between groups and the VPAC and fatigue conditions for each dependent variable. Follow-up tests were conducted as necessary, with alpha correction at each step. Statistical analyses were conducted using SPSS.

RESULTS AND DISCUSSION

Semitendinosus onset exhibited a significant three-way interaction effect between subject groups, and the VPAC and fatigue conditions (p=0.001). No other variables exhibited a significant three-way interaction effect. Follow-up analyses were conducted to examine the significant three-way interaction effect for the ST onset variable and consisted of calculating six 2x2 ANOVAs with all combinations of group, VPAC and fatigue conditions. Semitendinosus onset exhibited significant two-way interaction effects for three of the six 2x2 follow-up ANOVAs. Semitendinosus onset exhibited a significant two-way interaction effect between the VPAC and fatigue conditions in the healthy group (p=0.004, Table 1). Furthermore, semitendinosus onset exhibited a significant two-way interaction effect between group and VPAC condition during fatigue (p=0.018). In addition, semitendinosus onset exhibited a significant two-way interaction effect between group and fatigue condition during VPAC (p=0.004, Table 1).

Semitendinosus onset exhibited several significant simple main effects. Semitendinosus onset was significantly different between the VPAC
conditions without (p=0.001) and with (p=0.001) fatigue in the healthy group. Semitendinosus onset occurred before contact with VPAC but after contact without VPAC in both fatigue conditions. Additionally, semitendinosus onset was significantly different between VPAC conditions in both the healthy (p=0.001) and LBP (p=0.001) groups with fatigue. Semitendinosus onset occurred before contact with VPAC but after contact without VPAC. Moreover, semitendinosus onset was significantly different between the fatigue conditions in the healthy (p=0.001) and LBP (p=0.001, Table 1) groups in the VPAC condition. Semitendinosus onset occurred before contact but earlier in both groups without fatigue compared to with fatigue. Several significant main effects were exhibited such as earlier onset with VPAC and later onset with fatigue in the LBP group; earlier onset with VACP and later onset in the LBP group without fatigue; and later onset with fatigue and in the LBP group without VPAC.

Maximum pelvic obliquity angle exhibited a significant two-way interaction effect between VPAC and fatigue conditions (p=0.045). No other significant two-way interactions were observed for this variable. Additionally, VPAC and fatigue decreased GRF and lumbar spine motion during landing, as indicated by several significant main effects (p = 0.001 to 0.002).

Based on our results, the VPAC appears to create a protective advantage for the knee and lumbar spine as suggested by the earlier ST activation in the VPAC conditions during the 0.30 m drop vertical jump landing, which could potentially translate into injury prevention if a perturbation is encountered during the landing task. In addition, these changes suggest that the neuromuscular system may be better prepared prior to initial ground contact for encountering the stresses imposed by the landing sequence. The VPAC can alter lower extremity neuromuscular control and improve pelvic and spine stabilization during a 0.30 m drop vertical jump in healthy individuals [5]. Moreover, our evidence suggests that lower extremity injury risk may increase when individuals are suffering from low back pain and while under the influence of fatigue, which is consistent with the literature [4,6].

**CONCLUSIONS**

Our results provide evidence that a VPAC strategy that is performed during a fatigued landing sequence decreases exposure to biomechanical factors that can contribute to lower extremity injury. This apparent protective response is present in both healthy and LBP individuals when landing from a 0.30 m height. Incorporating VPAC during dynamic stressful activities, with and without the presence of fatigue, appears to help improve sensorimotor control and facilitate positioning of the lower extremity, while protecting the lumbar spine. Clinicians can use this information when designing neuromuscular control training programs for people who have recurrent LBP to improve lower extremity control, spine stability, and potentially decrease injury risk.

**REFERENCES**


**Table 1. Semitendinosus Onset (seconds) for Healthy and LBP Groups in VPAC and Fatigue Conditions.**

<table>
<thead>
<tr>
<th>Group/Time</th>
<th>Healthy NFV -.072</th>
<th>Healthy NFV -.039</th>
<th>LBP NFV -.009</th>
<th>LBP NFV -.006</th>
<th>LBP NFV .022</th>
<th>LBP NFV .040</th>
<th>LBP NFV .034</th>
<th>LBP NFV .040</th>
<th>LBP NFV .050</th>
<th>LBP NFV .060</th>
<th>LBP NFV .080</th>
<th>LBP NFV .080</th>
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</thead>
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<tr>
<td>Time zero</td>
<td>0.080</td>
<td>0.070</td>
<td>0.060</td>
<td>0.050</td>
<td>0.040</td>
<td>0.030</td>
<td>0.020</td>
<td>0.010</td>
<td>0.000</td>
<td>0.010</td>
<td>0.020</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Time zero = Initial Contact. NFNV=No Fatigue and No VPAC, NFV=No Fatigue and VPAC, FNV= Fatigue and No VPAC, FV=Fatigue and VPAC