THE EFFECT OF EVERSION FATIGUE ON NEUROMUSCULAR CONTROL DURING CURB-WALKING IN INDIVIDUALS WITH AND WITHOUT ANKLE INSTABILITY

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INTRODUCTION

Ankle injuries result in a significant amount of time lost from work and sport activity. The ankle is the most commonly injured joint in the body and 85% of those ankle injuries are lateral ankle sprains.1 These injuries often result in residual disability with over 70% of those who suffered a lateral ankle injury reporting persistent symptoms 6 to 18 months post-injury, including pain, weakness, neuromuscular dysfunction, and most problematically, recurrent sprains; a condition termed ankle instability.23 Repetitiveankle sprains have been linked to osteoarthritis and articular degeneration.4

Some would suggest that fatigue plays a role in contributing to the occurrence of injury. Research on elite level soccer players has shown that injury risk is highest in the last 15 minutes of the contest, when fatigue has set in.5 Specifically, the peroneals are the primary dynamic lateral stabilizers of the ankle, so fatigue of those muscles specifically may affect the dynamic control of the ankle.

A more complete understanding of neuromuscular control of the ankle during activities of daily living in persons with ankle instability is vital to elucidating the pathoetiology of the condition. Further, evaluating persons with history of lateral ankle sprain without instability may help illuminate proper neuromuscular control following injury. Therefore, the purpose of this study was to investigate the effect of isokinetic ankle eversion fatigue on neuromuscular function at the ankle during curb-walking (stepping up and down from a curb) in persons with ankle instability (AI group), those with a history of injury without instability (WAI group), and uninjured controls (CTL group).

METHODS

Twenty-nine subjects gave informed consent and completed a physical screening form to assure that they were free from any cardiovascular, neuromuscular, and musculoskeletal conditions or injury that may affect movement patterns. See Table 1 for subject demographics. All subjects completed the Cumberland Ankle Instability Tool (CAIT) to assess the severity of AI. Subjects in the AI and WAI groups had a self-reported history of at least one lateral ankle sprain and a CAIT score ≤ 24 (AI) or ≥ 28 (WAI). Subjects in the CTL group were free from any history of lateral ankle sprain. The test leg was either the more affected leg (lower CAIT score) or determined via coin flip if CAIT scores were equal.

Table 1. Subject demographic data, mean (SD)

<table>
<thead>
<tr>
<th></th>
<th>CTL</th>
<th>WAI</th>
<th>AI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Subjects, No.</td>
<td>11</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Age, y</td>
<td>26 (5)</td>
<td>26 (3)</td>
<td>26 (4)</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.70 (.07)</td>
<td>1.73 (.09)</td>
<td>1.70 (.11)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>68.08 (10.97)</td>
<td>69.31 (12.74)</td>
<td>76.77 (20.42)</td>
</tr>
<tr>
<td>Test Leg Sprain Freq., No.</td>
<td>n/a</td>
<td>2.11 (1.62)</td>
<td>5.22 (3.15)</td>
</tr>
<tr>
<td>Ankle Pain During Sport, No.</td>
<td>1</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>CAIT Score</td>
<td>29 (1)</td>
<td>28 (2)</td>
<td>18 (5)</td>
</tr>
</tbody>
</table>

Abbreviations: Freq. - Frequency; n/a - not applicable.

Subjects had reflective markers placed on both legs and kinematic data were acquired at 120Hz using five infrared cameras (ProReflex, Qualisys, Inc., Gothenburg, Sweden). EMG electrodes were placed on the belly of the peroneus longus (PL) and tibialis anterior (TA) muscles of the test leg. EMG data were collected using an 8 channel system (Bagnoli-8, Delsys, Inc., Boston, MA, USA). A custom 8.5 m walkway was built with a 15 cm step to simulate a street curb, with 2 embedded force plates (Kistler, Inc., Winterthur, Switzerland) positioned to capture data during the curb-walking transitions. All analog data were sampled at 1200Hz.

Subjects were asked to walk barefoot on the ground level walkway, step up onto the elevated walkway with the test leg and keep walking until the end of the platform for the step-up tasks. Conversely, subjects stepped down from the elevated walkway to the ground level walkway with their test leg for the step-down tasks. Three trials of each, in randomized order, were collected. Trials were discarded and performed again if subjects did not contact the force plates cleanly, visually targeted the plates, or if speed exceeded +/- 5% of their pre-determined self-selected speed. Immediately following the fatigue protocol (within 5 minutes), all subjects were post-tested in the exact same manner as the baseline test.

The fatigue protocol was executed on an isokinetic dynamometer (System 3, Biodex, Inc., Shirley, NY, USA). Subjects performed three maximal concentric (CON) and eccentric (ECC) eversion muscle actions at 90°/sec to calculate the maximal ECC eversion force. Then, they performed a fatigue protocol, which consisted of continuous ECC-CON ankle eversion muscle actions at 90°/sec until fatigued. Subjects were considered fatigued when the ECC force output fell below 50% of the maximal ECC force for three consecutive ECC muscle actions.
All data were analyzed using Visual3D (C-motion, Inc. Germantown, MD) software. Since reflective markers on the foot were removed to properly position subjects for the fatigue protocol and replaced prior to post-testing, two separate models were created in the Visual3D software – one for the pre-test and another for the post-test. Kinematic data were low pass filtered and the value at touch-down (TD) was reported. Kinetic data were calculated using inverse dynamics analysis over the stance phase. For each muscle, the EMG signal was band-pass filtered, rectified, smoothed, and the signal was normalized to the maximal activation for each muscle during the dynamic trials. The preparatory activation of all muscles was calculated as the integral of the EMG signal (area under the curve) in the 200ms prior TD. The reactive activation was calculated in the 200ms following TD.

The independent variables were group and time (pre/post fatigue). The dependent variables were percentage of stride in double limb support during the transition (%DS), percentage in stance (%ST), TA and PL preparatory and reactive EMG area, ankle plantar flexion and inversion angle at TD, peak ankle sagittal plane moment, peak sagittal plane power, and ankle sagittal plane work. Two independent 3x2 MANOVAs were executed (1 each for step up and step down). Tukey HSD post hoc tests were performed when significant group main effects were found. The alpha level was set at .05, a-priori.

RESULTS AND DISCUSSION
Since many dependent variables were introduced into each MANOVA, no multivariate differences were noted, even though several significant univariate differences exist. These fatigue state and group differences in neuromuscular control are worthy of discussion, absent multivariate significance.

Stepping Up
%DS significantly decreased (p=.03) following fatigue during the step-up tasks, likely due to the unstable nature of the transition. This possibility is supported by the unchanged stride time, indicating that the only factor which changed involved speeding up the transition. During level ground gait, the double support phase is typically the most stable phase of gait and impaired individuals often increase their double support time to increase safety at the expense of speed and efficiency. However, during curb-walking, this phase is occurring with the feet on different levels and the muscles needing a stronger contraction to make the transition. Since some musculature was fatigued, it is possible that these individuals transitioned quicker to minimize the amount of time in an unstable position. %DS also significantly decreased in the step-down trials (p<.01), which support this hypothesis.

Contrary to our hypotheses, a significant increase in EMG was noted in the preparatory activity of the PL muscle after fatigue across all groups (p=.01). Concomitantly, preparatory activation of the TA also increased after fatigue, although not significantly. This is also likely due to the unstable nature of the transition. The likely neuromuscular response to PL fatigue was to increase activation, to accommodate for the decrease in force-production capacity of the muscle.

Stepping-Down
The WAI group demonstrated a distinctly different pattern of activation than the other two groups. They had significantly greater activation in both preparatory and reactive activity of the TA (p<.05), with similar, but non-significant, increases in preparatory and reactive activity of the PL. This indicates a co-contraction strategy during the unstable transition phase, which may represent a “coping” strategy employed by individuals who have sprained their ankles, but do not suffer from symptoms of instability. More specifically, they co-contract the muscles responsible for frontal plane movement/control of the ankle to stabilize that joint in potentially unstable situations. Similar differences were also noted in the step-up tasks, albeit not significantly different.

There was also a trend (p=.09) towards a more plantarflexed foot in the AI group, relative to the other two groups. Specifically, the AI group was approximately 4° more plantar flexed than the CTL group and 8° more plantar flexed than the WAI group. Plantar flexion is an important component of ankle stability, due to the shape of the talar dome. Specifically, it is narrower on the posterior end, making the ankle more open-packed during plantar flexion, thus more mobile and unstable. This decreased plantar flexion in the WAI group is likely related to the significantly higher activation of the TA, which is also a strong dorsiflexor as well. This provides additional support for the conclusion that the WAI may demonstrate a safer neuromuscular control strategy to manage dynamic ankle stability following a lateral ankle sprain.

The trade-off to this strategy would be a decreased ability to absorb force at the ankle, due to the decreased plantar flexion. This is supported by the trend (p=.07) toward a decreased amount of negative work done in the sagittal plane of the ankle noted in the WAI group. This suggests that the WAI group needs to absorb the force at other, more proximal joints like the knee, hip, and spine. For this reason, it has become evident that the role of the knee and hip in dynamic ankle joint stability cannot be understated and therefore must be evaluated in future research on individuals with ankle instability and those with a history of injury but no instability.

CONCLUSIONS
The effects of ankle eversion fatigue on gait patterns during curb-walking were minimal. However, distinct differences were noted in the WAI group, which suggest that they may have developed an altered neuromuscular strategy following injury to manage dynamic ankle joint stability. Future research on ankle instability should focus on this group, as well as include analyses of the contribution of more proximal joints (i.e., hip and knee) to ankle stability.

REFERENCES
2. Braun BL. Arch Fam Med.8:143-8, 1999.