INTRODUCTION

The incidence of knee injuries is greater in latter rather than earlier moments of athletic competition [1], leading to speculation that neuromuscular fatigue may contribute to knee injuries. Studies have concluded that fatigue induces mechanical changes during dynamic landing tasks, including decreased flexion angles and increased valgus moments and anterior shear forces at the knee [2,3].

Geiser et al [4] investigated the influence of gluteus medius fatigue on lower extremity (LE) mechanics and concluded that only small increases (<2°) in knee valgus occur during side-cutting or jumping post-fatigue. Given that gluteus medius fatigue may have little effect on LE mechanics, it is possible those mechanics may be influenced by impaired gluteus maximus (GMax) function instead. It is unclear whether that may be explained by impaired strength or impaired motor control of the muscle.

The purpose of this study was to examine whether experimentally-induced GMax fatigue alters LE kinematics or EMG recruitment during a jump-landing task in women.

METHODS

Forty healthy women (age, 25±3 years; BMI, 23±3 kg/m²) were randomly assigned to two groups. Subjects in the experimental group completed a modified Biering-Sorensen test to fatigue the GMax muscles, whereas subjects in the control group completed repeated push-ups to exhaustion.

Testing consisted of three repeated maximal vertical jumps. Kinematic data were measured at 100 Hz with a Vicon MX motion analysis system. Raw data were smoothed with a Woltring quintic spline filter at a mean square error of 20 mm. Nexus software was used to quantify LE kinematics in the sagittal, frontal and transverse planes of motion. EMG data were measured with a Bagnoli-16 system and DE-3.1 double-differential surface electrodes. The common mode rejection ratio was 92 dB at 60 Hz, input impedance exceeded 10¹⁵ Ω and data were collected through a 16-bit NI-DAQ PCI-6220 analog-to-digital acquisition card. Signals were sampled at 1000 Hz, bandpass filtered from 20 to 450 Hz with a Butterworth filter and processed with EMGworks® 3.7.2.0 data acquisition and analysis software. Data were processed with a root mean square algorithm and normalized to maximum voluntary isometric contractions (MVIC).

Muscle fatigue in the GMax during the Biering-Sorensen test was assessed by examining power density spectra of EMG signals. Spectral analysis was conducted with Hanning window processing and a fast Fourier transformation. Fatigue was represented by the slope of a regression through the median frequency time series. Effects of the intervention were also assessed by measuring pre- and post-fatigue isometric hip extension force production with a microFET2 dynamometer.

We analyzed pre- and post-fatigue ranges of motion at the hip and knee and peak EMG recruitment during the landing phase of the second vertical jump. Data were analyzed with 2-way mixed model ANOVAs (α = 0.05) and with post hoc Bonferroni-adjusted tests for multiple comparisons.

RESULTS AND DISCUSSION

Evidence of Fatigue. Subjects in the experimental group experienced a 0.06 Hz/s decrease in the median EMG frequency during the Biering-Sorensen test (Fig. 1; p = 0.020) and a 23% decrease in isometric hip extension strength (Fig. 2; p < 0.001). No change in median EMG frequency or
in isometric hip extension strength occurred in the control group.

![Graph](image.png)

**Fig. 1.** A participant’s EMG power spectrum during the modified Biering-Sorensen test.

![Graph](image.png)

**Fig. 2.** Pre- and post-fatigue isometric gluteus maximus strength (% body weight).

Kinematic Analysis. Hip and knee kinematics differed neither in the experimental group nor in the control group post-fatigue (p>0.05).

EMG Analysis. GMax EMG recruitment during the jump-landing task increased by 38% in the experimental group following the fatigue-inducing protocol and changed negligibly in the control group (Fig. 3; p = 0.005).

![Graph](image.png)

**Fig. 3.** Pre- and post-fatigue EMG recruitment during the landing phase of the jump-landing test.

Despite a 23% reduction in isometric hip extension strength, no change in jump-landing hip or knee kinematics occurred following an intervention that fatigued the GMax muscles. Participants increased their GMax EMG recruitment by 38%. These findings suggest that reduced GMax strength does not appear to cause LE pathomechanics (e.g., increased hip flexion, internal rotation and adduction accompanied by increased knee valgus) during a jump-landing task that may predispose a knee to injury. Rather, participants accommodated for the loss of GMax strength by recruiting more motor units to complete the task. The findings may indicate that in young, active women, GMax motor control (muscle recruitment) may influence LE mechanics during a jump-landing task to a greater extent than does GMax strength.

**CONCLUSIONS**

No changes in jump-landing hip or knee kinematics occurred following an intervention that weakened the GMax. The strength reduction in the GMax was compensated for by increased EMG recruitment. Reduced GMax strength may have little effect on hip and knee kinematics during a jump-landing task in women. Impaired motor control of the GMax, rather than impaired strength, may be responsible for pathomechanics that lead to increased knee valgus during a dynamic weightbearing activity.

**REFERENCES**