# GENDER DIFFERENCES IN ACTIVE KNEE JOINT STIFFNESS

Kevin P. Granata, PhD. and Sara E. Wilson, PhD
Motion Analysis and Motor Performance Laboratory
University of Virginia
E-Mail : KPG8n @ Virginia.edu

## INTRODUCTION

Active female suffer 2 to 8 times the number of musculoskeletal injuries as equivalently trained men for both knee injury and low-back pain[1,2]. Research suggests these injuries may be related to biomechanical instability. One of the primary contributing components to stability during functional tasks is the mechanical stiffness of active muscles[3]. Research demonstrated that active co-contraction increases total joint stiffness, less in women than men, suggesting gender differences active muscle stiffness[4]. Gender differences in joint stiffness from active muscle contraction may cause decreased stability in women and contribute to the greater risk of musculoskeletal injury. As part of a larger study of biomechanical stability we measured the active knee stiffness as a function of gender in a controlled (non weight bearing) experiment.

## METHODS

Sixteen male and fourteen female healthy volunteers between the ages of 21 and 39 participated following informed consent. Subject's thighs were securely fastened in to a isokinetic dynamometer with the lower leg free to move. Neutral ankle posture was maintained by means of a fixed ankle-foot orthosis (AFO). Subjects were required to support the lower leg and added weights of 0 kg, 6 kg and 20% max. at a knee flexion angle of $45^0$. A sudden transient perturbation, i.e. a quick tap thrusting the leg downward (Figure 1), was applied to the angle. The resulting knee flexion / extension motions were recorded by an accelerometer attached to the heel of the orthosis. Subjects were asked to maintain a orthosis. Subjects were asked to maintain a constant muscle activity by monitoring an electromyographic display measured from bipolar surface electrodes over the belly of the biceps femoris (hamstring activity) and rectus femoris (quadriceps activity).

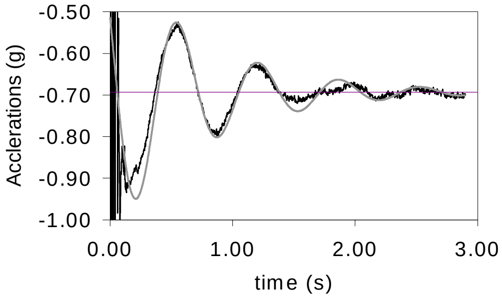

Figure1. Second-order damped harmonic model (gray) was fit to the acceleration data (black).

Flexion / extension oscillations of the knee were used to calculate stiffness. Fast Fourier transforms were performed to obtain the damped natural frequency, and peak-to-peak analyses recorded the exponential decay of the oscillation. These data were applied to a second order model of knee motion to determine active muscle stiffness and damping. Multiple regression and ANOVA were performed to assess the influence of gender, knee moment, and muscle (hamstring vs quadriceps) on active joint stiffness.

## RESULTS

The model accurately represented the measured motion data explained 69% of the data variability with RMS error less than 5.9 % of the baseline acceleration of gravity. There was no performance difference as a function of gender.

The female subjects produced less than 57% of the active stiffness demonstrated by the male subjects, ($K_{Female}$=109.3 Nm/rad, $K_{Male}$=153.1 Nm/rad) (Figure 2). As expected, stiffness increased with the knee moment. Multiple regression demonstrated much of the gender difference could be explained by moment (men supported heavier leg mass thereby applying greater total moment in the 0 kg and 6 kg conditions). However, even when accounting for total knee moment, strength and thigh length there continued to be a gender difference in active stiffness.

Active stiffness in the quadriceps was significantly greater than in the hamstrings ($K_{Quad}$=178.4 Nm/rad, $K_{Ham}$=113.6 Nm/rad). Due to the test protocol, the total knee moment during the quadriceps conditions was relatively lower than during the hamstrings tests. Despite lower knee moments the quadriceps continued to produce greater stiffness than the hamstrings. The ratio of quadriceps to hamstrings stiffness was not significantly different between genders.

It is known that antagonsitic co-contraction contributes to increased active joint stiffness[5]. Women were found to have significantly higher levels of agonist and antagonist activity suggesting these trials required a higher percentage of maximum strength. This is notable in that the females were performing at increased activation levels yet continued to demonstrate less biomechanical stiffness than the males. However, the ratio of antagonist to agonist activity was not significantly different between genders or between the hamstrings and quadriceps tests.

Reflex response also contributes to active joint stiffness. Although subjects were instructed to maintain a constant activation level throughout the transient motion, reflex responses were observable in the EMG data. Fourier analyses demonstrated that the frequency of the response was identical to the damped frequency of motion in both men and women. Further analyses concluded that no significant gender differences existed in the normalized amplitude of the reflex EMG at the damped frequency. Thus, reflex activation in response to the damped cyclic motion did not contribute to the gender difference in measured active stiffness.

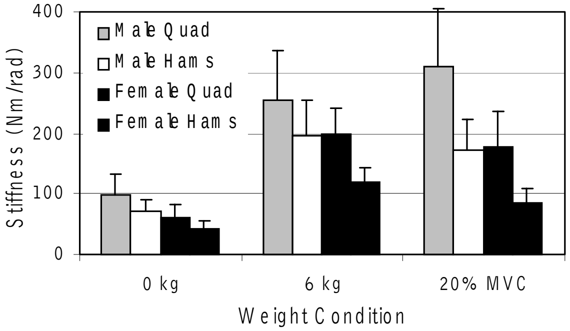

Figure 2. Active hamstring and quadricep stiffness was greater in males than females.

## SUMMARY

Biomechanical stability has been implicated as a factor in musculoskeletal injury and may contribute to gender bias in risk of injury. Factors that contribute to biomechanical stability include joint kinematics, load and stiffness. To initiate this investigation of gender factors in stability, we have begin by evaluating active stiffness, and concluded that females have reduced active stiffness compared to age matched males. Future analyses will require the investigation of factors that might contribute to this gender difference.

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