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PILOT STUDY: ELECTROMYOGRAPHIC QUADRICEPS/HAMSTRING RATIOS DURING DROP JUMPS

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This experiment examined the differences in the rectus femoris and biceps femoris EMG patterns during a drop jump performed on a 30° incline sledge. Thirteen volunteers (6 males and 7 females) participated in the study. A total of five jumps (two for familiarization and three for data collection) from a distance greater than 70 cm from the force plate were performed by all subjects. Subjects were instructed to hit the platform, (perpendicular to the sledge), watch a light go out upon landing (set for 90° of knee flexion), extend legs and jump forcefully. The EMG was gathered from the rectus femoris and biceps femoris to examine the ratio between the two muscles. The results indicated no significant ratio of quadriceps to hamstring activity between the two muscles when landing and takeoff phases were combined.

KEY WORDS: rectus femoris, biceps femoris, sledge.

INTRODUCTION: Muscles of the thigh have long been thought to be the major stabilizers of the knee in relation to shear forces; however, the theory has been called into question. Aune et al. (1995) showed that contraction of the quadriceps did not affect the anterior translation of the tibia at 30o of knee flexion and that hamstring contraction restricted the anterior shear forces of the tibia on the anterior cruciate ligament (ACL) from rupturing in rats. However, Hirokawa et al. (1992) stated the quadriceps contraction elicits significant displacement of the tibia in the range of 0° to 80° of knee flexion, peaking at 30° with displacement reaching 8 mm for 12 kg load. Then again, Howell (1990) found the quadriceps active posterior force at 15°, 60°, and 75° of flexion was significantly less than a manual maximum translation of 89 N (20 pounds) and that forces generated by the quadriceps stabilized the joint to externally anterior shear. Though it still seems the hamstrings are the dominant mechanism to protect the ACL (Aune et al. 1995) as the synergistic effect of the gastrocnemius-hamstring muscles absorbed 154% of energy during ACL failure. They found by contracting the gastrocnemius-hamstring muscles the failure load increased by 70%. Their test was conducted with rats at a loading rate of 2.5 mm/sec with knee kept flexed at 60° to mimic a strain rate greater than that seen in skiing injuries, according to Crowninshield and Pope in Aune et al. (1995).

Though the overall injury rate in alpine skiing has decreased, sprains to the ACL have increased (Johnson, et al., 1993 in Schaff et al. 1996). Indeed, Johnson and Pope (1991) reported a 172% increase in the days between Grade III knee sprains. Others noted only a significant decrease in Grade I medial collateral ligament injuries (Johnson and Ettlinger 1982). Further investigation via epidemiology and/or into the mechanism of ACL injury and prevention is warranted for not only skiers, but anyone experiencing anterior tibial translation forces.

The purpose of this investigation was to detect a possible lack of tension in the posterior protection force generated hamstring during drop jumps performed on a 30° incline sledge. It was hypothesized that there is a decrease in tension of the hamstring (as indicated by decreased electromyography (EMG) in the hamstring and/or increased EMG of the quadriceps) for short time periods, providing a "window of opportunity" for shear forces to rupture the ACL.

METHODS: This study compared the rectified EMG quadriceps/hamstring ratio during a drop jump. The recruitment patterns of the dominant leg (defined as the subject's preferred planting leg when performing a kick) were monitored during a drop jump on a 30° inclined sledge described by Harrison et al. (2001).

Six males (average height, age, and mass of 186.7 cm ± 7.3, 21.2 yrs ± 0.8, and 82.9 kg ± 5.9) and 7 female (average height, age, and mass of 164.9 cm ± 10.1, 21.4 yrs ± 1.9, and 63.9 kg ±13.9), were recruited from the campus of Northern Michigan University. A Physical Activity Readiness - Questionnaire was used to screen subjects. Based on that screening, individuals with recent, reoccurring, chronic knee and/or ankle injuries, and diseases that might impair cardiac and/or muscle function were excluded. Prior to participation, a written consent was obtained from each subject.

The subjects were placed into the chair of the sledge with feet on the force plate to zero it (weight of the sledge chair and subject were zeroed to minimized GRF variability between subjects). They then were measured at 90° of knee flexion for reference during the drop (a light was set to indicate when subject's knees attained 90°). Subjects were instructed to land on the platform (perpendicular to the sledge), watch a light go out upon landing (landing phase), extend their legs and jump forcefully (take off phase). Subjects were allowed two practice jumps to become accustomed to the drop of 70+ cm (depending on leg length). For the first familiarization trial, the subject was to jump when the feet hit the force plate; while for the second practice jump, they were to watch the signal light and jump when it went out. Followed by the familiarization, three drops from a height of 70+ cm were performed, during which data for EMG and GRF were recorded.

Universal preparation methods were followed for EMG, i.e. shaving, cleansing with alcohol, and rubbing the electrode sites with a rough pad to reduce signal resistance to <5000O. Surface electrodes were placed on the rectus femoris and biceps femoris muscle sites as described by Ebben & Jensen (2002).

The EMG data were recorded at 2000 Hz via surface electrodes connected to a semi-portable amplifier (TEL 100) and then to an analog/digital converter, (Biopac Systems, Inc. Goleta, CA, USA) which stored them using a Windows format computer. A force plate (OR6-7-2000, AMTI, Watertown, MA, USA) was mounted 60 degrees to the floor to monitor the GRF perpendicular to the sledge drop. The GRF were recorded at 2000 Hz using Biosoft 1.0 software (AMTI Watertown, MA, USA). All EMG data were filtered with a 10-500 Hz Band pass filter and saved using AcqKnowledge 3.2 software (Biopac Systems, Inc. Goleta, CA, USA). Comparisons were then made of the rectified EMG ratios of quadriceps/hamstring activity during the landing and take off phases.

To align the EMG and GRF data chronologically, both computers were synchronized to a single signal. Data were collected for analysis from the moment the feet touched the force plate until the feet left the force plate. In addition, data were examined separately from when the knees attained 90° of flexion (indicated to the subject by the signal light) until the feet left the force plate. Both sets of data were examined statistically. A cubic spline data interpolation program was written (using Matlab 6.5) to time normalize the data files.

A one way Repeated Measures ANOVA (SPSS v11.5) was performed to examine the ratio (quadriceps/hamstrings) of muscle stimuli across the drop jump. Muscle activity during the whole range of motion was compared. In addition, because it was thought that the biggest change would be after the subject achieved 90° knee flexion, the time from the 90° flexion light signal to the moment the feet left the plate was also observed. Alpha was set at 0.05 and pair-wise comparisons using a Bonferroni adjustment were performed when significance was detected.

RESULTS: The duration of data ranged from 0.95 to 0.63 seconds for the entire range of motion (duration of landing to take off) and was compacted to 40 samples. The ANOVA indicated no significant differences ($p>0.05$) for the muscle activity ratio (quad/hamstring).

The data from the 90° signal light to the point of leaving the force plate was analyzed for 11 of the subjects. Time ranged from 0.15 seconds to 0.75 seconds and was compacted several different ways. First, all 11 subject's data were compacted into 40 samples and an ANOVA was run. This test found significance ($p<0.05$) for the ratio data which ranged from .07 to 33.03. Of these 11, seven of the subjects took longer than 0.5 seconds and their data was compacted into 30 samples; an ANOVA showed no significance for ratio ($p>0.10$). Eight of these 11 subjects took less than 0.63 seconds. The data was compacted to 25 samples and did not show significance when an ANOVA was ran for the ratio ($p>0.10$).

DISCUSSION: Closer examination of the data samples revealed the difference in the recruitment of the quadriceps and hamstring (see Figure 1). The "window of opportunity" for the anterior shear force is heightened when the hamstring tension is low.

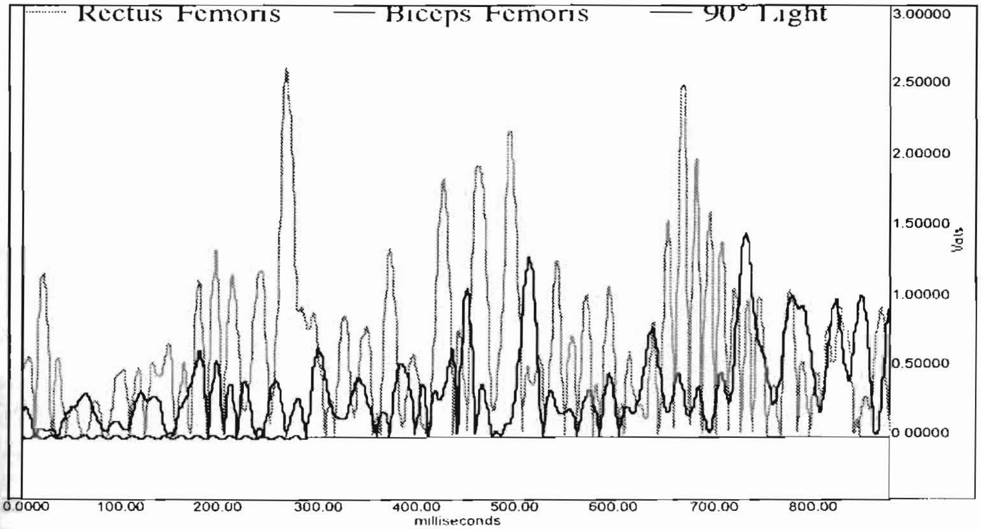

Figure 1: Subject 4 trial 1 EMG data from feet contact of force plate to moment feet leave force plate.

Jump time varied greatly between subjects (0.63-0.95 seconds). The use of a cubic spline interpolation technique allowed all files to be matched to the same length. However, because the landing and takeoff phase times varied (See fig. 2), as did the depth of flexion, the angles of knee flexion could not be matched between subjects. To better address this issue, a video camera should be used to monitor joint angle and then the EMG could be placed in order of joint angle, not time.

The compacting of samples may have caused error, giving too few samples to analyze. It was found in the first ANOVA (performed for the take off phase and including all eleven subjects after 90° knee flexion), there was a significant difference over time for the ratio. However, there were no differences evident in the pairwise comparisons (-.86 to .86 mean difference with large deviations). The large deviations suggest the subjects did not have the same recruitment patterns during each of the 40 samples which likely resulted in the lack of significance.

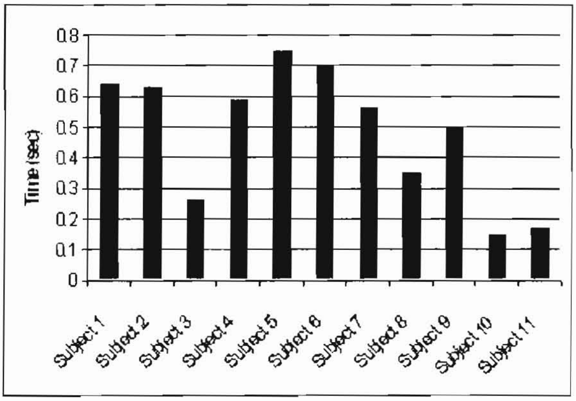

Figure 2: The duration of muscle activity for each subject in the take off phase (after 90 degrees).

Another possibility might be that by using a smaller number of points, within the interpolated samples, a shorter duration of the changes in the ratio may be evident.

The high degree of variability between subjects, jump time, and data minimized the chances of statistically showing when during the jump a change in the ratio of quadriceps to hamstrings muscle activity took place; however, the presence of the main effect indicates that a difference did occur. This suggests that replication of the current study with the inclusion of high speed video analysis may be warranted.

CONCLUSION: The ratios of quadriceps/hamstring activity after 90° flexion was found to vary, but individual sample variability made definite location difficult. This was possibly due to the large degree interpolation, making the number of samples too small. Furthermore, a replication of the study, with video analysis, may allow comparison of the EMG at specific joint angles during the time it takes to go through full drop jump. Doing such may prove that the differences in quadriceps to hamstring recruitment are significant, opening the "window of opportunity" for anterior tibial translation.

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