EVIDENCE THAT QUADRICEPS MUSCLE CONTROL IS A KEY FACTOR IN COPING WITH ANTERIOR CRUCIATE LIGAMENT DEFICIENCY

Glenn N. Williams, Peter J. Barrance, Lynn Snyder-Mackler, Thomas S. Buchanan

Center for Biomedical Engineering Research, University of Delaware, Newark, DE. USA
E-mail: glennwms@udel.edu

INTRODUCTION

It is estimated that 250,000 anterior cruciate ligament (ACL) injuries occur in the United States each year (Boden, 2000). Most people cannot return to sports after an ACL injury without surgical intervention (Non-copers), but some people can (Copers). Coping with an ACL injury does not appear to be dependant on knee laxity or quadriceps strength; however, recent research suggests that the ability to cope with ACL injury is related to neuromuscular function (Rudolph, 2000). The purpose of this study was to evaluate the neuromuscular control strategies of ACL deficient (ACL-D) Non-copers, ACL-D Copers, and people with uninjured knees by assessing their specificity of muscle action using an established target-matching protocol (Buchanan and Lloyd, 1997) and circular statistics methods.

METHODS

Thirty-two subjects (12 ACL-D Non-copers, 8 ACL-D Copers, and 12 people with uninjured knees) volunteered to participate in this study. All subjects were regular participants in activities that required quick changes of directions and/or jumping. Subjects were seated on a small platform so that their thighs were unloaded. A fiberglass cylinder cast was applied to the distal shank and then rigidly clamped to a 6-axis load cell. The experimental task required subjects to position a circular cursor over a narrow target for one second. The cursor moved in response to isometric loads that the subjects produced against the load cell. Targets appeared in random order at one of 18 positions (located at every 20° of a circle in the flexion-extension-varus-valgus plane). Seventy-two trials (4 trials at each target) were performed bilaterally at each of three knee flexion angles: 50°, 70°, and 90°.

Electromyographic (EMG) signals were collected from the semitendinosus (ST), biceps femoris (BF), sartorius (SAR)*, rectus femoris (RF), tensor fascia lata (TFL)*, gracilis (GRA)*, vastus medialis (VM), vastus lateralis (VL), and the medial (MG) and lateral gastrocnemius (LG) muscles using surface or indwelling (*) electrodes. The EMG data were rectified, averaged, and normalized using maximum values collected earlier in the session.

Specificity of muscle action was analyzed by calculating a specificity index for each muscle using the formula:

$$\text{Specificity Index} = \frac{|R_{EMG}|}{\sum_{i=1}^{18} |EMG_i|},$$

where $EMG_i$ is a vector describing the EMG magnitude in each target direction and $R_{EMG}$ is the resultant vector determined by summing the EMG vectors in the 18 target directions. A multivariate ANOVA with each muscle as a dependent variable was used to test for significant differences in specificity of muscle action. Post hoc
Bonferroni multiple comparison tests were used to further define main effects.

RESULTS AND DISCUSSION

The muscles of the Non-coper’s and Coper’s involved knees always had specificity indices that were less than those of the uninjured subjects. The specificity indices for the RF, TFL, VL, and LG of the Non-coper’s involved knees were significantly different ($p<.05$) from the respective values of the Uninjured subjects; the VM had a noteworthy trend toward significance (Figure 1). The only muscles with significant differences in the Copers were the VL and the LG.

![Figure 1](image1.png)

**Figure 1:** Mean specificity indices by group.

Although no statistically significant differences were observed between the Non-copers and Copers involved knees, the Copers exhibited greater neuromuscular control in their quadriceps muscles (Figures 1 & 2). The specificity indices for the RF, VM, and VL of the Coper’s involved knees were 5%, 3%, and 21% higher than the respective values for Non-coper’s muscles.

SUMMARY

The findings of this study indicate that ACL-D leads to reduced specificity of muscle action, especially in the quadriceps muscles and LG. Our findings also suggest that one of the key factors in the ability to cope with an ACL injury may be quadriceps muscle control. Poor quadriceps control may promote the giving-way episodes often observed in Non-copers (the primary factor leading to surgery), whereas good control may produce dynamic knee stability.

![Figure 2](image2.png)

**Figure 2:** Mean vastus lateralis activity patterns. Note that the Copers involved limb activity patterns (yellow) are more similar to those of the uninjured/uninvolved limbs than the Non-copers involved limbs (red).

REFERENCES


ACKNOWLEDGEMENTS

NIH Grant RO1-AR46386 and the Foundation for Physical Therapy.