QUADRICEPS STRENGTH AND NEUROMUSCULAR STRATEGIES CONTINUE TO IMPROVE TWO YEARS AFTER ACL RECONSTRUCTION

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INTRODUCTION

After anterior cruciate ligament (ACL) rupture, some individuals demonstrate the ability to dynamically stabilize their injured knee (potential copers). The majority of ACL deficient individuals, however, are classified as non-copers; they have knee instability with daily activities, exhibit quadriceps weakness, and have altered movement patterns. Prior to surgery, non-copers have been shown to make initial contact with less knee flexion on their involved side, achieve less peak knee flexion, and exhibit reduced knee power absorption during weight acceptance [1]. These non-copers customarily undergo ACL reconstructive surgery (ACLR) to repair the damaged ligament.

Quadriceps weakness is ubiquitous following surgery. Restoring quadriceps strength post-ACLR has been shown to increase knee angles and moments at peak knee flexion (PKF) during gait [2]. However, no one has evaluated the performance of this non-coper cohort two years post-ACLR. Loss of quadriceps strength and limb symmetry could result in long-term changes in movement patterns. Additionally, aberrant joint motion has been proposed as a mechanism for articular degeneration [3]. Therefore, it is imperative to understand how this non-coper cohort behaves after leaving a formal post-ACLR training protocol. The goal of this study was to determine whether altered neuromuscular control strategies, evident acutely after injury, resolved over time.

METHODS

Fifteen athletes who underwent ACL reconstructive surgery were recruited for this study (Table 1). Subjects were included in the study if they were 13-55 years old with no concomitant ligament injury in the ipsilateral limb, had no articular cartilage damage, and had >1 giveaway episodes prior to surgery. Each subject was tested for maximal volitional quadriceps strength normalized to BMI before surgery and at 6 and 24 months post-ACLR. They also participated in a motion analysis session during each of the three testing sessions in which they walked overground across an embedded force plate. Kinematic and kinetic data reduction was performed with custom software programming. We analyzed quadriceps strength, and knee/hip angles, moments, and powers during the weight acceptance phase of gait (first 25% of stance). Paired t-tests were used to compare outcome variables between limbs and over time (p<.05).

RESULTS AND DISCUSSION

Prior to surgery, quadriceps strength was greater in the uninvolved limb compared to the involved limb (Table 2). These strength asymmetries resolved over time as quadriceps strength in the involved limb improved at 24 months. Quadriceps strength in the uninvolved limb did not significantly change over time. While PKF angles were symmetrical prior to surgery, asymmetries emerged at 6 months because the PKF angle of the uninvolved limb increased. These asymmetries resolved at 24 months as the PKF angle of the involved limb significantly increased. Differences in knee extensor moment at PKF between limbs were detected prior to surgery and at 6 months. These asymmetries also resolved at 24 months as the moment at PKF in the...
involved limb significantly improved. At 24 months, no differences in quadriceps strength or knee angles and moments at PKF were detected between limbs.

Prior to surgery, the uninvolved hip appeared to compensate for the involved knee by absorbing power early in stance (Figure 1). This behavior persisted at 6 months, but eventually resolved at 24 months. At 24 months, hip power in both limbs was positive early in stance, suggesting improved gait behaviors between limbs.

Knee power was also positive early in stance, but it appeared to diminish at 24 months. The involved and uninvolved knees appeared to absorb power more symmetrically over time; they also began to absorb power earlier in stance. Peak negative knee power also improved over time and appeared more symmetrical at 24 months.

CONCLUSIONS

Long term outcomes of the non-coper cohort have not been previously described. Our results suggest that non-copers have the capacity to improve their quadriceps strength and weight acceptance strategies long after ACLR. Six months post-ACLR is a common time for surgeons to clear their patients to return to sport. While quadriceps strength became symmetrical at 6 months, differences in kinematics and kinetics were still present. This suggests that six months of intensive physical therapy might not be long enough to resolve all strength and movement asymmetries prior to returning to sport for some non-copers. Although limb differences were evident 6 months after surgery, recovery of symmetrical movement patterns 2 years after ACLR was noted. Our results suggest that non-copers have the capacity to improve their quadriceps strength and neuromuscular strategies long after ACLR.

REFERENCES


ACKNOWLEDGEMENTS

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Table 2: Quadriceps strength, PKF, and moment at PKF were compared between limbs and across time. Mean ± SD are shown with significant differences between time points (*) and between limbs (shaded) (p < 0.05).

<table>
<thead>
<tr>
<th></th>
<th>Quad Strength (N/kg/m²)</th>
<th>Peak Knee Flexion (deg)</th>
<th>Moment at PKF (Nm/kg*m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Involved</td>
<td>Uninvolved</td>
<td>Involved</td>
</tr>
<tr>
<td>Pre</td>
<td>34.9 +/- 12.4</td>
<td>42.5 +/- 13.0</td>
<td>24.3 +/- 5.7</td>
</tr>
<tr>
<td>6 mo</td>
<td>40.5 +/- 13.0</td>
<td>42.6 +/- 10.3</td>
<td>24.9 +/- 7.0</td>
</tr>
<tr>
<td>24 mo</td>
<td>45.9 +/- 14.7*</td>
<td>45.3 +/- 9.6</td>
<td>27.5 +/- 6.4*</td>
</tr>
</tbody>
</table>

Figure 1: Knee and hip power of the involved and uninvolved limbs at three time points: pre surgery, 6 months post-ACLR, and 24 months post-ACLR. Data is presented from heel strike to 25% of stance. Positive values = power generation. Negative values = power absorption.