ABSTRACT

Introduction:

ACL injuries are common, and are usually surgically reconstructed to allow individuals to return to their prior levels of activity. However, there is a differential response to ACL injury. Some ACL deficient individuals are able to adapt to perform dynamic tasks, such as running and cutting, without reconstruction while others experience their knee giving-way repeatedly during activities of daily living. A screening algorithm has been developed and validated to predict those individuals that have the potential to cope with ACL injury, and separate them from non-copers (Fitzgerald, 2000). Non-copers are characterized by repeated giving-way events, quadriceps atrophy, and reduced neuromuscular control. Potential copers use coordinated muscle contractions to stabilize the knee during walking and jogging. However, the difference between potential copers and non-copers is not always clear. Subjects initially classified as non-copers were recently demonstrated to have a 70% chance for success without surgical management, after extensive rehabilitation, when randomly assigned to a non-operative group. There is a need to improve our ability to accurately differentiate those that require surgery from individuals that are capable of returning to their prior level of function without ACL reconstruction. Therefore, the purpose of this study was to evaluate the muscle morphology and neuromuscular control of those screened to be potential copers and non-copers to improve our understanding on what distinguished the two groups. We hypothesized that non-copers would demonstrate quadriceps atrophy and less specific neuromuscular control while potential copers would not, and that neither group would demonstrate hamstring atrophy.

Methods:

Twenty ACL deficient athletes were recruited and screened within 6 months of ACL injury, and prior to surgery. All subjects signed written informed consent forms approved by the University of Delaware Human Subjects Review Board. All were regular participants (>50 hrs./yr.) in sports requiring cutting, pivoting, and jumping at the time of injury.

Axial spin-echo T1-weighted images were acquired with a 1.5T GE Signa LX scanner from the base of the calcaneus to the iliac crest as subjects lay supine. Images were acquired in 4 sequences including the lower-leg, knee, thigh, and pelvis. Repetition time was 350 ms, echo time was 9 ms, slice thickness was 11.5 mm (6 mm over the knee for more detailed tendon data), interslice gap was 1.5 mm (1.0 mm over the knee), matrix was 256x160 pixels, and field of view varied with subjects’ pelvis size.

Image processing required three steps. First, the muscle contours were manually traced in each slice they appeared using IMOD (U. of Colorado) and a digital palette. Muscle and tendon were traced as separate objects to differentiate tissue effects. Second, the contours of each muscle from the 4 sequences were grouped. Third, 3D reconstructions were generated in a custom written Matlab program (The MathWorks Inc., Natick, Massachusetts). Muscle volume (cm$^3$) and peak cross-sectional area (cm$^2$) were calculated. The 10 muscles traced were the semimembranosus, semitendinosus, biceps femoris – long head, biceps femoris – short head, rectus femoris, vastus medialis, vastus lateralis, vastus intermedius, and medial and lateral gastrocnemius. In addition, the volume and peak cross-sectional area were calculated for a knee extensors group and a knee flexors group by summing the values for each of the individual muscles. All digitization was performed by a single rater that was blinded to the groups.

Voluntary neuromuscular control was evaluated using an established seated target-matching protocol (Williams 2005). Electromyographic data were collected while individuals produced static isometric force contractions with their knee in a varus-valgus and flexion-extension plane, while flexed to 70°. Circular statistics were used to evaluate muscle activity using a specificity index that has been previously described, where the reduced neuromuscular control corresponds to smaller muscle specificity values.

In order to compare results between groups, muscle morphology data were converted in to a limb symmetry index. Demographic data were compared and compared between groups using t-tests. Muscle morphology Comparisons and specificity indices, for side-to-side differences and between groups were made using t-tests. The level of significance ($\alpha$) was set at 0.10.

Results:

Ten non-copers and 10 potential copers (both groups had 8 males and 2 females) were collected. Potential copers were younger ($p = 0.032$), had fewer giving-way episodes of the knee ($p = 0.035$), and a higher knee outcome survey of daily living score ($p = 0.0003$) when compared to non-copers. There were no significant differences for the other demographic variables.

The quadriceps muscles of both the non-copers and potential copers demonstrated significant atrophy when compared to their uninjured side. There were no significant neuromuscular control differences found between limbs for the potential copers, or between the injured limbs of the potential copers and the non-copers.

Non-copers used less specific muscle contractions for their rectus femoris ($p = 0.057$) and lateral hamstrings ($p = 0.064$) muscles when compared to their uninjured limbs (Fig. 1). There were no significant neuromuscular control differences found between limbs for the potential copers, or between the injured limbs of the potential copers and the non-copers.

Discussion:

Opposite to our hypothesis, both groups demonstrated quadriceps atrophy. However, only the non-copers used significantly less specific voluntary neuromuscular control of the rectus femoris and lateral hamstring muscles in comparison to their uninjured limbs. Neither group had hamstring atrophy. These findings indicate that the neuromuscular function of the muscles about the knee is critical for potential copers, more so than quadriceps muscle size alone. Findings may explain how potential copers are able maintain dynamic stability while the non-copers have reduced function.

Neuromuscular control is treatable; therefore these findings may also explain how non-copers are capable of returning to their prior level of function following extensive rehabilitation.

Significance:

Findings indicate that ACL injury results in reduced neuromuscular control for non-copers, and this is clinically meaningful because this may be improved with treatment.

Acknowledgements:

NIH Grant R01 AR46386

References:

Fitzgerald, GK, KSSTA, 8(2), 76-82, 2000.