STRENGTH TRAINING OF THE QUADRICEPS MUSCLES FOLLOWING ACL TRANSECTION: EFFECTS ON STRENTH AND JOINT INTEGRITY

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INTRODUCTION

The quadriceps muscles have a complex role following injury to the anterior cruciate ligament (ACL) and in the development of osteoarthritis (OA). High correlations have been found between quadriceps strength and joint function in ACL deficient subjects (Keays et al., 2003). Similarly, quadriceps strength training has been shown to promote function in subjects with knee OA (Huang et al., 2003). However, there are two major complicating factors. First, quadriceps weakness in ACL deficient subjects often persists despite rehabilitation (Arrangio et al., 1997). Second, intense exercise has been shown to accelerate the development of OA in the knee (Appleton et al., 2007).

In this study, we asked two main questions: (i) could an aggressive strength training protocol eliminate quadriceps weakness in ACL deficient subjects? And (ii) what effect would this training protocol have on the articular cartilage of the knee?

METHODS AND PROCEDURES

New Zealand White rabbits underwent unilateral ACL transection and were divided into two groups: trained (n = 12) and untrained (n = 4). For one month, the untrained animals were allowed to recover while the trained animals underwent one of two strength training protocols 3 days a week. Both protocols used electrical stimulation of the quadriceps of anaesthetized rabbits. Each session in the first protocol, maximal training (n = 6), included 5 sets of 10 maximal contractions. Contractions were 0.5 seconds with 0.5 seconds between contractions in a set and 2 minutes between sets. Each session in the second protocol, 20% training (n = 6), consisted of a single maximal contraction followed by a 15 minute set of contractions at 20% of the force produced in the maximal contraction. Voltage and frequency were monitored and altered continuously to maintain the force at 20% of maximal throughout the testing period. Contractions in this protocol were 0.5 seconds with 1.5 seconds between contractions.

One month after ACL transection surgery, the quadriceps strength of both hind limbs was measured using electrical stimulation of the femoral nerve. Rabbits were then sacrificed, the quadriceps muscles were weighed and the knees were prepared for histological analysis.

For histological analysis of the cartilage, knees were separated into six areas: the medial and lateral tibia, the medial and lateral femoral condyles, the femoral groove and the patella. Each area was evaluated separately using the Mankin scoring system (Mankin et al., 1971).

RESULTS

Rabbits in the maximal training group showed increased force production over the course of the exercise sessions. Nonetheless, in the terminal experiment they showed persistent weakness and atrophy on the ACL deficient side compared to the contralateral side

(Figure 1). Further, there were no significant differences between strengths or percent weakness and atrophy between maximally trained and untrained rabbits (Figure 2). Maximal training group rabbits did, however, have a greater body weight normalized quadriceps mass.

In contrast to the maximal training group, 20% training group rabbits showed a balance in quadriceps strength between experimental and contralateral hind limbs following the four week training protocol (Figure 1).

For untrained and maximally trained rabbits, cartilage condition was significantly worse in specific areas of ACL deficient relative to contralateral knees. Also, in the areas with the worst signs of OA, OA was significantly worse in maximally trained compared to untrained rabbits. Histological analysis of the 20% trained group is ongoing; however, based on initial inspection, the ACL deficient knees had more signs of OA than contralateral knees.

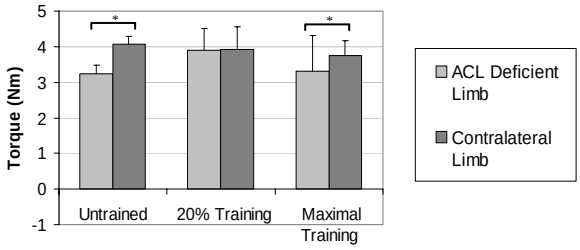

Figure 1: Torques produced in terminal experiments.

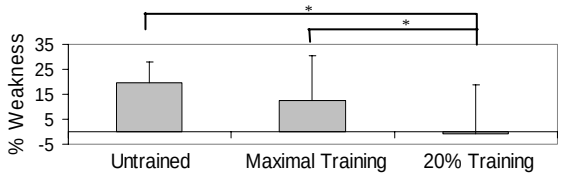

Figure 2: Percent weakness of the animals.

DISCUSSION

Despite an apparent improvement during the training sessions, the maximal training protocol was unable to eliminate side-to-side differences in strength in ACL deficient rabbits (Figure 1). A contralateral training effect likely contributed to this result, as the trained rabbits tended to have a greater quadriceps mass relative to their body weight than the untrained rabbits. The 20 % training protocol, however, did successfully eliminate side-to-side differences.

Further, both training protocols appeared to have a detrimental effect on the cartilage of the knee beyond that of ACL transection alone.

SUMMARY

In unilaterally ACL deficient rabbits, a strength training protocol involving sets of maximal contractions was unable to eliminate side-to-side differences in strength, whereas a protocol involving longer periods of repeated sub-maximal contractions was successful in eliminating these side-to-side differences. Both types of exercise had a detrimental effect on cartilage integrity. Therefore, we conclude that although some strength training might be beneficial for avoiding quadriceps atrophy and loss of strength, the protocols used here resulted in an increased rate of OA development.

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