Muscle and Tendon Morphology after Reconstruction of the Anterior Cruciate Ligament: the Effect of Graft Harvest

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ABSTRACT INTRODUCTION:
Anterior cruciate ligament (ACL) reconstruction is commonly performed with a cadaveric allograft (ALLO) or a hamstring semitendinosus-gracilis (STG) autograft. Knee flexor strength deficits following STG reconstruction are a growing concern. A reduction in semitendinosus and gracilis muscle volume and peak cross sectional area (CSA) has been demonstrated following STG reconstruction (Williams, 2004). Postoperative STG muscle and tendon length regeneration was found to be predictive of the respective muscle volumes. Since strength is directly related to muscle volume and cross sectional area, these findings may explain the knee flexor strength deficits found clinically. However, we do not know what morphological changes are attributable to ACL reconstruction alone, or if some are due to the STG tendon graft harvest procedure. Improving our understanding of how morphology changes as a result of reconstruction isolated from STG graft harvest will give us insight into the mechanisms behind knee flexor impairments. If the STG tendon graft harvest affects the hamstring muscles more than the ALLO procedure, then a muscle imbalance may result that could be remedied with hamstring strengthening exercises. Therefore, the purpose of this study was to compare potential changes in muscle and tendon morphology between STG and ALLO ACL reconstructed subjects. We hypothesized that STG tendon autograft reconstructed subjects would demonstrate 1) semitendinosus and gracilis muscle volume atrophy and reduced length, with variable tendon regenration and 2) remaining hamstring muscle volume hypertrophy, while those reconstructed with an allograft would not.

METHODS:
ACL deficient athletes were studied shortly before surgery and 6 months following ACL reconstruction. The hamstring autograft group underwent semitendinosus-gracilis graft harvest of their ipsilateral limb, including tendon stripping one cm proximal to the insertion while preserving the tendon sheaths in situ. 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 (University 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 contours were traced with the semimembranosus (SM), semitendinosus (ST), gracilis (GRA), biceps femoris – long head (BFL), biceps femoris – short head (BFS), sartorius (SAR), rectus femoris (RF), vastus medialis (VM) and lateralis (VL), vastus intermedius (VI), tensor fascia lata (TFL), medial (MG) and lateral gastrocnemius (LG).

Muscle and tendon morphology were of the ACL deficient and reconstructed limb were compared to the uninjured limb for both pre and postoperative results. Differences in muscle volume or CSA between groups prior to surgery.

RESULTS SECTION:
Ten ACL deficient subjects completed the data collection process prior to and 6 months following ACL reconstruction. Four were reconstructed with an allograft and six were reconstructed with a STG autograft.

Muscle Volume and Peak Cross-Sectional Area:
The volume of the semitendinosus and gracilis muscles were reduced after surgery for the hamstring reconstructed subjects (60.8 and 67.1%), but not for the allograft reconstructed subjects (101.8 and 99.6%) of their uninjured limb. Semitendinosus and gracilis volume and CSA were reduced in the hamstring reconstructed group both in comparison to their uninjured limb after surgery and in comparison to the same ACL deficient limb prior to surgery.

In comparison to their uninjured limb after surgery, the STG group demonstrated muscle volume and CSA hypertrophy of the BFL (106.4 and 109.6%), BFS (111.1 and 107.4%), and SM (104 and 104%) while the allograft group did not (range from 99.3 to 104.2%). There were no differences in muscle volume or CSA between groups prior to surgery.

Both post-surgical groups demonstrated reduced quadriceps volume and CSA, however only the STG group had reduced knee flexor volumes (figure). There were no differences detected in the volume or CSA of other muscles examined between pre and postoperative results.

DISCUSSION:
MRIs of hamstring autograft and cadaveric allograft ACL reconstructed subjects were obtained before and 6 months following surgery. Towards the purpose of this study we found that the ST and GRA muscles demonstrated reduced muscle volume and length. While there was varied STG tendon length regeneration, both demonstrated volume hypertrophy. Further, all of the subjects that underwent STG tendon graft harvest demonstrated BFL, BFS, and SM muscle volume and CSA hypertrophy. STG muscle and tendon morphological changes found within this abstract are supported by previous findings (Williams, 2004). These findings support our hypotheses.

In addition, we found that even though the remaining hamstring muscles hypertrophied in the STG group, they did not make up for the loss found due to graft harvest. Early identification of knee flexor deficits following STG graft harvest, with modified treatment, may reduce these impairments. In addition, alternate surgical options may be considered when knee flexor strength is of concern.

Although the current sample size was small, the differential morphological response gives insight in to how muscle regeneration may be affected by graft harvest. Our findings indicate that graft harvest plays a role in muscle and tendon morphological response.

REFERENCES:

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Figure: Comparison of the total Volume and CSA of the quadriceps (QUAD) and hamstrings (HS), sartorius (SAR), and gracilis (GRA) muscles after surgery for the STG and ALLO groups. Note the relative difference in knee flexor volumes between surgical groups.

Musculotendinous Length and Tendon Volume:
In the STG group, the ST and GRA muscles were both shorter (74.6 and 77.5%) and reduced in volume (60.8 and 67.1%) in comparison to their uninjured limb. The ST and GRA tendons were shorter (58.8 and 83.6%) after surgery than the uninjured limb. However, both ST and GRA tendon volumes hypertrophied (130 and 113%) in comparison to their uninjured limb. The ST and GRA muscle and tendon lengths and volumes were not different over time or between limbs for the ALLO reconstructed subjects.

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