

Variable Thigh Muscle Volume Losses and Compensations Exist 5-Years After Bone-Patellar Tendon-Bone and Hamstring Autograft Anterior Cruciate Ligament Reconstruction

Justin J Ernat, Collin Donald Roy Hunter, Stephen K Aoki, Patrick Greis, Travis G Maak, Joseph Featherall, Reece Meyer Rosenthal, Natalya Elle McNamara, Benjamin Theodore Johnson

INTRODUCTION:

The purpose of this study is to radiographically evaluate mid-term thigh muscle volume changes and patient reported outcomes among patients status-post primary anterior cruciate ligament reconstruction (ACLR) using allograft, bone-patellar tendon-bone autograft (BTB), or hamstring autograft (gracilis and semitendinosus; HS) using magnetic resonance imaging (MRI)-based 3D modeling.

METHODS:

Patients aged 18–45 years with a body mass index (BMI) < 30 who underwent primary ACLR with either allograft, BTB, or HS with minimum 5-year follow-up were identified via retrospective chart review. Revision ACLR and patients with any subsequent knee procedures after the index ACLR were excluded. Bilateral thigh 3T MRI scans were obtained, and images were rendered using 3D modeling software. Individual muscle volumes, compartmental volumes, and total thigh volume were calculated. Individual muscle volumes were calculated for each thigh and then normalized as a percentage of the total volume of their respective muscle compartments. These compartment-relative percentages in the operative thigh were subsequently compared to the corresponding percentages in the contralateral, non-operative thigh. Multivariable linear regression linked injured to contralateral muscle preservation ratios (total and compartmental) to IKDC scores, adjusting for age, sex, BMI, and graft type. Paired Student's t-tests and chi-squared tests were used for statistical analysis.

RESULTS:

Thirty patients were included: 10 Allograft, 10 BTB and 10 HS. Allograft patients (mean age 34.6 years; range: 31-40) were significantly older at surgery than BTB (mean age 23.4 years; range: 17-33) and HS cohorts (mean age 22.7 years; range: 16-28) ($p < 0.001$). No significant differences in total thigh or individual muscle volumes were found between operative and non-operative limbs with Allograft. BTB demonstrated a significant reduction in mean muscle volume percentage of the vastus intermedius in the operative thigh compared with the non-operative thigh (13.98% vs. 16.48%; $p < 0.001$). With HS, significant reductions were observed in mean muscle volume percentages of the gracilis (15.61% vs. 27.35%; $p < 0.001$) and semitendinosus (7.49% vs. 17.49%; $p = 0.001$) muscles in the operative thigh compared with the non-operative thigh. Conversely, the semimembranosus exhibited a significant increase in mean muscle volume percentage in the operative thigh relative to the non-operative thigh (42.50% vs. 36.57%; $p = 0.006$). Across graft types, greater preservation of operative limb muscle volume predicted better function: total thigh preservation correlated with higher IKDC scores ($B = 61.8$; $p = 0.043$), and anterior compartment preservation showed the strongest association ($B = 110.3$; $p = 0.004$; model $R^2 = 0.48$). No covariate (age, sex, BMI, graft type) independently influenced IKDC.

DISCUSSION AND CONCLUSION:

Five years after anterior cruciate ligament reconstruction, thigh muscle adaptation depends on graft choice and carries meaningful functional consequences. Hamstring autografts produced lasting atrophy of the semitendinosus and gracilis with compensatory hypertrophy of the semimembranosus, whereas BTB autografts were associated with selective loss of the vastus intermedius and no compensatory enlargement in the remaining quadriceps. Across all patients, larger differences in muscle volume between limbs, especially in the anterior compartment, were linked to lower IKDC scores.