Quadriceps Tendon Autograft Patients Demonstrate Greater Asymmetry in Landing Kinetics than Bone-Patellar Tendon-Bone Autograft Patients 6 Months After Anterior Cruciate Ligament Reconstruction

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INTRODUCTION:

Alarmingly, up to 33% of active individuals experience a second anterior cruciate ligament (ACL) injury within 2 years of primary ACL reconstruction (ACLR), regardless of graft source. Therefore, it is crucial to evaluate whether modifiable factors such as graft source have an impact on performance on tasks that can predict second injury. Asymmetry in lower extremity loading during a drop jump task 6 months after ACLR is known to be predictive of second ACL injury after a patient returns to sport. However, there is a paucity of literature investigating loading asymmetry after ACLR with quadriceps tendon (QT) autograft, despite its growing popularity and proposed benefits, including its large cross-sectional area and reduced donor site morbidity as compared to bone-patellar tendon-bone (BPTB) autografts. Additionally, most research regarding post-ACLR loading asymmetry has been done in biomechanics labs with techniques that are not translatable to the clinical environment. Tools such as the loadsol, a wireless force sensing insole, have been developed and validated against traditional force plates and 3-dimensional motion capture for the measurement of limb loading during landing tasks in post-ACLR patients. Therefore, the purpose of this study was to compare limb loading symmetry during a drop jump task 6 months post-ACLR between BPTB and QT autograft patients using loadsol wireless force sensing insoles in the clinical environment. Given the proposed benefits of QT autograft, we hypothesized that limb loading would be more symmetrical among patients who underwent ACLR with QT autograft as compared to BPTB autograft, and that patient-reported outcome measures (PROMs) would be associated with landing symmetry.

METHODS: Patients 13-40 years old who underwent primary ACLR with BPTB or QT autograft completed 3 to 5 trials of a drop jump assessment in a rehabilitation clinic. Participants were asked to drop from a 12-in box onto a standardized landing area ½ of the participant's height away from the box, immediately jump upward with maximal effort, and land in the same area. Impact force data (N) were collected at 100Hz using loadsol single sensor insoles during the first landing phase of the drop jump task. Data were normalized to participant body weight and the variables of interest were peak impact force (PIF), average loading rate (ALR), and impulse. Limb symmetry indices (LSI; %) were calculated for each biomechanical variable. Continuous demographic variables and surgical characteristics were compared between graft source groups using one-way ANOVA while categorical variables were compared between groups using χ^2 tests. International Knee Documentation Committee (IKDC) and ACL Return to Sport after Injury (ACL-RSI) scores were compared between graft source groups using one-way ANOVAs. Involved limb, contralateral limb, and LSI for PIF, ALR, and impulse were compared between graft source groups using separate ANOVAs. Cohen's d effect sizes and 95% confidence intervals were calculated to estimate the standardized magnitude of difference between graft sources for each kinetic variable. Relationships between IKDC score, ACL-RSI score, and LSIs for each biomechanical variable were assessed using Pearson's product moment correlation coefficients. A-priori alpha level was $p < 0.05$ for all analyses.

RESULTS: 44 participants (22 BPTB, 22 QT) completed biomechanical assessment and PROMs at 6±1 months post-ACLR. Graft source groups did not differ based on age, sex, mass, height, months since surgery, or meniscus tear treatment rate (Table 1). QT autograft participants demonstrated greater contralateral limb PIF, lower PIF LSI, lower involved limb impulse, and lower impulse LSI when compared to BPTB autograft participants (Table 2). Graft source groups did not differ in IKDC score or ACL-RSI score (Table 1). Among all participants, IKDC score was weakly associated with contralateral limb impulse ($r = -0.304$) and impulse LSI ($r = 0.374$), but no other kinetic variables. Among BPTB autograft participants, IKDC score was not associated with any kinetic variable, but among QT autograft participants, IKDC score was moderately associated with contralateral limb PIF ($r = -0.480$) and contralateral limb impulse ($r = -0.534$). Among all participants, ACL-RSI score was weakly associated with PIF LSI ($r = 0.315$) and impulse LSI ($r = 0.351$), but there were no associations between ACL-RSI score and kinetic variables among BPTB or QT autograft participants alone.

DISCUSSION AND CONCLUSION:

Our findings indicate that QT autograft patients experience greater kinetic asymmetry during the jump landing compared to those with BPTB autograft 6 months post-ACLR, which has been shown to be predictive of second ACL injury after return to sport. In addition, neither IKDC nor ACL-RSI score are strongly associated with landing kinetics, regardless of graft source. This study was performed in the clinical environment with clinically feasible and well-validated wearable technology to assess lower extremity loading asymmetry. As a result, our findings not only provide evidence that QT autograft patients display movement patterns that elevate their risk of second ACL injury than BPTB autograft patients,

but also describe a framework for feasible in-clinic assessment of landing mechanics that may aid in identifying deficits that would not be detected using traditional methods of assessment.

Table 1. Comparison of participant demographics and surgical characteristics between graft sources

	BTB Autograft	QT Autograft	p-value
Age (yrs)	23.0±9.2	22.5±9.6	0.884
Sex, n (%)			
Females	13 (59.1%)	15 (68.2%)	0.531
Males	9 (40.9%)	7 (31.8%)	
Mass (kg)	71.0±16.1	70.3±13.7	0.872
Height (m)	1.72±10.0	1.71±9.5	0.572
Months since surgery	6.4±0.6	6.3±0.6	0.683
Lateral Meniscus Treatment, n (%)			
Repair	4 (19.0%)	1 (9.1%)	0.637
Meniscectomy	1 (4.8%)	1 (4.5%)	
None	16 (76.2%)	19 (86.4%)	
Medial Meniscus Treatment, n (%)			
Repair	5 (23.8%)	2 (9.1%)	0.416
Meniscectomy	2 (9.5%)	3 (13.6%)	
None	14 (66.7%)	17 (77.3%)	
IKDC Score	76.5±12.5	73.2±10.1	0.333
ACL-RSI Score	63.7±22.5	52.2±18.4	0.070

BTB, bone patellar tendon bone; QT, quadriceps tendon; IKDC, International Knee Documentation Subjective Knee Evaluation Form; ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury Survey

Table 2. Comparison of landing kinetics between graft sources

	BTB Autograft	QT Autograft	p-value	Cohen's *d* (95% CI)
Peak Impact Force (BW)				
ACLR limb	1.58±0.45	1.53±0.45	0.691	0.12 (-0.47, 0.71)
Contralateral limb	2.02±0.53	2.55±0.63	0.004	-0.91 (-1.55, -0.25)
LSI (%)	81.3±23.8	62.9±20.7	0.009	0.83 (0.18, 1.46)
Average loading rate (BW*s^{-1})				
ACLR limb	30.24±14.40	33.25±16.27	0.519	-0.20 (-0.79, 0.40)
Contralateral limb	39.76±14.35	50.36±23.19	0.077	-0.55 (-1.16, 0.07)
LSI (%)	79.54±34.50	74.14±32.19	0.594	0.16 (-0.43, 0.75)
Impulse (BW*s)				
ACLR limb	0.54±0.09	0.44±0.09	<0.001	1.16 (0.46, 1.84)
Contralateral limb	0.66±0.10	0.67±0.11	0.898	0.04 (-0.55, 0.63)
LSI (%)	82.1±9.9	67.0±14.0	<0.001	1.24 (0.53, 1.93)

BTB, bone patellar tendon bone; QT, quadriceps tendon; ACLR, anterior cruciate ligament reconstruction; LSI, limb symmetry index; BW, body weight