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Anterior cruciate ligament reconstruction using quadriceps tendon autograft is a viable option for small-statured female patients

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Abstract

Purpose The choice of graft for anterior cruciate ligament (ACL) reconstruction remains controversial. The quadriceps tendon (QT) autograft is a good alternative for ACL reconstruction. However, concerns regarding its use in short-statured patients, related to donor site morbidity, anterior knee pain, or loss of muscle strength remain. This study aimed to compare muscle strength and morbidity between patients with short and normal statures following ACL reconstruction with a QT autograft.

Methods A total of 73 female patients (mean age, 33.8 ± 11.5 years) who underwent primary ACL reconstruction between 2016 and 2019 were included. Patients were categorized into two groups: group S, with a height ≤ 163 cm, and group L, with a height > 163 cm. Muscle strength, harvesting site morbidity, and ACL-return to sport after injury scale (ACL-RSI) were evaluated, with a mean timing of the follow-up of 9.0 ± 2.3 months.

Results The mean quadriceps strength for the isokinetic measurements at 60° and 240° was 65.0% and 74.0% in group S, respectively, and 70.0% and 75.7% in group L, respectively. There was no significant difference in the postoperative muscle strength or mean ACL-RSI (group S, 70.0; group L, 65.9) between the groups. No donor site morbidity was observed in either group.

Conclusion Muscle strength recovery, morbidity, and readiness to return to sports were similar in both groups, which supports the possibility of QT autografts for patients with a small stature. The results of this study may provide useful information for surgeons who are hesitant to perform QT autografts because of patient physique.

Level of Evidence IV.

Keywords Anterior cruciate ligament reconstruction · Quadriceps tendon · Graft choice · Muscle strength · Small stature patient

Abbreviations

ACL Anterior cruciate ligament
ACLR Anterior cruciate ligament reconstruction
QT Quadriceps tendon

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Introduction

Anterior cruciate ligament (ACL) tears are one of the most common sports injuries, and ACL reconstruction is a common treatment [5, 33]. Despite numerous studies, the choice of graft for primary or revision ACL reconstruction remains controversial [18, 24]. Current literature suggests QT as a valuable option in ACL reconstruction [12, 32, 37], and its use has been increasing [22, 39]. In 2010, 2.5% of all anatomic ACL reconstructions were performed with QT autografts [38], which increased to 11% in 2014 [26].

Recent studies have reported many histological [9], biomechanical [1, 10, 34, 36], and clinical advantages of QT autografts. Many recent reports, including meta-analyses, reported that QT autografts had comparable clinical and functional outcomes and graft survival rates compared with BPTB and hamstring tendon (HT) autografts [4, 8, 17, 19,

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27, 29, 32], and patients with QT autografts reported significantly less harvest site pain compared with those receiving the BPTB and HT autografts [2, 15, 17]. Even though there is still some controversy in the literature regarding clinical outcomes [23], the QT autograft could be "the graft of the future" [42], and its use may be widespread not only in Western countries but also in Asian countries, where the use of QT is still limited [22, 40, 41].

However, there are concerns regarding its use in Asia, because their average height is lower than in most European countries or North America [30]. There is a question of whether harvesting a QT graft for a small-statured patient would cause any adverse events. A harvested tendon can be relatively large in small-statured patients, which might lead to donor site morbidity (defined as anterior knee pain, kneeling pain, and sensitivity loss), or loss of muscle strength. Postoperative quadriceps function can influence patient self-reported outcomes, functional performance, and return to preinjury activity level [20, 21, 31]. Thus, the aim of this study was to compare muscle strength and morbidity following ACL reconstruction with QT autografts in patients with small, normal, or large statures. Several studies have compared postoperative muscle strength between different types of grafts [6, 11, 13–15], but there have been no studies comparing muscle strength by stature. The clinical relevance of this study is that it may provide useful information for surgeons who are hesitant to perform QT autografts because of patient physique. The hypothesis of this study was that the loss of muscle strength and morbidity was not greater in the small-statured patients than in the control group.

Materials and methods

A total of 88 female patients (mean age, 33.6 years; range, 15–58 years) who underwent primary ACL reconstruction using QT autografts between 2016 and 2019 were included. The exclusion criteria were as follows: revision ACL surgery, prior trauma and/or surgical history around the knee, previous muscle injuries on both lower limbs, and comorbidities affecting lower limb muscle strength. Data were collected and retrospectively analyzed. Patients were categorized into two groups as follows: group S, with a height ≤ 163 cm, and group L, with height > 163 cm. Muscle strength, H:Q ratio, harvesting site morbidity, and ACL-return to sport after injury scale (ACL-RSI) were evaluated. Fifteen patients were excluded due to missing data, and eventually 73 patients were eventually recruited. Demographic data are shown in Table 1.

Table. 1 Patient demographics

	Overall	Group S	Group L	*p* value
n (L/R)	73 (42/31)	22 (10/12)	51 (32/19)	
Age	33.8 ± 11.4	35.4 ± 10.9	33.1 ± 11.7	n.s
Height (cm)	165.5 ± 5.6	159.2 ± 3.6	168.2 ± 2.8	< 0.01
Body weight (kg)	62.2 ± 9.4	57.7 ± 7.0	64.2 ± 9.7	< 0.01
Body mass index	22.7 ± 3.5	22.8 ± 2.6	22.7 ± 3.8	n.s
Length of QT graft (cm)	7.9 ± 0.4	7.9 ± 0.5	7.9 ± 0.4	n.s
Diameter of QT graft (mm)	8.0 ± 0.5	8.0 ± 0.6	8.0 ± 0.5	n.s

n.s not significant.

Surgical technique

Patients were positioned supine with a thigh tourniquet and knee flexion of 90°, and an approximate 2.5–3-cm longitudinal skin incision was made over the superior pole of the patella. The QT graft was harvested by measuring 7–10 mm in width and 80–90 mm in length with a bone block (approximately 15–20 mm) using specialized instrumentation (Karl Storz, Tuttlingen, Germany). All autografts were harvested with the bone block. The exact size was chosen according to patient anatomy and operation type. The thickness of the graft was determined using a sharp cutting blade at a depth of 6 mm. The defect of the harvested tendon was carefully and tightly closed with absorbable sutures (No. 2 Vicryl; Ethicon). Bone defects in the proximal patella were filled with bone debris generated during tunnel drilling. In all cases, the harvested tendons were of partial thickness. Finally, the superficial layers were closed over the donor site.

After harvesting the QT graft, routine diagnostic arthroscopy was performed, and then meniscal treatment and/or a chondral procedure were performed according to the diagnosis and necessity. The femoral bone tunnel was created using the outside-in technique. Graft fixation was achieved using interference screw fixation with a MILAGRO bioabsorbable screw (DePuy Synthes, Warsaw, Indiana). A detailed description has been described in a previous study [25].

Postoperative rehabilitation

All patients underwent the same postoperative protocol. Partial weight-bearing (15–30 kg) was allowed as soon as possible, with progression to full weight-bearing at 3 weeks postoperatively. A stationary bicycle was recommended at 6 weeks, jogging was permitted at 3 months, and a full return to strenuous sports activity was permitted between 8 and 12 months [25].

Evaluation of muscle strength and readiness to return-to-sports (RTS)

To evaluate muscle strength, the isokinetic strength of both the knee extensors and flexors was measured using an isokinetic dynamometer (Biodex Medical Systems). Muscle strength was evaluated when the patient acquired the ability to perform a single-leg squat. The mean timing of evaluation was 9.1 ± 2.3 months in group S and 8.9 ± 2.6 months in group L, showing no significant difference. After warm-up, three maximal contractions were performed with patients positioned in the dynamometer with their hips flexed at 90° and knee flexed at 90°. Stabilization in the dynamometer was maintained with straps across the chest, hip, and knees. Patients were asked to perform torque as hard and fast as possible bilaterally via five repetitions at angular velocities of 60° and 240°/s through a full range of motion. The peak torque of the maximal repetitions was regarded as the muscle power. The results of the operated leg were calculated as a percentage relative to the non-operated leg. The H:Q ratio was also calculated using these data.

To evaluate readiness to return to sports (RTS), the ACL-return to sport after injury scale (ACL-RSI) was evaluated at the same time. In addition to the routine clinical interview, questioning of the post-operative condition included anterior knee pain or kneeling pain as "donor site morbidity".

Statistical analyses

All statistical analyses were performed using the R software package (version 3.2.1; R Development Core Team, Vienna, Austria). Differences in the postoperative muscle strength and ACL-RSI between groups S and L were analyzed using the Mann–Whitney U test. Statistical significance was set at $P < 0.05$. A minimum sample size of seven patients in each cohort was required to provide appropriate power (beta ¼ 0.80) using a significance level of 0.05, by considering the mean and standard deviations of height. To examine subinferiority, the clinically significant difference in muscle strength was calculated to be 5% based on the difference in muscle strength between the two groups and the results of previous studies [6, 11], and the required sample size was 21. This study was conducted in accordance with the World Medical Association Declaration of Helsinki. According to federal law, this retrospective study dealing with anonymized data did not require the approval of the regional ethics committee.

Results

The mean quadriceps strength for the isokinetic measurements at 60° and 240° was 65.0 ± 15.8% and 74.0 ± 18.5% in group S, and 70.0 ± 13.7% and 75.7 ± 11.4% in group L, respectively (Fig. 1). There was no significant difference in the postoperative muscle strength and the H:Q ratio between the groups (Table 2). Postoperative hamstring strength was not significantly different between the groups (Table 2). No donor site morbidity was observed in either group. In addition, there was no significant difference in mean ACL-RSI between group S and L, which was 68.0 ± 18.5 and 65.3 ± 20.0, respectively.

Discussion

The most important finding of this study was that there were no significant differences in quadriceps muscle recovery after ACL reconstruction using QT autografts (QT-ACLR) between small- and large-statured patients. None of the

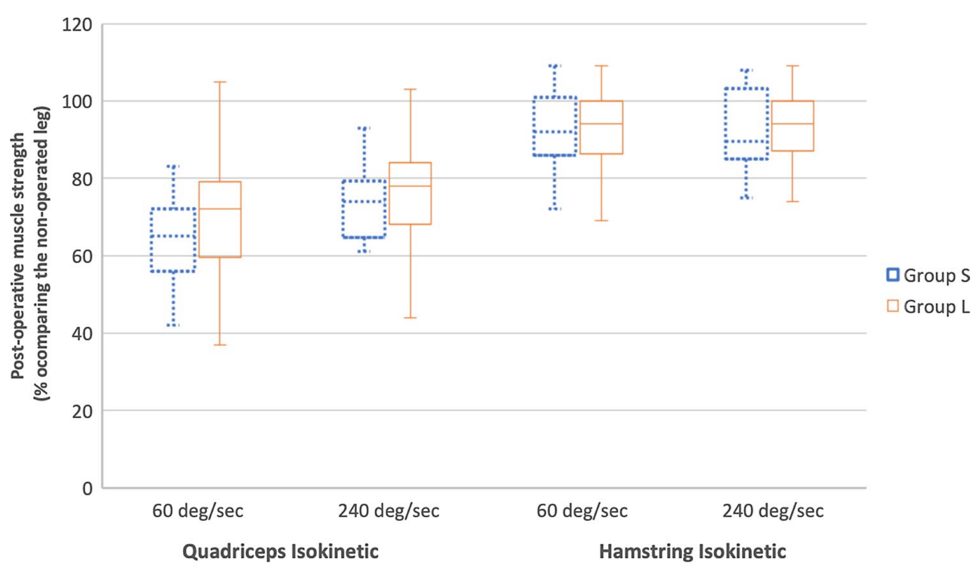

Fig. 1 Post-operative isokinetic knee torque (mean ± 95% confidence interval) for the small-statured patients' group (Group S; dotted line) was not significantly lower than the control group (Group L; solid line)

Table. 2 Postoperative muscle strength in each group

Muscle			Group S	Group L	p value
Quadriceps	Isokinetic	60 deg/sec	65.0 ± 15.8	70.0 ± 13.7	n.s
	Isokinetic	240 deg/sec	74.0 ± 18.5	75.7 ± 11.4	n.s
Hamstring	Isokinetic	60 deg/sec	93.0 ± 9.7	92.2 ± 10.1	n.s
	Isokinetic	240 deg/sec	92.6 ± 9.9	92.3 ± 10.6	n.s
H:Q ratio		60 deg/sec	1.53 ± 0.5	1.33 ± 0.4	n.s
		240 deg/sec	1.36 ± 0.3	1.24 ± 0.2	n.s
Timing of measurement (months)			9.1 ± 2.3	8.9 ± 2.6	n.s

Muscle strength and the H:Q ratio were calculated as percentages compared to the contralateral limb. *n.s* not significant

patients complained of donor site morbidity, and the readiness to RTS was not significantly different.

Several studies of QT autografts have been conducted, revealing the remarkability of the QT autograft as “the graft of the future”. The cross-sectional area of the QT was found to be nearly twice that of the BPTB, and the ultimate load to failure (2186 vs. 1581 N) and stiffness (466 vs. 278 N/mm) were significantly higher for the QT graft than for the BPTB [3, 6, 10, 19, 34, 36]. Several recent reviews have reported that both the functional outcomes and postoperative stability of the QT autograft were equivalent to those of the HT and BPTB autografts [4, 12, 32], whereas QT autografts showed less harvest site pain [2, 17, 28]. Nevertheless, there are few studies on postoperative muscle recovery or the effect of differences in individual patient characteristics, such as their skeletal length.

This is the first study to investigate muscle strength after QT-ACLR by classifying the two groups according to the patients’ stature. Iriuchishima et al. reported that muscle recovery after QT-ACLR was almost the same as that previously reported in double-bundle and single-bundle ACL reconstruction using hamstring autografts [15]. Cavignac et al. demonstrated that the side-to-side difference in the postoperative isokinetic test showed no significant difference in both extension and flexion between the QT and HT groups [6]. In another previous study comparing quadriceps recovery between QT and patellar tendon autografts, it was reported that the isokinetic strength of the knee extensor isokinetic strength at 60° was similar in both groups at the average postoperative follow-up of 7–8 months [11]. Similar reports stated that the knee extensor strength at 5 to 8 months postoperatively for QT was similar to that of PT but weaker than that of HT ACL reconstruction, while the knee flexor strength at 5 to 8 months postoperatively for QT was significantly greater than that of HT patients [14, 15].

However, it can be expected that the harvested graft may become relatively larger in small-statured patients. In a similar study focusing on female patients with small skeletons in ACL reconstruction, Shimozaki et al. reported that partial lateral meniscus anterior root injuries were more likely to occur in small patients whose average height was 157.7 cm [35]. Thus, complications can occur in populations with low average height, as in the above study. It is also possible to obtain a QT at full thickness in cases with small stature, although we did not encounter one in our study. Kanakamedala et al. compared the outcomes and complication profiles of ACL reconstruction between full-thickness and partial-thickness QT autografts. It was concluded that the outcome and complications were not significantly different between full-thickness and partial-thickness in primary ACL reconstruction [16].

Esthetic appearance after knee surgery is also an important problem for female patients. Mouarbes et al. reported that the appearance of the scar and the length of the incision were significantly better in QT vs. BPTB and tended to be better without reaching a significant threshold of 2.5% in QT vs. HT patients. Moreover, in that study, the harvesting of QT autografts for ACLR produced a significantly smaller area of hypoesthesia than in both BPTB and HT autografts [28]. Fink et al. also reported that a 2.5 to 3 cm transverse skin incision is useful for minimally invasive QT harvesting and is regarded as one of the advantages of QT autografts. Thus, QT is a good choice for patients in terms of cosmetic aspects [7].

There were some limitations to this study. First, the follow-up duration was short; thus, further investigation with mid- and long-term follow-up is required. Second, the sample size of this study was small, especially for the small patient group ($n = 22$). However, in the cohort of this study, the average height was over 165 cm; therefore, the sample size in the small-statured patient group was inevitably reduced. Third, presurgical data could not be collected. Therefore, it is impossible to evaluate the differences in surgery that affect patient progress. Fourth, the timing of the muscle strength evaluation was variable. However, all patients underwent evaluations after more than 6 postoperative months, and there were no significant differences between the two groups. Fifth, other pre/postoperative objective and subjective data were not collected. This is a limitation from the retrospective nature of this study. The possibility of inferior outcomes in patients with a smaller status is undeniable and vice versa. Finally, there is no evidence supporting a height cutoff of 163 cm. Nevertheless, the average height of the small group was 159.7 cm, which is similar to the average height of Japanese and South Korean females [30]. In contrast, the average height in the control group was 168 cm, which is almost the same as that of the Islandic and Danish persons. Obviously, there are differences between races other than height; thus, it is not possible to directly apply this result. Despite these limitations, this study is useful, because it is the first study to show that patient stature has little effect on postoperative muscle recovery, donor site morbidity, and readiness to return to sports following ACL reconstruction with QT autograft.

Conclusion

Muscle strength recovery, morbidity, and readiness to RTS were similar between the small-statured female group and the control group. This result supports the notion that QT autografts for small-statured patients is a viable option without the risk of significant postoperative muscle weakness.

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Code availability Not applicable.

Declarations

Conflicts of interest The authors declare that they have no competing interests.

Ethics approval This study was approved by our institutional review board.

Consent to participate Written informed consent was obtained from the patients for participation of this case series.

Consent for publication Written informed consent was obtained from the patients for publication of this case series and accompanying images.

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