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Comparison of knee sonography and pressure pain threshold after anterior cruciate ligament reconstruction with quadriceps tendon versus hamstring tendon autografts in soccer players

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ABSTRACT

Objective: The aim of this study was to compare the pressure pain threshold and muscle architecture after an anatomic single bundle reconstruction with quadriceps tendon and hamstring tendon autografts of the anterior cruciate ligament in competitive soccer players. We hypothesized that both procedures will obtain similar outcomes.
Methods: Fifty-one participants were enrolled in this secondary analysis of a randomized controlled trial and were categorised into two groups: quadriceps tendon (QT) group (23 men and 3 women; mean age 18.7 ± 3.6; BMI 23.0 ± 2.2) or hamstring tendon (HT) group (16 men and 9 women; mean age 19.2 ± 3.6 BMI 23.5 ± 3.5). Both groups followed the same rehabilitation staged protocol. Pressure pain threshold (PPT), as a measure of perceived pain, was obtained in several points of quadriceps and hamstring muscles. Ultrasound imaging measurements were obtained in quadriceps tendon and knee cartilage thickness. Four measurements were taken in this study: baseline, 1, 3, 6, and 12 months after the anterior cruciate ligament (ACL) reconstruction.
Results: The analysis of PPT did not find significant differences in both groups × interaction time in the points evaluated: epicondyle (QT = 421.1 ± 184.1 vs HT = 384.7 ± 154.1 kPa), vastus lateralis (QT = 576.2 ± 221.3 vs HT = 560.1 ± 167.7 kPa), vastus medialis (QT = 544.7 ± 198.8 vs HT = 541.1.1 ± 181.77 kPa), patellar tendon (QT = 626.3 ± 221.1 vs HT = 665.0 ± 205.5 kPa), QT (QT = 651.1 ± 276.9 vs HT = 660.0 ± 195.2 kPa).
(QT = 667.8 ± 284.7 vs HT = 648.2 ± 193.4 kPa) injured knee (all $P > 0.05$). The results of ultrasound imaging did not show significant differences in both groups × interaction time in the thickness of the QT (QT = 9.9 ± 2.4 vs HT = 9.4 ± 1.7 kPa) and patellar cartilage (QT = 3.2 ± 0.6 vs HT = 3.2 ± 0.4 kPa) ($P > 0.05$).
Conclusion: A QT autograft produces similar results to a HT autograft in ACL reconstructions in terms of pressure pain threshold and ultrasound muscle architecture during the 1-year follow-up.
Level of Evidence: Level I, Therapeutic Study.

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Introduction

Anterior cruciate ligament (ACL) reconstruction is considered the gold standard treatment after ACL rupture in young athletes.[1] One of the most controversial aspects about this procedure is the choice of the graft. Different authors have described the quadriceps tendon (QT) as an effective choice in ACL reconstruction.[2–4]

The proprioception sense is often impaired after ACL reconstruction,[5] and little information is available concerning pain sensitivity after ACL rupture and posterior recovery. Self-reported pain intensity is one of the most used procedures to assess pain. A recent study postulated that the FQT autograft for ACL reconstruction produces less self-reported pain intensity than the HT autograft in the immediate postoperative period.[6] Another study confirmed the absence of pain at the donor graft site after an ACL reconstruction with a QT graft at a 10-year follow-up after the surgery.[7] Whereas, using objective pain measurements, such as pressure algometry, would give more precise information about pain evolution after ACL reconstruction and would provide a broader perspective on the health condition. The normalisation of pressure pain threshold (PPT) has been confirmed after orthopaedic surgery in hip replacement surgery,[8] but there is no information available in this sense regarding the influence of ACL reconstruction.

A huge research gap about ultrasound assessment of muscle and tendon architecture increase interest of research community in the last years. Changes in muscle length and pennation angle in biceps femoris have been described after an ACL injury reconstruction with an HT autograft.[9] However, a previous study by Longo et al did not find similar findings in bone-patellar tendon-bone autograft after a 2-year follow-up in vastus lateralis.[10] These to the best of our knowledge, to date, no previous study has focused on morphology ultrasound changes after an ACL reconstruction using FQT autografts.

Controversial results have been reported about the best graft choice for ACL reconstruction when QT grafts and HT grafts were compared. A less residual laxity of QT graft was reported by Sofu et al,[11] and recent study have reported similar results between these autograft modalities using a cohort design.[12] In a previous randomised controlled trial we found that QT grafts had similar functional results with a better isokinetic ratio compared to HT grafts.[13]

The aim of this secondary analysis was compare the pressure pain threshold and muscle architecture of anatomic single bundle reconstructions with quadriceps tendon and hamstring tendon autografts in competitive soccer players. To compare the pressure pain threshold and muscle architecture after an anatomic single bundle reconstruction with quadriceps tendon and hamstring tendon autografts of the anterior cruciate ligament in competitive soccer players. We hypothesized that both procedures will obtain similar outcomes.

Materials and methods

Setting and participants

This study is a secondary analysis of the data from a previously completed randomised controlled trial.[13] The methods of this randomised controlled trial (Clinical Trials.gov NCT02832791) have been previously reported.[13] The trial was carried out following the Helsinki Declaration (last modification in 2000) and the Law 14/2007 on Biomedical Research, and the protocol was approved by the Ethics Committee on Human Research (CEIH). Before being evaluated, the participants or their legal representatives signed a written informed consent.

The participants (n = 56) were recruited by their surgeon according to the following inclusion criteria: (i) confirmed ACL rupture, (ii) surgery carried out less than 6 months after the injury, and (iii) being recreational or federated athletes. The exclusion criteria were having had a previous knee injury or surgery, having concomitant ligament injuries and/or a meniscal tear, and having joint cartilage lesions greater than Outerbridge grades III–IV.

The randomisation of the participants was carried out with the Epidat 3.1 software (Xunta de Galicia, Spain) in two random number cycles. The produced sequence was introduced in numbered, opaque, sealed envelopes by an external non-participant researcher. The groups (QT: quadriceps tendon or HT: hamstring tendon) were treated by their surgeon after the baseline assessment of the patients.

Intervention

The intervention was described in detail in our prior report.[13] Briefly, the QT and HT groups followed an identical rehabilitation protocol, including the prehabilitation and rehabilitation stages, same objectives, and defined criteria, to start the following phase[13] that was carried out by their physiotherapists.

A single surgeon and his team executed all the ACL reconstructions. The surgical technique was the same in both groups except for the graft harvesting and the femoral fixation method.

An arthroscopic anatomic single bundle ACL reconstruction was performed after conducting a routine diagnostic arthroscopy confirming the ACL rupture and the need to treat any meniscus or cartilage injuries if necessary. The free bone plug QT graft was obtained through an anterior 4 cm longitudinal incision extending from the superior pole of the patella. The graft was 80 mm long, 10 mm wide, and 7 mm thick. In the HT group, the semitendinosus and gracilis tendons were harvested through an oblique 3 cm-incision medial to the tibial tuberosity. Once the graft was harvested, the femoral tunnel was drilled through an antero-medial (AM) portal with a sized drill upon graft width. In order to locate the femoral tunnel, the ACL stump, the intercondylar area, and the bifurcated ridged were used as anatomical references. After the femoral tunnel was completed, the tibial tunnel was drilled using the previous ACL stump, the anterior horn of the lateral meniscus, and the anterior tibial spine as anatomic references. The graft was finally passaged and fixated with a cortical suspensory button in the hamstring graft group and with a bioabsorbable interference screw in the QT graft group. The tibial fixation was carried out with an interference bioabsorbable screw in all patients.

Evaluation and end points

The face to face assessments of the end points were carried out in four moments: before the surgery and 3, 6, and 12 months after the surgery. The evaluations were made by an expert physiotherapist with over 6 years of experience in research.

The main end points (isokinetic, perceived functionality, and anteroposterior laxity) were reported in our prior report.[13] Below, we present below the pain and muscle structure end points.

Pain measurement

PPT was evaluated with an electronic algometer (Somedic AB, Farsta, Sweden) with a probe of 1 cm^2 and an approximate rate of 30 kPa/s. We assessed one point in epicondyle and five points in both knees (vastus lateralis, vastus medialis, patellar tendon, quadriceps tendon, and hamstring tendon), based on a prior protocol[14,15] (Fig. 1). We performed three evaluations at each point with a 30-s rest and the average (KPa) was recorded for analysis. Prior to the evaluation, the patients were trained to signal the first

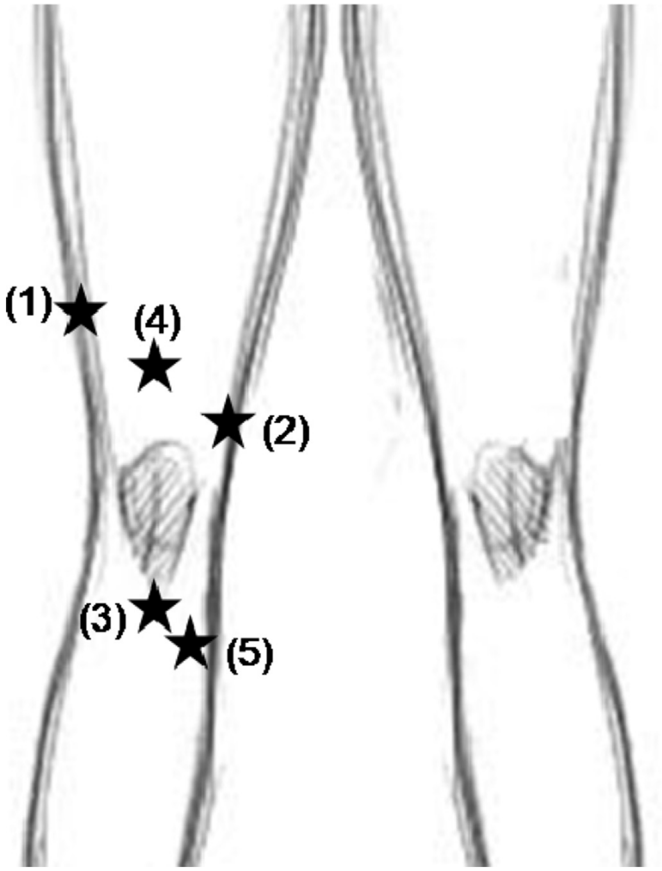

Fig. 1. PPT points: (1) 10 cm lateral to the midpoint of the superior edge of the patella; (2) 3 cm medial to the midpoint of the superior edge of the patella; (3) at the midpoint between the lower edge of the patella and tibial tuberosity; (4) 3 cm proximal to the superior edge of the patella; and (5) 3 cm medial to the tibial tuberosity, in the insertion of pes anserinus.

change from pressure to pain. The algometry showed a 0.91 intra class correlation coefficient (ICC).[16]

Ultrasound imaging measurements

The muscle architecture assessment with an ultrasound (MyLab 25, Esaote Medical Systems, Genova, Italy) was used to obtain ultrasound images with a 12 MHz linear probe with a 6-point depth penetration. The quadriceps tendon measurements and patellar cartilage thickness were registered (mm) according to the previously described methodology.[17] Ultrasound imaging has been considered reliable in quadriceps with an ICC = 0.95[18] and for cartilage thickness with an ICC = 0.71.[19]

Statistical analysis

Data are presented as the mean ± standard deviation for continues data and as percentage (%) for categorical data. The Shapiro–Wilk test was used to review the normal distribution of variables. We conducted repeated measures analyses of the covariance (ANCOVA) with outcome variables (PPT, Single leg hop test, and Ultrasound) as dependent variables, groups (QT and HT groups) as between-subjects variables, time (pre, 3, 6, and 12 months of follow-up) as within-subjects variable. To assess the influence of anthropometric measurements which could influence in the graft's size of hamstring group we include weight, height and body mass index as covariates. We used the intention-to-treat (ITT) principle for all analyses, with the worst-case value for missing data. To conduct the statistical analysis, we used the Statistical Program for Social Sciences (IBM SPSS version 22.0), and the level of significance was set at 5%.

Results

In summary, 56 patients were randomised into the QT group (n = 26; mean age 18.7 ± 3.6; BMI 23.0 ± 2.2) or the HT group (n = 25; mean age 19.2 ± 3.6 BMI 23.5 ± 3.5) (Table 1). The session attendance was 88.3% (22.0 ± 1.1 of 24 sessions). Among the randomised participants there was a 7.1% drop-out (n = 2) in the QT group and 10.7% (n = 3) in HT group. The different reasons and patient flow are showed in Fig. 2. There were no significant differences between the groups in terms of assistance to the treatment (Table 2).

Effects of surgery in pain measurements

The analysis of PPT did not find significant differences in both groups × interaction time in the points evaluated: epicondyle (F = 1.19, p = 0.32), vastus lateralis injured knee (F = 0.48 p = 0.69 injured knee; F = 0.85, p = 0.47 non-injured knee), vastus medialis injured knee (F = 0.41, p = 0.74 injured knee; F = 0.16, p = 0.91 non-injured knee), patellar tendon injured knee (F = 0.16, p = 0.92 injured knee; F = 0.20, p = 0.89 non-injured knee), quadriceps tendon injured knee (F = 0.96, p = 0.42 injured knee; F = 0.53, p = 0.66 non-injured knee), and hamstring tendon injured knee (F = 0.33, p = 0.80 injured knee; F = 0.84, p = 0.48 non-injured knee) (Table 3). Covariance did not show influence in these results.

Effects of surgery in muscle architecture measurements

The results of muscle architecture obtained with ANCOVA analysis showed no significant differences group × interaction time in neither the injured knee (F = 1.07, p = 0.22 thickness quadriceps; F = 0.11, p = 0.92 thickness knee cartilage) nor the non-injured knee (F = 0.44, p = 0.19 thickness quadriceps; F = 2.61, p = 0.21 thickness knee cartilage) (Table 4). Covariance did not show influence in these results.

Table 1
Sociodemographic characteristics of the patients.

Characteristic	QT group (n = 26)	HT group (n = 25)
Age (year), mean (SD)	18.7 ± 3.6	19.2 ± 3.6
Gender n (%)		
Male	23 (88.5)	16 (64.0)
Female	3 (11.5)	9 (36.0)
Dominant side, n (%)		
Right	23 (88.5)	19 (76.0)
Left	3 (11.5)	6 (24.0)
Injured side, n (%)		
Right	12 (46.2)	13 (52.0)
Left	14 (53.8)	12 (48.0)
Educational level, n (%)		
Primary school	8 (30.8)	7 (28.0)
Secondary school	15 (67.7)	10 (40.0)
University	3 (11.5)	8 (32.0)
Tobacco		
No	26 (100)	24 (96.0)
Yes	0 (–)	1 (4.0)
Alcohol intake		
Never	15 (57.7)	16 (64.0)
Monthly	10 (38.8)	7 (28.0)
Weekly	1 (3.8)	2 (8.0)
Body mass index (kg/cm^2) mean(SD)	23.0 ± 2.2	23.5 ± 3.5
Time playing (years) mean (SD)	10.1 ± 3.8	10.2 ± 4.1

Values are expressed as the mean (SD) or frequency n (%). QT: quadriceps tendon; HT: hamstring tendon.

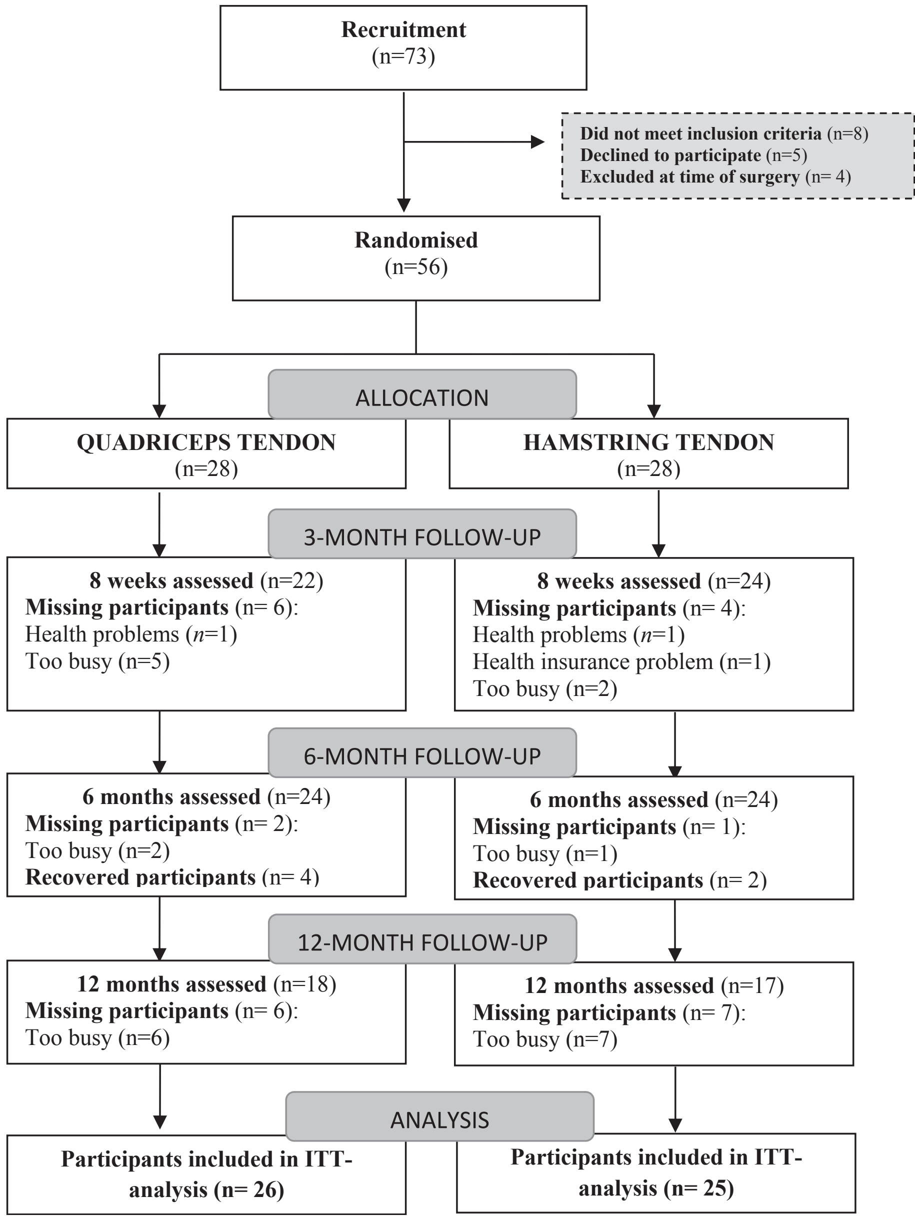

Fig. 2. Study flow diagram.

Table 2
Control of recovery.

Items	QT group (n = 26)	HT group (n = 25)	P value
Time attended to the treatment protocol (months), mean (SD)	1.2 ± 0.4	1.1 ± 0.4	0.66
Practice of crutch from the 4th day n (%)			0.79
No	7 (26.9)	2 (8.0)	
Yes	19 (73.1)	23 (92.0)	
Practice bicycle from the 3rd week, n (%)			0.13
No	11 (42.3)	6 (24.0)	
Yes	15 (57.7)	19 (76.0)	
Practice running from the 3rd month, n (%)			0.08
No	1 (3.8)	5 (20.0)	
Yes	25 (96.2)	20 (80.0)	
Practice normal training after 6 months, n (%)			0.34
No	11 (65.4)	14 (56.0)	
Yes	9 (34.6)	11 (44.0)	

Values are expressed as the mean (SD) or frequency n (%). QT: quadriceps tendon; HT: hamstring tendon.

Table 3
Pressure pain thresholds (kPa) measurements at baseline, at 3, 6 months and 1-year of follow-up.

Group	Pre-surgery	3-month follow-up	6-month follow-up	1-year follow-up	P value
Epicondyle					
QT group	268.8 ± 150.6	278.4 ± 125.4	290.1 ± 130.5	425.1 ± 184.1	0.32
HT group	280.3 ± 128.6	230.2 ± 81.7	289.1 ± 117.6	384.7 ± 154.1	
Vastus lateralis injured knee					
QT group	408.1 ± 225.4	419.0 ± 191.9	422.9 ± 163.2	576.2 ± 221.3	0.69
HT group	458.1 ± 195.0	407.8 ± 152.3	414.4 ± 146.1	560.1 ± 167.7	
Vastus medialis injured knee					
QT group	360.6 ± 175.5	351.9 ± 166.3	385.1 ± 177.1	544.7 ± 198.8	0.74
HT group	372.1 ± 120.3	340.5 ± 109.2	410.5 ± 174.4	541.1 ± 181.7	
Patellar tendon injured knee					
QT group	529.4 ± 265.4	482.3 ± 206.3	486.8 ± 221.8	626.3 ± 221.1	0.92
HT group	530.6 ± 178.4	484.3 ± 142.0	522.9 ± 181.2	665.0 ± 205.5	
Quadriceps tendon injured knee					
QT group	503.4 ± 244.1	450.6 ± 198.5	505.3 ± 245.3	651.1 ± 276.9	0.42
HT group	525.6 ± 149.8	568.1 ± 165.0	562.8 ± 194.9	660.0 ± 195.2	
Hamstring tendon injured knee					
QT group	426.5 ± 235.1	344.5 ± 154.6	367.4 ± 175.2	667.8 ± 284.7	0.80
HT group	445.8 ± 203.8	387.1 ± 130.1	397.0 ± 140.8	648.2 ± 193.4	
Vastus lateralis non-injured knee					
QT group	447.8 ± 261.8	442.8 ± 233.1	485.6 ± 233.5	603.3 ± 268.3	0.47
HT group	459.2 ± 158.4	426.1 ± 133.4	423.1 ± 121.1	566.5 ± 177.1	
Vastus medialis non-injured knee					
QT group	411.7 ± 213.1	407.8 ± 206.9	433.6 ± 197.2	549.1 ± 198.5	0.91
HT group	384.1 ± 140.9	369.0 ± 107.5	411.8 ± 151.6	546.2 ± 163.8	
Patellar tendon non-injured knee					
QT group	618.2 ± 364.4	545.4 ± 240.1	563.0 ± 306.7	632.5 ± 190.9	0.89
HT group	606.1 ± 215.7	589.3 ± 158.5	591.4 ± 171.9	670.8 ± 190.9	
Quadriceps tendon non-injured knee					
QT group	522.1 ± 273.3	507.1 ± 231.9	520.5 ± 205.8	690.4 ± 292.3	0.66
HT group	541.8 ± 205.1	536.1 ± 158.2	590.7 ± 175.2	659.8 ± 211.2	
Hamstring tendon non-injured knee					
QT group	417.7 ± 230.9	407.5 ± 186.9	410.0 ± 182.1	707.2 ± 281.4	0.48
HT group	445.3 ± 156.1	408.2 ± 115.7	411.9 ± 139.9	625.5 ± 177.2	

Values are expressed as mean ± standard deviation for pre, post-intervention and 6-month follow-up data (repeated ANCOVA test). QT: quadriceps tendon; HT: hamstring tendon.

Table 4
Structural measurements at baseline, at 3, 6 months and 1-year of follow-up.

Group	Pre-surgery	3-month follow-up	6-month follow-up	1-year follow-up	P value
Functional end points					
Thickness quadriceps injured knee (mm)					
QT group	6.8 ± 1.6	8.3 ± 1.8	7.6 ± 1.5	9.9 ± 2.4	0.22
HT group	6.3 ± 1.2	6.7 ± 1.2	7.7 ± 2.4	9.4 ± 1.7	
Thickness knee cartilage injured knee (mm)					
QT group	3.4 ± 0.5	3.0 ± 0.7	2.9 ± 1.1	3.2 ± 0.6	0.92
HT group	3.5 ± 0.7	3.1 ± 0.8	2.9 ± 0.9	3.2 ± 0.4	
Thickness quadriceps non-injured knee (mm)					
QT group	6.9 ± 1.2	7.2 ± 1.4	7.6 ± 1.4	9.1 ± 1.7	0.19
HT group	7.0 ± 1.6	6.8 ± 1.3	6.7 ± 1.3	9.5 ± 1.6	
Thickness knee cartilage non-injured knee (mm)					
QT group	3.2 ± 0.5	3.3 ± 0.9	2.7 ± 0.7	2.9 ± 0.6	0.21
HT group	3.4 ± 0.6	2.9 ± 0.6	2.8 ± 0.7	3.1 ± 0.3	

Values are expressed as mean ± standard deviation for pre, post-intervention, and 6-month follow-up data (repeated ANCOVA test). QT: quadriceps tendon; HT: hamstring tendon.

Discussion

The most relevant finding of this study was that the QT and HT autografts showed similar outcomes in terms of pressure pain threshold and ultrasound architecture outcomes after the 1-year follow up. The hypothesis of this study was confirmed given that both procedures showed similar results. The only difference was observed in the evolution of the QT group in the jump test performance, which showed better performance at 6 months from the baseline value, but it was not maintained at the 12th month evaluation.

We did not find differences between both grafts in the evolution of PPT of muscles in the knee region. However, a clear increase in PPT in both groups was observed at 1-year follow-up compared to pre-surgery values in muscles involved in the knee and also from a distance, which could be interpreted as a total recovery of pain after 1 year. Furthermore, the types of surgeries used in this study did not involve a decrease in PPT around the surgical area of the knee in the long term. These findings are in line with previous results of our research group regarding the ability of surgery procedures to normalise PPT, such as total hip replacement in hip osteoarthritis patients.[7] A possible explanation could be that inflammation and muscle response to knee instability could be implied in the initial pain trigger in ACL injuries.[20] ACL reconstruction with both techniques could reduce principal starter of pain in instability level and this could help to restore and improve pain threshold at 1 year. A recent study stated that patients with FQT autografts for ACL reconstructions suffered less pain and consumed less analgesics in the immediate postoperative period compared with HT autograft for ACL reconstructions.[6] Our study, with a different method to assess pain, did not show similar results. Future studies should be carried out to better understand the pain processes after ACL reconstruction.

Another relevant finding of this study is that there were no differences in ultrasound parameters in the FQT autograft at the donor site compared to the contralateral side and the HT autograft group after the 1-year follow-up. The results of this study differ from those obtained by Akkaya,[21] who found a decrease in strain ratio along with thickening and shortening of the quadriceps tendon in ACL reconstruction patients using a bone patellar tendon autograft. Similar results to our study have been observed in a previous research in animals, in which a 90% recovery of the mechanical properties of the patellar tendon was found following the removal of the central third of the patellar tendon.[22] The use of suture in tendon donor sites has been a resource of ultrasonographic abnormalities.[23] The fact that this QT graft was a partial thickness and partial width quadriceps tendon harvest and only small violations of the proximal suprapatellar pouch occurred could explain our results in the ultrasound images parameter of our study.

Nevertheless, this study presents several limitations: i) the sample size was small; ii) as a secondary report, this study was not powered for the outcomes presented in this study, hence significant differences were not found; iii) a single orthopaedic surgeon was involved in each study group, which could reduce the generalizability of these results; IV) finally, we have not control of graft's size in the HT group. Future studies must to study influence of graft sizes in ultrasound changes after ACL reconstruction.

In conclusion, with respect to ACL reconstruction, this secondary analysis shows that QT autografts obtained similar results to HT autografts in quadriceps muscle pressure pain threshold and quadriceps and knee cartilage thickness during the 1-year follow-up.

Conflict of interest

All authors have no conflict of interest.

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