Changes in muscle torque following anterior cruciate ligament reconstruction

A comparison between hamstrings and patella tendon graft procedures on 45 patients

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ABSTRACT – We designed a prospective study to examine the influence of graft type (hamstring or patella tendon) on thigh muscle torque recovery after anterior cruciate ligament reconstruction. 60 patients undergoing ACL reconstruction, using a hamstring or patella tendon graft, were studied and 45 were followed up to 1 year. Concentric and eccentric quadriceps and hamstring torque were recorded, using an isokinetic dynamometer preoperatively, 6 and 12 months after ACL reconstruction. We found an improvement in all muscle functions in both the operated and unoperated legs during the recovery period. Graft type had no effect on recovery. During the first 6 months, torque was restored to preoperative levels and continued to improve in all muscles and actions between 6 months and 1 year.

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In anterior cruciate ligament reconstruction (ACL), controversy still exists about the choice of graft between the bone/patella/bone or patella tendon graft (PT), and the four-strand semitendinosus and gracilis or hamstring tendon (HT) grafts. One of the reasons for the move towards hamstrings is the possibility of complications with the PT procedure (Rosenberg et al. 1992).

However, the recent popularity of the hamstring graft has been based on minimal objective supporting data, especially regarding muscle morbidity. Several studies have been published on isokinetic muscle strength following ACL rupture (Kannus 1988, Seto et al. 1988, Dvir et al. 1989, Kannus et al. 1992, Lephart et al. 1992, Hole et al. 2000, St Clair Gibson et al. 2000), and reconstruction, using a PT graft (McComb and Kerr 1992, Yasuda et al. 1992, Kramer et al. 1993, Chapman et al. 1995, Bush-Joseph et al. 2001); these are mostly based on retrospective data. Fewer studies have examined muscle strength following a hamstring graft (Lipscomb et al. 1982, Marder et al. 1991, Goradia and Grana 2001). Elmqvist et al. (1989) reported on the function of the knee extensors pre- and postoperatively. At 1 year, the normal preoperative strength had returned, but it was still less than in the unoperated leg. After reconstruction using the hamstring, graft conflicting results have been reported. Lipscomb et al. (1982) found no negative effect on hamstring torque, while Marder et al. (1991) noted a decrease in torque.

We studied the recovery pattern of concentric and eccentric muscle strength in knees reconstructed with HT or PT graft.

Method

We undertook a prospective observational study to examine the recovery of concentric and eccentric hamstring and quadriceps torque over a 1-year period in patients who had undergone arthroscopic ACL reconstruction.

Patients

60 consecutive patients admitted to the hospital for

ACL reconstruction were included in this study. The patients were those consisted of those undergoing primary anterior cruciate ligament reconstruction and able to undergo repeated testing at 6 and 12 months after surgery. Patients were excluded from the study if they reported marked pain, swelling or problems with the contra-lateral limb. 45 patients were successfully followed up to 1 year.

The anterior cruciate ligaments were reconstructed, using a 4-strand hamstring graft (HT) or a middle-third patellar tendon graft (PT). The same surgeon (CAD) performed all operations using an arthroscopically-aided technique, interference screws were used for fixation. Rehabilitation was standardized and done at the Nuffield Orthopaedic Centre NHS Trust and local centres, using an accelerated rehabilitation programme (Shelbourne and Nitz 1990).

Our local research ethics committee approved the study. An information sheet outlining the testing procedure was provided and all patients gave informed written consent to participation before any testing.

Procedure

Patients were assessed the evening before their operation and had their weight, height and leg dominance recorded. They were asked about their symptoms, including levels of pain, and the contralateral limb. They were then aligned on a Kincom 125* isokinetic dynamometer in a sitting position, with a hip flexion angle between 80°–90° and a 3 cm gap between the popliteal fossa and seat cushion, to permit free flexion of the knee. The lever arm was set so that the axis of rotation centrally aligned with the lateral joint line. The unoperated limb was always tested first in the sequence of muscle testing for each muscle action, followed by the affected/operated leg. We initially attempted a random order of testing, but discounted it as patients were found to be more comfortable using their uninjured limb first. The threat to validity by recording a non-maximal effort on the operated limb was thought to be greater than that posed by failure to use a random order of testing. Each patient was tested at the same time of day. Straps restrained the thigh and pelvis and the force transducer cuff was attached to the anterior tibia in a standardized position.

10 practice flexion/extension movements were performed before recordings were made; these were meant to warm the musculature and familiarize the patient with the apparatus and measurement requirements. An angular velocity of 60°/sec was set for all measurements, and the range of movement limits were set at 20° and 90° flexion. Full extension was not chosen since pilot studies showed that some patients could not begin an eccentric contraction from 0°. In addition, dynamic maximally-resisted extension into low flexion angles may threaten the graft postoperatively (Zavatsky et al. 1994). When the subject had become familiar with the device, we recorded the torque for quadriceps and hamstrings for both concentric and eccentric muscle actions. Verbal cues were given to the patient throughout. The added stage of gravity correction was found to weaken repeatability and was therefore not used. The omission of gravity correction was considered unimportant for this type of study design, where patients acted as their own control and percentage change in limb weight during the study is insignificant. The means of 3 repeatable torque/angle curves, with a 15-second rest between each, were stored for each action and muscle group and used for analysis. Repeat measurements were taken on the other unoperated leg.

The postoperative protocol, rate and type of progression of exercises were the same in both groups and were based on that described by Shelbourne and Nitz (1990). After surgery, a continuous passive motion machine was used to attain 90° knee flexion. Weight bearing as tolerated was encouraged. During the first 6 weeks after surgery, range of motion and strengthening exercises were encouraged including step-ups, straight leg raises, isometric hamstring and quadriceps, calf raises, hamstring catches, leg presses, squats, stationary cycling and stair climbing. After 6 weeks, activities in a lateral direction, light jogging, jumping rope, weight room activities, balance exercises, stationary bicycle and swimming were introduced. After 4 months, when the patients had a full range of motion they could start to run. Return to sports was encouraged after 4–6 months, if they had a full range of motion, no effusion and good knee stability.

At 6 and 12 months after surgery, all the measurements were repeated.

Table 1. Demographic details of 45 patients with ACL injury (complete data sets) and 15 patients with incomplete follow-up data

	Patellar tendon (n = 22)	Hamstring tendon (n = 23)	Non-attendees (n = 15)
Female	4 (18%)	8 (35%)	6 (40%)
Male	18 (72%)	15 (65%)	9 (60%)
Age (year)	30 (20–42)	34 (20–53)	34 (27–46)
Height (cm)	172 (160–185)	174 (155–189)	173 (159–183)
Weight (kg)	76 (58–95)	74 (58–97)	78 (62–98)
Leg dominance	40% dominant	60% dominant	44% dominant
Injury to surgery (mo)	46 (9–101)	55 (6–130)	54 (10–96)
Mechanism of injury			
RTA	0	1	0
Other	1	2	3
Non-contact	6	4	6
Contact	15	16	7

Analysis

The Kincom software generated measurements of mean torque throughout the range. Data were normally distributed. The differences between people who completed the full follow-up period (1 year) and those who did not were evaluated and tested for statistical significance using an independent sample t-test or chi squared test for any categorical data. For each graft type, mean torque values for the four muscle actions were computed at baseline (on the night before surgery), as well as at 6 and 12 months after surgery. We used a general linear model for repeated measures to evaluate whether changes in torque during the study were statistically significant, and if the graft type was a significant factor in determining recovery.

If statistically significant changes in torque were seen, other tests were used to establish the exact times when these occurred. Recovery was assessed between 0–6 months, and 6–12 months postoperatively. Changes were summarized as the mean difference and 95% confidence interval of the mean difference; statistical significance was analyzed with a paired t-test. The ratio of torque in the operated leg to the unoperated leg was calculated as another indicator of recovery of the leg. Statistical significance was set at the $p < 0.05$ level. We used the statistical package SPSS version 7.5 for analysis of the data.

Results

Only patients with full sets of data were included in the final analysis (n = 45). The reasons for loss to follow-up included relocation for work or family considerations, and failure to attend for measurements. The characteristics of patients lost to follow-up did not differ from the main sample (Table 1).

Raw mean torque values for baseline data and subsequent testing at 6 and 12 months postoperatively in both groups (HT and PT) are shown in Table 2. No statistically significant differences were seen between HT and PT groups at baseline (before surgery).

A further analysis focused on changes in muscle torque over a longer period for both muscle groups and both muscle actions by graft type. In the operated leg, improvement was seen as the overall trend in all 4 variables measured in the year after ACL reconstruction. The type of graft (whether HT or PT) had no statistically significant effect on the recovery of muscular function. Eccentric muscle action is used to show the similarity of the two groups because there is little published data about eccentric action. Since the type of graft had no effect, the data were added and changes over time examined for the entire sample.

Muscle torque of the hamstrings and quadriceps in the unoperated limb in both concentric and eccentric action steadily increased during the study (Table 2). Again we found no

Table 2. Raw values of concentric and eccentric muscle torque (Nm) in 45 patients with ACL injury who underwent ACL reconstruction. Mean (SD)

Graft type	Injured/operated limb			Unoperated limb		
PT = 22; HT = 23	Preop	6 months	12 months	Preop	6 months	12 months
Quads						
PT						
Concentric	103 (28)	92 (31)	109 (26)	117 (31)	129 (32)	134 (31)
Eccentric	134 (39)	131 (40)	158 (46)	152 (48)	171 (52)	172 (49)
HT						
Concentric	92 (35)	96 (30)	105 (29)	114 (43)	122 (51)	132 (39)
Eccentric	123 (48)	133 (41)	146 (50)	152 (59)	165 (51)	170 (62)
Hams						
PT						
Concentric	101 (32)	91 (30)	104 (31)	98 (29)	104 (25)	106 (29)
Eccentric	119 (33)	119 (37)	135 (37)	122 (37)	141 (46)	143 (45)
HT						
Concentric	86 (29)	77 (28)	91 (34)	94 (33)	95 (28)	103 (33)
Eccentric	111 (39)	106 (34)	117 (42)	121 (44)	128 (38)	132 (45)

Table 3. Changes in torque over time in the operated limb of 45 patients with ACL injury. Positive values signify an increase in torque (improvement), negative ones a decrease (deterioration)

	Pre op to 6 months			6–12 months		
	Mean torque change (Nm)	95% CI	P-value	Mean torque change (Nm)	95% CI	P-value
Conc. Hams						
HT graft	–8.0	0.5 to –16.7	0.06	10.3	–1.9–22.6	0.09
PT graft	–7.5	3.5 to –18.6	0.17	15.13	5.9–24.3	0.002
Ecc. Hams						
HT graft	–4.0	8.6 to –16.8	0.51	9.81	–6.7–19.7	0.05
PT graft	2.8	16.7 to –11.1	0.67	9.78	0.8–18.7	0.03
Conc. Quads						
HT graft	3.8	14.9 to –7.3	0.48	17.2	7.0–27.4	0.002
PT graft	–13.6	2.1 to –29.3	0.08	9.5	0.7–18.16	0.03
Ecc. Quads						
HT graft	10.8	27.9 to –6.1	0.19	25.8	12.0–39.5	0.001
PT graft	–2.8	18.2 to –12.6	0.70	16.0	0.5–31.4	0.04

statistically significant effects of the graft on recovery of muscular function of the unoperated limb. Muscle torque values in the operated limb were less uniform (Table 2). The muscle torques in both muscles and actions at 6 months were similar to those before surgery. However, muscle torque at 1 year had increased significantly from that at 6 months in all subjects and in both actions and muscle groups. This change is reflected in the data for relative changes over time (Table 3).

Changes in torque in the operated limb were also examined relative to the unoperated limb. The overall trend differed from that for raw torque values. Relative torque in all muscle groups and actions decreased after surgery. Concentric quadriceps torque of the operated limb was most affected by ACL injury and was the slowest to recover; it remained only 83% as strong as the unoperated limb even 1 year after surgery. At 1 year, all other muscle torque values in the operated limb had increased to at least 90% of the unoperated leg.

Table 4. Comparison of thigh muscle strength values in ACL-deficient knee studies (TSI = time since injury)

Author	Date	Patient sample	TSI (months)	Action and velocity	Torque variable	Hamstrings		Quads	
						Unoperated	Operated	Unoperated	Operated
Current study	2002	45	50	conc. 60° sec	average	96	92	115	97
				ecc. 60° sec		118	113	152	125
Kannus	1988	41	96	conc. 60° sec	peak	107	96	241	143
Dvir et al.	1989	35	N/A	conc. 30° sec	average	70	65	125	90
Lephart et al.	1992	41 [a]	26	conc. 60° sec	peak	114	106	211	187

[a] ACDLD

Discussion

The reduction in thigh muscle strength after ACL injury and reconstruction is well documented and has been further illustrated by our study. We compared values of torque magnitude in the ACL-deficient subject with other studies and found similar patterns in muscle strength deficits as seen in all other studies. As reported by others, the quadriceps muscles are more affected by anterior cruciate rupture when examined in relation to the uninjured contralateral limb, especially in concentric mode (Table 4).

The suggested reasons for muscle strength deficit following ACL rupture have been well reported and include various muscle atrophy models and neuromuscular deconditioning (Baugher et al. 1984, Elmqvist et al. 1989, Lorentzon et al. 1989). However, it could be argued that the isolated nature of the quadriceps deficit, with no hamstring involvement, supports the notion of compensatory muscle activation (Andriacchi and Birac 1993, Ciccotti et al. 1994), rather than any pathological atrophy or neuromuscular inhibition model (Snyder-Mackler et al. 1994, Hurley 1997). Quadriceps contraction will probably increase tibial translation in a sagittal unstable knee, but hamstring contraction will reduce tibial translation.

The main aim of our study was to compare muscle torque after patellar tendon or hamstring reconstructions. In agreement with others (Lipscomb et al. 1982, Aglietti et al. 1994, Carter and Edinger 1999), no great differences in muscle strength were seen between patients who had undergone reconstruction with HT or PT grafts at 1 year. A significant loss of quadriceps torque in the PT group might have been expected because the patella tendon autograft procedure compromises the extensor mechanism of the knee and may cause patellofemoral joint dysfunction. Weakness of hamstrings in the HT group might have been expected because of the harvest site for the HT graft. The major concern here is that damage to the flexor apparatus and, subsequent muscle weakness, may interfere with the vital stabilizing role of the hamstrings in the cruciate-deficient knee (More et al. 1993). The findings indicate that, in terms of muscle strength at least, one procedure is no better better than another for patients undergoing ACL reconstruction.

Carter and Edinger (1999) did a study similar to ours; 85% of their patients had a reconstruction within 3 months of injury. Our patients had chronic ACL instability, with a mean of 4 years between injury and reconstruction. The patients in both groups had a similar rehabilitation protocol postoperatively. Carter and Edinger followed their patients for 6 months after surgery and concluded that there were no differences between the strength of quadriceps and hamstrings from the different sources of the graft, but that most patients had not recovered adequate strength to participate in unlimited activity. In our study, the period of follow-up ws longer—up to 1 year after surgery.

We found that the pattern of change in torque over time showed a minimal change between preoperative and 6-month measurements. This does not mean that reconstruction had no effect on torque, only that by 6 months, the muscle torque may have returned to a level comparable to before surgery. In our study, unfortunately, no previous measurements were available to highlight the drop in torque, but Elmqvist et al. (1989) found a sudden reduction in the injured limb following reconstruction, particularly in the quadriceps. The significant changes in torque seen in all muscle groups between 6 and 12 months suggests that this period of recovery remains essential for complete rehabilitation and return to sports. Our study design did not include a control group and therefore we could not determine whether torque would spontaneously recover without rehabilitation. This must remain a possibility, although it has not been evaluated in any studies as yet.

We found increase in torque over time in the contralateral uninjured limb. This was probably due to the ACL reconstruction which permitted return to exercise and to the bilateral nature of training programs and functional activity. Some caution is necessary when using the contralateral limb as a "control". To avoid misinterpretation we recommend that both absolute and relative torque changes should be reported.

Relative torque in all muscle groups and actions decreased after surgery. However, this decrease is the combined effect of a substantial increase in torque in the unoperated limb and some slight decrease in torque in the operated limb. It can be seen that the relative torque of concentric quadriceps was affected most by the ACL injury and the slowest to recover; it remained only 83% as strong as the unoperated limb even 1 year after surgery. All significant changes occurred between 6 and 12 months postoperatively. At one year, all other muscle torque values the operated limb had increased to at least 90% of the unoperated limb.

There are some limitations in our study. Isokinetic evaluation has been criticized for lack of functional relevance, particularly as regards training (Elmqvist et al. 1989). Although this view is accepted, in view of the paucity of alternate methods of generating interval level muscle strength data, isokinetic evaluation remains a convenient and appropriate method of assessment after intervention. In agreement with other authors, only one speed of angular velocity was used, 60° per second (Marder et al. 1991, Rosenberg et al. 1992). The recovery at faster speeds would also be of interest as this may correlate with the increased speeds seen in sporting activities. Furthermore, it would have been good to have more measurements between those before surgery and at 6 months. Finally, because of the changes that were not significant and the small sample size, a power analysis must be done to avoid type II errors. Although the average power of the study was 0.7 to detect differences of 25 Nm between groups, a larger sample size and higher power would be preferable to detect smaller changes and for future studies.

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