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Isokinetic performance of the thigh muscles after tibial plateau fractures

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Summary. *The isokinetic performance of thigh muscles was evaluated in 37 patients at an average of 7 years after sustaining a fracture of the tibial plateau. The mean torque deficit in the quadriceps of the injured limb was an average of 15% at a speed of 60°/s and 16% at 180°/s, while the corresponding deficits in the hamstrings were 3% and 8%. The radiological appearance of the injured knee correlated significantly to the quadriceps deficit at both speeds. Limited knee movement and thigh atrophy also correlated with the deficit at the lower speed. The strength deficit tended to decrease during follow-up. A multiple step-wise regression analysis showed that the radiological result, length of follow-up and thigh atrophy accounted for 47% of the variation in loss of quadriceps strength. At the higher speed, the functional result was associated with the deficit in quadriceps strength, and older patients had greater deficits than younger. Regression analysis indicated that the radiological and functional result accounted for 31% of the variation in quadriceps strength. Anatomical restoration of the tibial plateau and good muscle rehabilitation are important in obtaining good long term results after this fracture.*

Résumé. *Nous avons évalué la performance isokinétique des muscles de la cuisse sur 37 sujets, en moyenne 7,4 ans après une fracture du plateau tibial. Le pic moyen du déficit (moment de torsion) du membre atteint a été de 15% à la vitesse de 60°/sec et de 16% à la vitesse de 180°/sec pour le quadriceps, et respectivement de 3% et 8% pour les fléchisseurs du genou. Le déficit de la force du quadriceps est en corrélation avec le résultat radiologique du membre atteint aux deux vitesses (respectivement P = 0.01 et P = 0.004). De plus, à la vitesse lente, la perte de force du quadriceps est en corrélation avec la limitation de mobilité du genou (P = 0.3) et l'atrophie de la cuisse (P = 0.04). Durant le suivi, ce déficit de force musculaire tend à s'atténuer (R = –0.35 pour un P = 0.04). Une analyse à régression multiple par étape a montré que le résultat radiologique, la durée du suivi et l'atrophie musculaire comptent pour 47% des variations observées dans la perte de la force musculaire du quadriceps. A la vitesse rapide, il y a corrélation entre la force musculaire du quadriceps et résultat fonctionnel (P = 0.008). Chez les sujets âgés la faiblesse musculaire a été plus grande que chez les sujets jeunes (P = 0.03). L'analyse régressionnelle a montré qu'à cette vitesse les résultats radiologiques et fonctionnels comptent pour 31% des variations observées dans la perte de la force musculaire du quadriceps. En conclusion, la restoration de l'intégrité anatomique du plateau tibial et une bonne réeducation musculaire semblent importants pour obtenir un bon résultat à long terme dans le traitement des fractures du plateau tibial.*

Introduction

Good strength of the quadriceps muscle is important in restoration function after tibial plateau fractures [12]. However, quadriceps function has

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been evaluated only indirectly by subjective criteria, such as weakness or easy fatigue of the thigh [2], or by comparing measurements of the circumference of the thighs [4].

Isokinetic dynamometers have been valuable in evaluating knee ligament injuries during the last 20 years [5, 10]. There have been, as far as we are aware, no studies of quantitative assessment of the performance of the thigh muscles after tibial plateau fractures.

The purpose of this study was to evaluate the strength of the quadriceps and hamstring muscles in patients after these fractures and to analyse the factors which might predict the long term outcome.

Patients and methods

Thirty-seven patients were assessed who had no history of injury other than the tibial plateau fracture in the involved knee, and no previous injuries to the opposite knee. There were 13 women and 24 men with a mean age of 39 years (range 15 to 61 years). The mean time between fracture and assessment was 7 years (range 3 to 13 years).

The fracture involved the lateral condyle in 22, the medial in 5 and was bicondylar in 10. The injury had been operated on in 21 cases, while the 17 fractures with minimal displacement were treated conservatively. A cylinder cast was used as conservative treatment and after operation (average 7 ± 2 weeks).

Isokinetic testing was carried out with the Cybex system (Cybex II, Lumex Inc, Ronkonkoma, New York). The subject was fixed to the apparatus with straps around the chest, pelvis, thighs and ankles, and was instructed to perform a sufficient number of submaximal and maximal repetitions of extension and flexion at both speeds, in order to become familiar with the system before testing was begun. The range of movement was 0° to 90°. Quadriceps and hamstring torque was measured first at a low speed of 60°/s with 5 maximal repetitions and, after one minute's rest, at a high speed of 180°/s with 25 maximal repetitions. The repetition was recorded in which maximal peak torque was produced. The first knee to be tested was chosen randomly in order to eliminate a learning effect. The total extension and flexion work done during the 25 repetitions at 180°/s was also recorded.

In the functional tests, the ability to walk, climb stairs, squat, jump and duck-walk were graded and recorded. Radiographs were analysed looking in particular at tilting of the plateau, the alignment of the leg; steps in the articular surface, condylar widening and secondary degenerative changes. The functional and radiological scoring in our previous study was used to classify the outcome of the injured knee [4].

All data were analysed using the programme library of BMDP-90 (BMP Software, UCLA, Berkeley, USA). The calculations between the differences of the means were made by Student's *t*-test (BMDP-3D). The relation between each continuous-type predictive variable and the outcome variables was determined by the regression equation (BMDP-6D). Within the noncontinuous-type predictors, the group means of outcome variables were compared by the analysis of variance (BMDP-7D). A multiple forward step-wise regression was then performed, starting with the predictor which had the strongest effect on the outcome in the individual comparisons (BMDP-2R).

Table 1. Thigh muscle strength in patients with an old tibial plateau fractures (n = 37, mean ± standard deviation)

	Peak torque (Nm)			
	Uninjured	Injured	Difference (%)	*P*-value
Quadriceps				
60°/s	175 ± 67	149 ± 61	15 ± 13	0.000
180°/s	103 ± 47	88 ± 44	16 ± 15	0.000
			P = 0.59	
Hamstrings				
60°/s	113 ± 45	108 ± 43	3 ± 12	0.05
180°/s	78 ± 36	70 ± 34	8 ± 20	0.007
			P = 0.07	
Total work				
Quadriceps	1957 ± 1008	1646 ± 928	17 ± 18	0.000
Hamstrings	1682 ± 863	1488 ± 794	10 ± 23	0.001
			P = 0.07	

Results

The mean torque deficit of the quadriceps in the injured knees was 15 ± 13% at 60°/s and 16 ± 15% at 180°/s (P = 0.000) (P = 0.59 for the percentage difference) (Table 1). The corresponding deficits were lower in the hamstrings at 3 ± 12% (P = 0.05) and 8 ± 20% (P = 0.007) respectively (P = 0.07 for the percentage difference). In total work, the deficit was 17 ± 18% in the quadriceps (P = 0.000) and 10 ± 23% in the hamstrings (P = 0.001); the percentage difference between quadriceps and hamstrings was also not significant (P = 0.07).

Comparison between the noncontinuous predictive variables and percentual deficits in the peak torque of both muscles after tibial plateau fractures are shown in Table 2. The radiological result was associated with a strength deficit of the quadriceps (P = 0.01 at 60°/s and P = 0.004 at 180°/s). There was a significant decrease in quadriceps strength in patients with limited knee movement at 60°/sec (P = 0.03 for both extension and flexion loss), but not at the higher speed (P = 0.41). Patients with any impairment in the functional tests showed significantly greater quadriceps strength deficits than those with a full functional score at 180°/s (P = 0.008). At 60°/s the difference was not significant (P = 0.08). There was no statistical relation between the peak torque deficits of the thigh muscles and the sex of the subjects, or between conservative or surgical treatment (Table 2).

The relation between continuous predictive variables and percentual differences in the peak torque of the thigh muscles after fracture are shown in Table 3. The deficit in quadriceps strength of the injured limb increased with age at

Table 2. The relation between the non continuous-type predictive variables and percentual deficits in the peak torque of quadriceps and hamstrings muscles of the injured extremity

		Quadriceps		Hamstrings	
Predictors	*n*	60°/s	180°/s	60°/s	180°/s
Sex					
Men	24	15 ± 15	15 ± 14	4 ± 10	10 ± 17
Women	13	15 ± 9	20 ± 17	2 ± 15	4 ± 26
P =		0.90	0.33	0.61	0.43
Treatment					
Conservative	16	14 ± 15	17 ± 20	3 ± 12	8 ± 24
Operative	21	16 ± 11	16 ± 10	3 ± 12	8 ± 17
P =		0.66	0.84	1.0	0.99
Radiological result					
Good	24	12 ± 14	11 ± 13	2 ± 13	8 ± 21
Fair	13	22 ± 9	26 ± 14	4 ± 11	8 ± 18
P =		0.01	0.004	0.64	0.97
Extension deficit					
No	27	12 ± 13	15 ± 15	4 ± 12	9 ± 19
Yes	10	23 ± 9	20 ± 14	2 ± 13	6 ± 22
P =		0.03	0.41	0.72	0.67
Flexion deficit					
No	29	13 ± 13	15 ± 16	2 ± 13	8 ± 22
Yes	8	24 ± 7	20 ± 9	6 ± 7	8 ± 13
P =		0.03	0.41	0.46	0.98
Functional result					
Normal	16	11 ± 13	9 ± 12	1 ± 11	6 ± 21
Impaired	21	18 ± 12	22 ± 15	5 ± 13	10 ± 20
P =		0.08	0.008	0.34	0.57

180°/s (R = 0.36), but not at 60°/s (R = 0.23 with P = 0.2). This deficit tended to decrease with the length of follow up at 60°/s (R = –0.35, P = 0.04), but remained unchanged at 180°/s. There was correlation between thigh circumference and quadriceps performance at 60°/s, but not at the higher speed. The body mass index and period of immobilisation did not show any statistical association with the deficit in quadriceps strength, nor did any predictive variable correlate with the hamstring tests (Table 3).

The forward-stepping regression analysis was started, according to the described quadriceps findings, by fixing the variable radiological result. Concerning the quadriceps deficit at 60°/s, inclusion of the predictive variables follow up time and atrophy of the thigh muscles significantly increased the prediction (R = 0.69, R^2 = 0.47). At 180°/s, the variable functional result significantly increased the prediction (R = 0.56, R^2 = 0.31). Since in the hamstrings no predictive variable showed an independent association with the outcome, namely the strength in the injured limb, regression analysis was unnecessary.

Table 3. The relation between the continuous-type predictive variables and percentual deficits in the peak torque of quadriceps and hamstring muscles of the injured limb

	Quadriceps				Hamstrings			
	60°/s		180°/s		60°/s		180°/s	
Predictors	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Age	0.23	NS	0.36	0.03	0.21	NS	0.01	NS
Body mass index	0.09	NS	–0.15	NS	0.03	NS	0.03	NS
Follow-up time	–0.35	0.04	–0.01	NS	–0.11	NS	–0.01	NS
Immobilization	0.05	NS	0.08	NS	–0.15	NS	–0.07	NS
Thigh atrophy	0.34	0.04	0.05	NS	0.03	NS	–0.04	NS

Discussion

Weakness of the thigh muscles is a well known consequence of lower limb injuries, but this is the first study which has evaluated the performance of these muscles after tibial plateau fractures. Our results show that several years after such fractures the patients had a weaker quadriceps in their injured than in their uninjured limb. There was, however, no difference in the severity of strength deficits between low or high speed movement which indicated lack of use of the limb during the average follow-up of 7 years. The same phenomenon has been found in ACL deficient knees [6].

Early movement has a beneficial effect on restoration of function of the knee and on cartilage healing [9, 11], the best function being achieved with early active exercises. We found that the length of immobilisation did not affect the severity of thigh weakness, but almost all our patients were treated in a cast for more than 6 weeks, so muscle weakness had already developed. The first few days after injury are critical in the prevention of quadriceps wasting.

Our most important finding was that the restoration of the radiological anatomy to normal, or nearly normal, after fracture was associated with the least loss of quadriceps strength. Loss of quadriceps strength measured at 180°/s was associated with the functional result. Our conclusion does not agree with reports which have found no association between the radiological and functional results [1, 8].

Our follow up was from 3 to 13 years during which the difference in quadriceps strength between the two knees tended to become equal (Table 3), indicating some recovery of atrophy in the slow-twitch muscle fibres while the fast-twitch fibres are unchanged. This is in keeping with the observation that immobilisation is associated with immediate atrophy of type I fibres, and that atrophy of type II fibres predominates after long disuse [6, 7].

Multiple step-wise regression analysis showed that at 60°/s the radiological result, length of follow up and the deficit in circumference of the thigh accounted for 47% of the variation seen in the loss of quadriceps performance, as determined by the R^2-value of these predictors. At 180°/s, the radiological and functional result accounted for 31% of the variation seen in this deficit.

Our results indicate that the best outcome will be achieved after tibial plateau fractures when the articular anatomy is restored accurately and this is followed by good muscle rehabilitation.

References

1. Apley AG (1979) Fractures of the tibial plateau. Orthop Clin North Am 10: 61–74
2. Hohl M, Luck JV (1956) Fractures of the tibial plateau. J Bone Joint Surg [Am] 38: 1001–1018
3. Dovey H, Heerfordt J (1971) Tibial condylar fractures. A follow-up of 200 cases. Acta Chir Scand 137: 521–531
4. Honkonen SE, Järvinen MJ (1992) Classification of fractures of the tibial condyles. J Bone Joint Surg [Br] 74: 840–847
5. Kannus P (1994) Isokinetic evaluation of muscular performance: Implications for muscle testing and rehabilitation. Int J Sports Med 15: S11–S18
6. Kannus P, Latvala K, Järvinen M (1987) Thigh muscle strengths in the anterior cruciate ligament deficient knee. Isokinetic and isometric long-term results. J Orthop Sports Phys Ther 9: 223–227
7. Nakamura T, Kurosawa H, Watarai K, Migashita H (1986) Muscle fiber atrophy in the quadriceps in the knee joint disorders. Arch Orthop Trauma Surg 105: 163–169
8. Rasmussen PS (1973) Tibial condylar fractures. Impairment of knee joint stability as an indication for surgical treatment. J Bone Joint Surg [Am] 55: 1331–1350
9. Salter RB, Simmonds DF, Malcolm BW, Rumble EE, Macmichel D, Clements ND (1980) The biological effect of continuous passive motion on the healing of full-thickness defects in articular cartilage. J Bone Joint Surg [Am] 62: 1232–1251
10. Sapega AA (1990) Muscle performance evaluation in orthopaedic practice. J Bone Joint Surg [Am] 72: 1562–1574
11. Schatzker J, McBrown R, Bruce D (1979) The tibial plateau fracture. The Toronto experience 1968–1975. Clin Orthop 138: 94–104
12. Schulak DJ, Gunn DR (1975) Fractures of the tibial plateau. A review of the literature. Clin Orthop 109: 166–177