MUSCLE FUNCTION AFTER MID-SHAFT FEMORAL SHORTENING

A PROSPECTIVE STUDY WITH A TWO-YEAR FOLLOW-UP

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We performed isokinetic knee testing to assess thigh muscle function in ten patients (12 legs) before and after mid-shaft femoral shortening averaging 46 mm (27 to 70). Tests were at angular velocities of 60°/sec and 180°/sec, and were performed preoperatively and after 3, 6, 12 and 24 months.

Isokinetic tests at two years showed a significant reduction in muscle function in both quadriceps and hamstrings, but recovery of function was significantly better for the hamstrings. There was a linear relationship with correlation of $r^2 = 0.31$ to 0.86 between loss of muscle force at two years and the magnitude of shortening. Long-term loss of muscle force should be expected after a mid-shaft shortening of the femur of more than 10%.

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Shortening of the femur may be performed for leg-length discrepancy (Szepesi et al 1990; Sasso, Urquhart and Cain 1993) or for unaccepted tallness (Persson, Unander-Scharin and Wiberg 1978; Olerud, Wallenstein and Olsson 1984; Nordsletten et al 1992).

To our knowledge there have been only two reports of objectively measured muscle function after femoral shortening. Olerud et al (1984) concluded that no muscle group ever returned to normal, and Nordsletten et al (1992) found that after mid-shaft shortening the quadriceps were relatively weaker than the hamstring muscles.

Others have reported no permanent loss of function. Blair et al (1989) concluded that muscle strength was equal on the two sides after unilateral shortening and that function was excellent. Kenwright and Albinana (1991) reported that shortening of 7.5 cm left no permanent loss of function, but

Fontanesi, Gianceschi and Rotini (1987) and Winquist (1986) emphasised that prolonged physiotherapy and exercise were necessary to achieve good muscle power and normal gait.

We studied muscle function over a period of two years after shortening using objective methods, and related it to the level of osteotomy and the magnitude of shortening.

PATIENTS AND METHODS

From 1989 to 1990 seven men and three women had 12 femoral shortening osteotomies in healthy legs. Their mean age was 22.5 years (16.6 to 29.2) and their mean preoperative height was 182 cm (170 to 191). Two had bilateral operations for unacceptable tallness; the other eight had operations for leg-length discrepancies resulting from idiopathic anisomelia (3), fracture of the femur (2), fibular aplasia (1), Perthes' disease (1), and pelvic osteosarcoma (1).

All shortenings were performed by two transverse osteotomies in the mid-shaft with removal of a bone segment. The femur was fixed by an intramedullary nail with distal and proximal locking screws (Fig. 1). The two patients who had bilateral surgery, had operations at a three-month interval. Full weight-bearing was allowed postoperatively, followed by an outpatient rehabilitation programme for three months under the supervision of a physiotherapist.

We measured muscle function in knee extension and flexion isokinetically on a Cybex 340 dynamometer (Cybex-Lumex Inc, Ronkonkoma, New York). Quadriceps and hamstring groups were tested preoperatively and at 3, 6, 12, and 24 months postoperatively. Before testing, each subject exercised for eight minutes on an ergometer cycle. On the apparatus, straps were used to secure the chest, pelvis, thigh and ankle; both limbs were tested, the uninvolved or dominant side first. During the testing, knee motion was restricted to the range from 0° to 90° with five repetitions at an angular velocity of 60°/sec followed by a one-minute rest period. After this, 25 repetitions at 180°/sec were performed. For evaluation we used the isokinetic peak torque (PT) at 60°/sec and the total work (TW) at 180°/sec.

At the 24-month review patients were asked for their opinion of their muscle function using a visual analogue scale.

We analysed the results using ANOVA for repeated

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Fig. 1

Postoperative radiograph after a mid-shaft femoral shortening osteotomy fixed by an intramedullary interlocking nail.

measurements with Fisher's probability by least significant difference post-hoc test. Differences between the first and the last tests and the differences in recovery between the two muscle groups were compared by paired *t*-tests. Simple linear regression analysis was used to find the relationship between recovery and relative femoral shortening (length reduction/original length $\times 100$). We considered *p* values of < 0.05 to be significant.

RESULTS

All osteotomies had healed primarily without complications after a mean operating time of 137 minutes (80 to 180) and a mean blood loss of 1213 ml (120 to 2250). The average femoral shortening length was 46 mm (27 to 70), giving a relative shortening of 9.3% (5.4 to 13.4).

No muscle group had returned to its preoperative

Fig. 2

Relative peak torque as a percentage of preoperative value at the angular velocity of 60°/sec for the quadriceps and hamstrings during follow-up (*, $p < 0.05$).

Fig. 3

Relative total work as a percentage of preoperative value at the angular velocity of 180°/sec for the quadriceps and hamstrings during follow-up (*, $p < 0.05$).

isokinetic strength at the two-year review; recovery was greater for the hamstrings than for the quadriceps (Table I). At three months, the average PT of the quadriceps was 31% of the preoperative value, compared with 53% for the hamstrings (Fig. 2). At two years, the mean quadriceps reduction was 26% for PT at 60°/sec ($p < 0.001$, Fig. 2), and 21% for TW at 180°/sec ($p < 0.01$, Fig. 3). For the hamstrings these differences were 12% ($p < 0.05$; Fig. 2) and 20% ($p < 0.05$; Fig. 3) respectively. The hamstrings had recovered

significantly better than the quadriceps at low speed ($p < 0.01$), resulting in a significant increase in the hamstrings/quadriceps PT ratios at 3, 6, 12 and 24 months compared with the preoperative values (Fig. 4).

The relationship between muscle force deficits at two years and the relative reduction in femoral length was linear at $r^2 = 0.56$ and $r^2 = 0.86$ for the hamstrings (Fig. 5a), and $r^2 = 0.31$ and $r^2 = 0.71$ for the quadriceps (Fig. 5b), for PT at $60^\circ/\text{sec}$ and TW at $180^\circ/\text{sec}$ respectively. Except for the quadriceps PT, muscle force after shortening of less than 10% ($n = 7$) did not differ significantly from the preoperative values, but shortening of over 10% ($n = 5$) resulted in a significant loss of muscle force for all parameters studied.

Fig. 4

Relative hamstrings/quadriceps ratios at angular velocities of $60^\circ/\text{sec}$ and $180^\circ/\text{sec}$ during follow-up ($p < 0.05$ between 0 and 3 months).

Fig. 5a

The average visual analogue score for patients' opinions was 89.6, but did not correlate well either with the relative length reduction or with the objective measurement of muscle recovery.

DISCUSSION

Our aim was to evaluate long-term muscle function after mid-shaft femoral shortening. At two years we found a significant reduction in force for both quadriceps and hamstrings, with more weakening of the quadriceps. There was a significant difference in recovery between the two muscle groups throughout the 24-month follow-up for PT at $60^\circ/\text{sec}$ and beyond six months for TW at $180^\circ/\text{sec}$. There was a significant increase in the hamstring/quadriceps ratios: this was 0.60 preoperatively and at three months exceeded 1.0, even for the lower angular velocity.

Isokinetic muscle strength is usually presented as PT at all angular speeds. We used PT as the strength parameter at $60^\circ/\text{sec}$, but used TW at $180^\circ/\text{sec}$ because this best expresses the ability to perform work over a given period of time, and is probably a better measurement of normal daily activities than PT.

Table I. Mean $\pm$ SD of peak torque and total work for quadriceps and hamstrings in ten patients (12 legs) before and after shortening at the femoral mid-shaft

Time	Quadriceps		Hamstrings	
	PT*	TW†	PT	TW
Preop	248.7 $\pm$ 63	2184.9 $\pm$ 486	143.6 $\pm$ 25	1466 $\pm$ 281
3 months	83.4 $\pm$ 32	863.4 $\pm$ 395	76.7 $\pm$ 21	845 $\pm$ 343
6 months	129.4 $\pm$ 35	1317.5 $\pm$ 477	112.2 $\pm$ 27	1143 $\pm$ 440
12 months	163.4 $\pm$ 45	1647.5 $\pm$ 520	113.9 $\pm$ 22	1170 $\pm$ 431
24 months	181.4 $\pm$ 47	1730.0 $\pm$ 598	125.5 $\pm$ 30	1191 $\pm$ 513

* peak torque (Nm) at $60^\circ/\text{sec}$

† total work (Joule) at $180^\circ/\text{sec}$

Fig. 5b

Linear regression of the total work (TW) at $180^\circ/\text{sec}$ at two years for the hamstrings (a) and quadriceps (b), related to the percentage of femoral shortening.

In our study the average shortening of 46 mm is about the length suggested as the upper limit by Kempf, Grosse and Abalo (1986). Relative shortening, probably a better measure than absolute values, averaged 9.3% in our study. We found a high correlation between percentage shortening and the decrease in total work ability at 180°/sec for both muscle groups at two years. This suggests that there is an upper limit for length reduction which will allow the regaining of normal muscle function after mid-shaft shortening. In our series this limit was about 10%: shortening of less than this produced only a moderate reduction of muscle performance.

After shortening, some time is needed to regain effective muscle contraction. Häggmark, Jansson and Eriksson (1981) point out that muscle spindles relax when there is no tension, and that this causes rapid atrophy of slow-twitch oxidative fibres. This may be because of loss of impulses back to the extrafusal muscle fibres via the monosynaptic reflex arc and cessation of the afferent impulses to the tonic type-1 fibres (Häggmark et al 1981). Leivseth and Reikerås (1992) considered that the muscle had to regain some passive stretch before any effective contraction can occur. Passive stretching with the development of isometric tension may be required to stimulate protein synthesis and prevent atrophy. These mechanisms could help to explain the considerable reduction in force which we found at three months, but they do not explain the differences between the two muscle groups.

The reason for the better recovery of the hamstrings has been widely discussed. Olerud et al (1984) considered that reduced muscle function was caused by selective atrophy of type-1 muscle fibres. In rats, Leivseth and Reikerås (1992) found a 28% reduction in the cross-sectional area of type-1 fibres and 23% for type-2 fibres in the vastus intermedius. They suggested that the atrophy was caused by the reduction of stretch and activity in the shortened muscle, but they took no biopsy from the hamstrings.

Similar changes have been found after knee injuries and knee surgery (Ingemann-Hansen and Halkjaer-Kristensen 1980; Häggmark et al 1981). Lopresti et al (1988) found selective atrophy of type-2 fibres in the quadriceps after repair of the anterior cruciate ligament and attributed the difference from type-1 atrophy to subject selection and timing of the biopsy. CT studies of thigh muscles have shown that loss of muscle tissue is greater in the quadriceps femoris than in the hamstrings after knee ligament injury (Ingemann-Hansen and Halkjaer-Kristensen 1980), and therefore this difference is probably not specific for shortening osteotomies although it may be more pronounced than after knee surgery.

Our patients started their training programme soon after operation and continued for about three months. It may be that supervised physiotherapy should be delayed for four to six weeks to allow muscles time to adjust and regain normal

passive stretch. Our results indicate that a prolonged training programme is important, especially for the quadriceps.

Mid-shaft femoral shortening is widely used (Kempf et al 1986; Blair et al 1989; Kenwright and Albinana 1991; Nordsletten et al 1992; Sasso et al 1993); we chose it because it allows immediate full weight-bearing. We found a greater loss of muscle strength, however, than after subtrochanteric osteotomy (Nordsletten et al 1992). Subtrochanteric shortening had a shorter operating time, less blood loss and a shorter time to union. There was better preservation of the normal strength relationship between quadriceps and hamstrings, probably because the quadriceps is less involved. When shortening is to exceed 10% of femoral length, subtrochanteric osteotomy should be preferred.

Most patients still admit mild weakness two years after a shortening osteotomy, but the ultimate consequence and effect on the normal activities are uncertain. It seems that improvement after two years is unlikely: the loss of muscle force is permanent.

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