Acta orthop. scand. 47, 101–107, 1976

POSTOPERATIVE RESTORATION OF MUSCLE STRENGTH AFTER INTRAMEDULLARY NAILING OF FRACTURES OF THE FEMORAL SHAFT

GÖRAN DANCKWARDT-LILLIESTRÖM & STAFFAN SJÖGREN

Departments of Orthopaedic Surgery and Clinical Physiology, University Hospital, Uppsala, Sweden.

The maximal isometric muscle strength of hip abduction, knee extension and knee flexion was measured in 23 patients operated on for femur diaphyseal fractures and fitted with a stable intramedullary Küntscher nail after reaming of the medullary cavity. The trauma, the immobilization and the surgery influenced the musculature of the operated as well as the intact leg. The muscle power recovered in a couple of years, but even after 2–6 years a significantly reduced power was found in the *knee extensors*, and a probably significant reduction in the power of the *knee flexors* in the operated leg when the two legs were compared. Malrotation of the fracture seemed to adversely affect the recovery of muscle power.

Key words: fracture; femur diaphysis; intramedullary nailing; muscle strength

Accepted 10.x.75

The most important aim in the treatment of fractures is to restore the function of the injured extremity to the maximum. The most reliable method of achieving this aim is by active exercise, during the healing process, of as many joints and muscle groups as the fixation methods allow (Charnley 1963, de Palma 1970, Palmer 1962 and others). With suitable diaphyseal fractures of the femur the intramedullary fixation with a thick intramedullary nail gives a fixation stable enough for the extremity to be weight loaded, at least partially, before healing of the fracture has taken place (Küntscher 1962, Müller et al. 1969, Böhler 1968). Thus, in connection with a follow-up of a group of patients with diaphyseal fractures of the femur, which were fixed with a stable intramedullary nail (Danckwardt-Lilliestrom 1973), it was considered to be of interest also to study the recovery of muscle power in the lower extremities. During the healing of the fractures all joints and muscle groups were actively trained in order to provide optimal conditions for the return of muscle power.

MATERIALS AND METHODS

The material consisted of 23 patients, 15 males and 8 females, with an average age of 29 years within the range 15–73 years. Fifteen of the fractures were transverse or short oblique, one

Table 1. The material divided into groups according to the observation time and rotatory dislocation.

Groups	Observation time (years)	Total number of patients
1. Total material	1 > 2	23
2. < 50 years	1 — 2	6
3. < 50 years	> 2	14
3a. < 50 years (rotatory dislocation)	> 2	5

was oblique, four were comminuted and three were double. Twenty of the fractures were situated in the middle third of the femur diaphysis, one in the upper, and two in the lower third. Seventeen fractures were treated with an intramedullary nail only, after reaming of the intramedullary cavity, four with a nail and cerclage, one with a compression nail and one with a compression nail and cerclage. Twenty-one fractures were treated with open reduction. Seven patients had sustained other serious injuries at the same time, four having fractures of a tibia diaphysis. For further details see Danckwardt-Lilliestrom (1973). The material has been divided according to age and observation time and also according to other special complications such as rotation deformities (Table 1).

Muscle strength measurements

Measurements of maximal isometric muscle strength during hip abduction, knee flexion and knee extension were performed using a technique and equipment described earlier from this hospital (Bäcklund & Nordgren 1969). A mechanoelectric transducer (Pressductor, ASEA, Sweden) was used for the measurements. Each test included three maximal efforts, each of a duration of about 3 seconds. The highest value recorded in each series was registered. Muscle strength values obtained from earlier studies in this hospital (Bäcklund & Nordgren 1969) and from a study by Asmussen & Heeböll-Nielsen (1961) were used as reference values. In our laboratory, healthy students of less than 30 years of age contributed to the reference values. These are regarded as representative for this age group and the values are also used routinely for patients up to 50 years of age. Asmussen & Heeböll-Nielsen (1961) used individuals up to 60 years of age and, in the present investigation, their reference values were used for patients of more than 50 years of age. Asmussen & Heeböll-Nielsen (1961) used a somewhat different system for muscle strength measurements, i.e. dynamometers with strain gauges instead of pressductors. There is, however, a fairly good agreement between the values obtained from the two materials.

Statistics

Standard statistical formulae were used. Mean values (Mean), standard deviation of the mean values (SD), mean difference ($\bar{d}$), and standard values of the mean difference (SEM $\bar{d}$) were calculated. Student's *t*-test was used for testing the significance and $P > 0.05$ was considered not significant, $P \leq 0.05$ probably significant, $P \leq 0.01$ significant and $P \leq 0.001$ highly significant.

RESULTS

Looking at *hip abduction* in the total material there was a probably significant difference between the muscle power values of the intact leg and the reference values and a highly significant difference between the operated leg and the reference values (Table 2 a). However, the numerical differences were small, and when the intact and operated legs were compared, the differences in muscle power were not significant (Table 2 b). As regards *knee flexion* there was a significant difference only in the comparison between the operated leg and the reference value (Table 2 a). Here also, the numerical values were small, but when the operated and intact legs were compared the difference was significant (Table 2 b). There were no significant differences from the reference values for *knee extension* (Table 2 a), but a comparison with the contralateral leg showed a highly significant difference with a numerically quite marked reduction in the value for the operated leg (Table 2b).

In patients aged less than 50 years, with an observation time of 1–2 years (group 2), there were no significant differences between the values of the intact leg and the reference values, whereas the difference between the values of the operated leg and the reference values

Table 2 a. Total material. Observation time 1 to more than 2 years. Muscle strength in Kp. SD signifies standard deviation of the mean value, $\bar{d}$ mean difference, SEM standard error of the mean difference and P significance. Comparisons between reference values (Bäcklund & Nordgren 1969, Asmussen & Heeböll-Nielsen 1961) and corresponding intact leg, and reference values and corresponding operated leg in hip abduction, knee flexion and knee extension.

	Reference	Intact leg	$\bar{d}$ ± SEM	$\bar{d}$, %	Reference	Op. leg	$\bar{d}$ ± SEM	$\bar{d}$, %
Hip abduction								
n = 23								
Mean	36.6	33.0	−3.5 ± 1.8	−9.6	36.0	30.6	−5.3 ± 1.6	−14.7
SD	6.7	11.9			6.3	11.0		
P			< 0.05				< 0.001	
Knee flexion								
n = 23								
Mean	24.3	24.2	−0.1 ± 1.4	−0.4	24.3	21.1	−3.0 ± 1.1	−12.3
SD	5.3	8.6			5.3	7.8		
P			> 0.05				< 0.01	
Knee extension								
n = 23								
Mean	58.2	61.9	3.7 ± 4.4	6.4	58.2	51.1	7.3 ± 4.1	−12.5
SD	7.4	26.8			7.4	24.4		
P			> 0.05				> 0.05	

Table 2 b. Comparisons between intact and operated legs.

	Intact leg	Op. leg	$\bar{d}$ ±SEM	$\bar{d}$, %
Hip abduction				
n = 23				
Mean	32.3	31.4	−1.9±1.1	−5.9
SD	11.7	10.9		
P			> 0.05	
Knee flexion				
n = 23				
Mean	24.2	21.1	−3.0±0.9	−12.4
SD	8.6	7.8		
P			< 0.01	
Knee extension				
n = 23				
Mean	61.9	51.1	−11.5±2.4	−18.8
SD	26.8	24.0		
P			< 0.001	

were probably significant in all tests (Table 3 a). When the two legs were compared, there was a probably significant decrease in the power of the operated leg as regards *knee flexion* and a significant decrease in *knee extension* (Table 3 b).

In patients aged less than 50 years, observed over a period of more than 2 years (group 3: the largest subgroup), there were no significant differences at all in the comparison between the intact and operated legs and their respective reference values (Table 4 a). A comparison between the two legs, however, showed a probably significant reduction of *knee flexion* values in the operated leg as well as a significant reduction of *knee extension* values (Table 4 b).

In patients aged less than 50 years, observed for more than 2 years, with fractures fixed with rotatory displacement (group 3a) there were no significant differences between the muscle power values of the two legs and their reference values. In this group, however, the values of the operated legs seemed to be a little lower than the corresponding reference values (Table 5a). A comparison between

Table 3 a. Patients aged less than 50 years. Observation time 1–2 years. Muscle strength expressed in Kp. Comparisons between reference values and corresponding intact leg, and reference values and corresponding operated leg in hip abduction, knee flexion and knee extension.

	Reference	Intact leg	$\bar{d} \pm$ SEM	$\bar{d}$, %	Reference	Op. leg	$\bar{d} \pm$ SEM	$\bar{d}$, %
Hip abduction								
n = 6					n = 8			
Mean	39.2	34.2	− 5.0 ± 2.9	− 12.8	37.0	30.0	− 7.0 ± 2.3	− 18.9
SD	5.5	5.6			6.4	8.0		
Range	28–42	27–40			28–42	20–40		
P			> 0.05				< 0.05	
Knee flexion								
n = 6					n = 8			
Mean	26.5	24.7	− 1.8 ± 1.4	− 6.8	24.8	20.9	− 3.9 ± 1.6	− 15.7
SD	4.7	1.3			5.3	1.6		
Range	17–29	20–27			17–29	19–23		
P			> 0.05				< 0.05	
Knee extension								
n = 6					n = 8			
Mean	61.8	64.8	3.0 ± 4.4	+ 4.9	59.3	48.1	− 10.0 ± 3.2	− 16.9
SD	6.3	13.6			7.4	7.8		
Range	49–65	47–82			49–65	39–52		
P			> 0.05				< 0.05	

Table 3 b. Comparisons between intact and operated legs.

	Intact leg	Op. leg	$\bar{d} \pm$SEM	$\bar{d}$, %
Hip abduction				
n = 6				
Mean	34.2	32.8	− 1.3 ± 3.3	− 3.8
SD	5.6	7.1		
Range	27–40	23–40		
P			> 0.05	
Knee flexion				
n = 6				
Mean	24.7	21.3	− 3.3 ± 0.8	− 13.4
SD	3.3	1.6		
Range	20–29	19–23		
P			< 0.05	
Knee extension				
n = 6				
Mean	64.8	48.0	− 16.8 ± 3.7	− 25.9
SD	13.6	9.0		
Range	47–82	39–63		
P			< 0.01	

the two legs showed no significant differences (Table 5 b).

All patients were able to leave the hospital within one and a half months after surgery. At X-ray check after 6 months, all fractures were healed. All patients (except two pensioners) had returned to work within 8 months of surgery (average 4.6 months, range 2–8 months). None of the patients had a knee extension defect exceeding 5°.

DISCUSSION

The erect position of man is a late acquisition in evolutionary development and hence relatively unstable. The muscles in the thigh, especially the quadriceps, which maintain this position, are, therefore, easily deranged by injury to the femur. Muscle wasting is rapid and muscle volume is difficult to regain. Therefore, it is of interest to know to what extent and how rapidly the muscles

Table 4 a. Patients aged less than 50 years. Observation time more than 2 years. Muscle strength expressed in Kp. Comparisons between reference value and corresponding intact leg, and reference value and corresponding operated leg in hip abduction, knee flexion and knee extension.

	Reference	Intact leg	$\bar{d} \pm$ SEM	$\bar{d}$, %	Reference	Op. leg	$\bar{d} \pm$ SEM	$\bar{d}$, %
Hip abduction								
n = 14								
Mean	36.9	37.1	0.3 ± 1.9	0.81	36.8	34.9	−2.0 ± 1.9	−5.4
SD	6.6	10.1			6.0	9.5		
P			> 0.05				> 0.05	
Knee flexion								
n = 14								
Mean	24.4	27.1	2.7 ± 1.7	11.1	24.6	24.6	−0.1 ± 0	−0.4
SD	5.7	7.7			4.9	6.4		
P			> 0.05				> 0.05	
Knee extension								
n = 14								
Mean	58.9	69.4	10.5 ± 5.6	17.8	58.9	60.4	−1.5 ± 4.9	−2.6
SD	26.4	7.4			6.8	23.8		
P			> 0.05				> 0.05	

Table 4 b. Comparisons between intact and operated legs.

	Intact leg	Op. leg	$\bar{d} \pm$SEM	$\bar{d}$, %
Hip abduction				
n = 14				
Mean	37.1	34.9	−2.3±1.4	−6.2
SD	10.1	9.5		
P			> 0.05	
Knee flexion				
n = 14				
Mean	27.1	23.7	−3.4±1.4	−12.6
SD	7.7	7.6		
P			< 0.05	
Knee extension				
n = 14				
Mean	69.4	60.4	−9.0±3.0	−13.0
SD	26.4	23.8		
P			< 0.01	

of the leg can recover after a femoral fracture, if the fracture is treated with an osteosynthesis stable enough to bear weight and is immobilized for as short a time as possible.

The results from all these cases indicate that the hip abduction power in the intact leg is more severely affected than other muscle groups studied. Likewise, on the operated side, hip abduction is the most affected, but also the knee flexion power is significantly reduced. The power of knee extension is numerically reduced to about the same extent, but, because of the wide distribution of the values, it does not appear significant in calculations. However, the extension power of the intact leg is very well maintained, resulting in the fact that an important and significant difference between the two legs can be registered. These results thus indicate that the hip abductors are affected on both sides, while in the operated leg it is mainly the knee extensors, and to a somewhat lesser degree, the knee flexors that show a reduced muscle power 1–6 years after an intramedullary nail has been introduced into a fractured femur.

A division of the material into smaller groups gives a better opportunity for analysing the importance, for muscle recovery, of, for instance, the age of the

Table 5 a. Patients aged less than 50 years. Observation time more than 2 years. Rotatory displacement of the fractured bone ends. Comparisons between reference value and corresponding intact leg, and reference value and corresponding operated leg in hip abduction, knee flexion and knee extension.

	Reference	Intact leg	$\bar{d} \pm$ SEM	$\bar{d}$, %	Reference	Op. leg	$\bar{d} \pm$ SEM	$\bar{d}$, %
Hip abduction								
n = 5								
Mean	33.8	35.8	2.0 ± 3.9	5.9	33.8	31.8	−2.0 ± 2.2	−5.9
SD	7.1	14.9			7.1	10.5		
Range	28–42	21–57			28–42	20–45		
P			> 0.05				> 0.05	
Knee flexion								
n = 5								
Mean	21.8	22.6	0.8 ± 0.5	3.7	22.2	22.2	−0.2 ± 1.1	−0.9
SD	6.2	5.6			5.9	5.6		
Range	16–29	17–29			16–28	17–31		
P			> 0.05				> 0.05	
Knee extension								
n = 5								
Mean	55.8	51.2	−4.6 ± 8.9	−8.2	55.8	43.2	−12.6 ± 6.4	−22.6
SD	8.0	26.7			8.0	20.7		
Range	49–65	25–90			49–65	18–67		
P			> 0.05				> 0.05	

Table 5 b. Comparisons between intact and operated legs.

	Intact leg	Op. leg	$\bar{d} \pm$SEM	$\bar{d}$, %
Hip abduction				
n = 5				
Mean	35.8	31.8	−4.0±2.1	−11.2
SD	14.9	10.5		
Range	21–57	20–45		
P			> 0.05	
Knee flexion				
n = 5				
Mean	22.6	19.8	−2.8±1.7	−12.4
SD	5.6	8.0		
Range	17–29	16–31		
P			> 0.05	
Knee extension				
n = 5				
Mean	51.2	43.2	−8.0±3.8	−15.6
SD	26.7	20.7		
Range	25–90	18–67		
P			> 0.05	

patient, the length of time since the operation and other special factors connected with the fractures.

In the group consisting of young patients with a short observation time, i.e. 1–2 years, the power of the intact leg was normal, while in the operated leg the power was considerably reduced, especially as regards knee extension. Thus, the results indicated that a stable fixation with an intramedullary nail allows satisfactory maintenance or a rapid recovery of the muscle power in the intact leg. However, the muscle power of the operated leg was not fully restored after 1–2 years; in particular this applied to the power of the quadriceps musculature. A factor contributing to the quadriceps being the most affected muscle group is, in all probability, this muscle being most traumatized in connection with the fracture and operation.

In young patients, 2–6 years after the accident, the muscle power of the intact

leg was numerically, but not significantly, greater than in the reference material. This may indicate that the patients had exercised their intact leg powerfully after the accident. On the fractured side the muscle power was about the same as in the reference material. When the intact and operated legs were compared, however, it was shown that the knee extension power was significantly lower on the operated side. Furthermore, the knee flexion power was reduced to about the same extent but with a lower degree of significance. Hence, the stable osteosynthesis in the medullary cavity seems to create conditions for the recovery of muscle power to practically normal values 2–6 years after surgery even in the operated leg. The muscles of the knee joint, particularly the extensors of the operated side, still did not acquire the same power as those on the intact side. In these patients the femur fracture was the predominating injury, and the osteosynthesis allowed full weightbearing on the operated leg, on an average, 1.8 months (range 0.5–5.0) after the operation.

With malrotation of the fracture of 10–20° there is a tendency (not significant) for a poorer recovery of muscle power, especially knee extension, in the operated leg.

REFERENCES

Asmussen, E. & Heeböll-Nielsen, K. (1961) Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis. No. 11.

Bäcklund, L. & Nordgren, B. (1968) Physical work capacity and muscular strength in patients undergoing rehabilitation. *Scand. J. rehab. Med.* **1**, 7.

Böhler, J. (1968) Closed intramedullary nailing of the femur. *Clin. Orthop.* **60**, 51.

Charnley, J. B. (1963) *The closed treatment of common fractures.* 3rd Ed. E. & S. Livingstone Ltd, Edinburgh and London.

Danckwardt-Lilliestrom, G. (1973) Intramedullary nailing of femoral shaft fractures after reaming of the medullary cavity. *Acta chir. scand.* **139**, 155.

Küntscher, G. (1962) *Praxis der Marknagelung.* F. K. Schattauer-Verlag, Stuttgart.

Müller, M. E., Allgöwer, M. & Willenegger, H. (1969) *Manual der Osteosynthese.* Springer Verlag, Berlin, Heidelberg, New York.

de Palma, A. F. (1970) *The management of fractures and dislocations.* V. B. Sonders Company, Philadelphia, London, Toronto.

Palmer (1962) *Öppen behandling av frakturer och ledskador.* Almquist & Wiksell, Stockholm.

Correspondence to: Göran Danckwardt-Lilliestrom, M. D., Department of Orthopaedic Surgery, University Hospital, S–750 14 Uppsala, Sweden.