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QUADRICEPS FUNCTION FOLLOWING FRACTURES OF THE FEMORAL SHAFT

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Assessment of the late results in patients treated for fracture of the femoral shaft involves complex problems (Aronsson 1956, Dencker 1963). In the numerous publications on this aspect the assessments have been based on a number of different criteria (Dencker 1963, Blichert-Toft & Hammer 1969). In an attempt to obtain more objective and reproducible parameters, we have studied, in particular, quadriceps function by measuring the isometric strength and dynamic endurance of this muscle.

MATERIAL

The material is derived from Odense Hospital and is from the decade 1957-1966. It is a selected one, as patients whose primary or after-treatment was carried out in other hospitals were excluded. Moreover, it includes only shaft fractures which, according to the definition of Dencker, were situated from 5 cm below the lesser trochanter to 6 cm above the distal end of the medial femoral condyle.

Out of 88 patients 75 presented themselves at follow-up. They represent 77 shaft fractures, as 2 were bilateral. 35 had only fractures of the femoral shaft, whereas 42 had other associated fractures. 34 fractures were right-sided and 43 left-sided. 15 fractures were complicated.

Figure 1 gives the age distribution and sex ratio. The youngest patient was 15 and the oldest 78 years of age at the time of the accident, average age 38.5 years. The age distribution shows a preponderance of persons under 30. Figure 2 presents the age and sex distribution in relation to the level of the fracture.

The follow-up period, calculated from the time of the accident, ranges from 4 to 13 years, average 7.0 years.

To classify the fractures by level and type, we used the method of Dencker (cf. Table 1). This classification was based upon revision of the primary X-ray films.

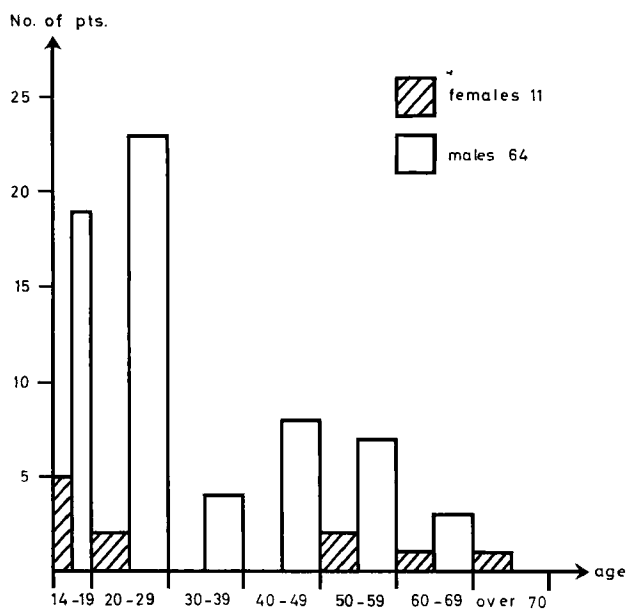


Fig. 1. Age distribution and sex ratio.



Fig. 2. Age distribution and sex ratio in relation to level of fracture.

Table 1. Classification and localization of 77 fractures of the femoral shaft.

Type of fracture	No. of fractures
Transverse	23
Short oblique	10
Long oblique	6
Comminuted	37
Double	1
Upper third	13
Middle third	49
Lower third	15

Table 2. Therapeutic method in 77 fractures of the femoral shaft.

Operative	No. of fractures
Street-Hansen nail	63
Rush pin	8
Parham band	1
Plates	2
Conservative	3

PREVIOUS TREATMENT

Table 2 lists the treatment of the 77 fractures. The routine method was osteosynthesis with intramedullary nailing by a strong, rhombic, massive nail (method of Street-Hansen). Through a direct, lateral approach above the fracture retrograde nailing was done. 53 fractures were treated in this way. In cases of 12 extremely comminuted fractures, this treatment was supplemented by Parham's band. In 24 cases it was further supplemented by a hip plaster cast. 8 fractures were treated by a Rush pin, in 4 cases supplemented by a hip cast. 2 fractures were treated by plates, in both cases 2 plates. One fracture was treated only by Parham's band and 3 by tibial condylar traction.

The principle of after-treatment was quadriceps exercises in bed from the 8th day in charge of a physiotherapist, ambulation with crutches from the 14th day, and permission for weight-bearing on the fractured leg after 3 months.

Otherwise, the treatment was individualized, according to the nature of the femoral fracture and the treatment of other, associated fractures.

METHOD

At follow-up all the knees were X-rayed. We also measured active knee flexion, the circumference of the thigh 8 and 15 cm above the patella, the length of the lower leg from the knee line to the tuberosity of the calcaneus, isometric strength, and dynamic endurance. The two last-mentioned measurements were only done in patients whose general condition allowed this exertion and whose knee flexion was $\geq 90^\circ$.

In the measurement of isometric strength and dynamic endurance, the patient was placed in the sitting position, his spine vertical and the entire thigh fully supported, but with a freely hanging lower leg. The patient was provided with a special shoe on which, at the level of the tuberosity of the calcaneus, a horizontal spring balance with a clock dial was fastened. After being carefully instructed in the procedure, the patient was asked to extend his lower leg, using maximum force, and the exerted strength was read in kg. In this manoeuvre the maximum elongation of the spring balance was 2 cm, so that the recorded strength is considered isometric. After the patient had rested for some time, his foot was fitted with weights. He was instructed in lifting his leg to an extended position and thereafter, in a given rhythm, extended the lower leg to this level. The first time that the fixed level could no longer be reached, the test was stopped.

Knowing the vector, viz. the length of the lower leg, the strength, viz. the load attached, and the way, viz. the number of elevations of the lower leg, it is possible to calculate the dynamic endurance.

The measurements of the strength were carried out on both legs. From the difference between the two we calculated the percentage reduction of strength in relation to the stronger leg. The calculations were done by computer, and in Tables 4 and 5 the difference is stated as negative in cases where the fractured leg was stronger than the other.

RESULTS

Osteoarthritis of the knee was assessed on the basis of the follow-up X-rays. As primary X-rays were not available for all the patients, we were unable to make a comparison with the condition at the time of the accident. The degree of osteoarthritis was classified as severe, moderate, and mild. Severe osteoarthritis of the fractured leg was found in 4 patients, moderate in 14, and mild in 28 patients. 18 patients had osteoarthritis of both knees. Two of them had had bilateral femoral shaft fractures. 13 patients exhibited shortening of the fractured leg. Measurement of strength was performed in 11 of these latter patients. All the fractures had united at the time of follow-up. In 29 cases the fracture had not united until one year after the accident. 20 of these patients had measurement of strength. None showed any notable deformity of the fractured leg.

Comparison of the level of the fracture (Table 1) with the incidence of osteoarthritis showed that osteoarthritis was present in 12 out

Table 3. Difference in circumference 8 and 15 cm above the patella in 57 patients.

	No. of patients	
	15 cm	8 cm
Fractured leg > good leg	9	15
No difference	17	15
Fractured leg —0.1 — 2 cm	30	18
Fractured leg —2.1 — 5 cm	1	9

Table 4. Percentage difference in isometric strength and dynamic endurance.

Percentage difference	Isometric strength No. of pts.	Dynamic endurance No. of pts.
Negative	9	11
0.1 — 5.0 per cent	5	2
5.1 —10.0 per cent	4	3
10.1 —15.0 per cent	9	6
15.1 —58 per cent (63 per cent)	30	31
Total	57	53

of 15 patients with fracture of the lower third, in 27 of the 49 patients with fracture of the middle third, and in 7 of the 13 patients with fracture of the upper third of the femur. In other words, there was a tendency for osteoarthritis to be more common the more distal the fracture.

Active knee movements were measured in the supine position in 73 patients, as 4 had undergone amputation and were naturally left out. 64 patients showed a flexion > 90°, 8 a maximum flexion of 60–89°, and one patient had a flexion of < 30°. An extension defect of 20° and 5° was found in 2 patients. 13 showed instability of the knee joint.

The difference in the circumference of the two thighs is shown in Table 3.

Isometric strength was measured in 57 patients and the dynamic endurance in 53. In the remaining patients these tests were not possible because of other diseases or insufficient mobility of the knee.

According to Heebøll-Nielsen's studies (1964) there is a difference in physiological strength of from 5 to 11 per cent between symmetrical muscle groups. In the present study we classified a difference ≥ 15

Table 5. Reduction in isometric strength and in dynamic endurance in relation to level of fracture.

Percentage difference	Level of fracture		
	Upper	Middle	Lower
	Number of patients		
<i>1. Reduction in isometric strength</i>			
Negative	1	7	1
0.1-15.0 per cent	3	12	3
15.1-58 per cent	6	19	5
<i>2. Reduction in dynamic endurance</i>			
Negative	1	10	0
0.1-15.0 per cent	5	5	1
15.1-63 per cent	4	21	6

per cent as pathological. Furthermore, we classified a reduction in circumference exceeding 2.1 cm as pathological.

Table 4 lists the percentage difference in isometric strength. In 9 cases the fractured leg was stronger than the good one. In 30 of the 57 patients there was a reduction in strength > 15 per cent. The maximum reduction was 58 per cent. On the average, the reduction of isometric strength was 30.6 per cent in the 30 patients.

The results of measuring the dynamic endurance are also given in Table 4. In 11 instances the fractured leg showed a greater dynamic endurance than the good one. In 31 of the 53 patients the dynamic endurance was reduced by > 15 per cent. The maximum difference was 63 per cent. On the average the reduction of dynamic endurance was 33 per cent. The difference between the fractured and the good leg was significant for isometric strength as well as for dynamic endurance.

(Isometric strength: T test: 6.420, d.f. 58, $p < 0.001$.)

(Dynamic endurance: T test: 5.429, d.f. 54, $p < 0.001$.)

Table 5 presents the measurements of strength in relation to the level of the fracture. It shows an increasing tendency to reduced strength the more distal the fracture.

Out of the 20 patients in whom the fractures had taken more than 1 year to unite, 12 and 14 respectively showed a reduction in the two strength measurements.

In the 11 patients having shortening of the fractured leg, the reduction of strength exceeded 15 per cent in 4 and 6 respectively.

We also calculated the mean of the two measurements of circum-

ference and related it to the measurements of strength. The difference in isometric strength correlated to the difference in circumference revealed a correlation coefficient of 0.271, which is statistically significant, but the correlation is slight (standard error 0.26). The corresponding correlation coefficient between dynamic endurance and circumference was 0.169, which is not significant (standard error 0.26).

DISCUSSION

Assessment of muscular function following fracture of a limb has received very scant attention in the literature and is little used as a criterion of assessing the therapeutic results. The status of the muscles following femoral fractures has often been assessed by measuring the circumference of the thighs (Blichert-Toft & Hammer 1969, Dencker 1963, Tophøj & Hanberg Sørensen 1969), whereas measurements of quadriceps strength have not been performed. In the present study we found a significant difference between the fractured and the good leg—in isometric strength as well as in dynamic endurance, there being an abnormal reduction of strength in the fractured leg in about two-thirds of the patients. The measurements of the circumference of the thighs proved insufficient for assessing muscular status, there being very little correlation between the circumference and the results of measuring muscle strength.

Measurements of the strength of healthy limbs have shown a certain tendency for right-sided muscle groups to be stronger than the symmetrical left-sided ones (Heebøll-Nielsen 1964), but the difference is not significant and cannot be attributed with any value. This was confirmed by our results, as we found a significant reduction in the strength of the fractured leg in 34 right-sided and 43 left-sided femoral fractures.

Experimental investigations (Hansen 1967) have shown that selective dynamic training of a muscle group increases only dynamic strength, but not definitely isometric strength. Reversely, isometric training increases only isometric strength. The same is indicated by our studies. Out of the 30 patients having an abnormally reduced isometric strength in the fractured leg, only 21 land in the same group that showed an abnormally reduced dynamic endurance. In the same way, only 20 out of the 31 patients with abnormally reduced dynamic endurance land in the same group as those with abnormally reduced isometric strength.

To obtain data as complete as possible concerning the muscle status, it thus appears to be necessary to perform both types of measurements—an observation to which regard must be paid in training programmes.

The four patients with severe osteoarthritis did not fulfill the named criteria of strength measurement. Out of the 14 patients with moderate osteoarthritis of the knee, 5 were found to have > 15 per cent reduction of strength in both measurements. Thus, in relation to the material as a whole, the group with moderate osteoarthritis does not exhibit an increased incidence of reduced strength.

CONCLUSION

Our study demonstrated that in measurement of isometric strength and dynamic endurance, about two-thirds of the patients showed an abnormally reduced strength of the quadriceps following fracture of the femoral shaft.

Patients with slight shortening or moderate osteoarthritis of the fractured leg did not exhibit an increased incidence of reduced strength as compared with the material as a whole. On the other hand, reduction of strength was increased in patients in whom the fracture had taken more than one year to unite.

Owing to the unequal distribution of the therapeutic methods in the present material, it is not possible to assess them mutually in relation to the results of measuring the strength.

There was little correlation between the circumference of the thighs and quadriceps strength, as there might be reduced strength despite slight or no measurable atrophy of the fractured leg.

As the recovery of normal quadriceps strength following femoral fracture is of great importance, we feel that measurement of quadriceps strength is a relevant parameter in the follow-up of patients treated for fractures of the femoral shaft.

SUMMARY

75 patients with 77 fractures of the femoral shaft were investigated at follow-up for atrophy of the thigh, osteoarthritis of the knee, and quadriceps strength which was measured as isometric strength and dynamic endurance. 35 of the patients had had isolated fracture of the femur, whereas 42 had had other associated fractures. 15 fractures

were complicated. Age at accident ranged from 15 to 78 years, average 38.5. The follow-up period ranged from 4–13 years, average 7 years. The principle of the primary and after-treatment is outlined. The method of the study—in particular of the measurements of strength—is described and the results are submitted. A significant difference was found between the fractured and the good leg. In isometric strength as well as in dynamic endurance a reduced strength was found in about two-thirds of the patients.

It is concluded that measurement of strength is a relevant method and that both types of strength test should be performed in order to obtain as complete data as possible concerning the status of the quadriceps.

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