Muscle strength in children treated for displaced femoral fractures by external fixation

31 patients compared with 31 matched controls

Hanne Hedin[1] and Sune Larsson[2]

Orthopaedic Departments, [1]Falun Hospital, SE-791 82 Falun, [2]Uppsala University Hospital, Uppsala, Sweden.
Correspondence: hanne.hedin@ltdalarna.se
Submitted 02-02-14. Accepted 02-10-21

ABSTRACT In a prospective study (1993–2000), we measured the isokinetic strength of the quadriceps and hamstring muscles in 31 children aged 5–17 years, on average, 3 (1.5–5) years after treatment for a displaced femoral fracture by external fixation and early mobilization. A group of age-, sex- and weight-matched children without previous injury were used as controls. The hop-index test was used to assess the patient's confidence in the injured limb and was similar in the fractured and unfractured legs as well as in the patients and controls.

We measured the peak torque output at 2 angular velocities (60°/s and 180°/s) in the hamstring and quadriceps muscles, using Cybex testing equipment. Torque to body weight ratios were used to compare muscle strength in patients and controls.

We found no differences in muscle strength between patients and controls or in the distribution of which leg was stronger, equal or weaker in the patients or controls at any test speed.

External fixation and early mobilization seem to prevent residual muscle weakness, which occurs with traction or a cast for femoral fractures in children.

Femoral fractures in children heal quickly and often remodel almost completely. The presumption that recovery will occur without long-term residual muscle weakness has been challenged by several authors. Damholt and Zdravkovic (1974) measured the isometric strength and dynamic endurance of the quadriceps and found a substantial reduction of strength in the affected leg. 47 of their 53 patients had been treated with a cast and/or traction. Neel and Glancy (1990) used a Cybex dynamometer to assess 15 children at least 2 years after a closed mid-shaft femoral fracture treated by traction and a cast. They found that 14 children had a reduction in quadriceps strength on the injured side. Hennrikus et al. (1993) evaluated 33 patients, treated with traction and a cast for an isolated femoral fracture, with the Cybex dynamometer and found that 13 had a reduction in quadriceps strength when tested 1.5–5 years after the fracture.

We studied whether any change in muscle strength occurred in children treated for displaced femoral fractures by external fixation and early weight bearing

Patients and methods

We measured muscle strength in a prospective and consecutive series (1993-2000) of 70 children with 71 displaced femoral fractures, whose fractures had been treated by unilateral external fixation (Monotube system, Stryker Howmedica Osteonics, Malmö, Sweden) and early mobilization. The children were allowed unrestricted weight bearing, as tolerated, from the day after surgery when mobilization with crutches or a small walking frame was begun. All of them could walk without crutches or any other walking aid at 2–4 weeks. All fractures healed. The fixator was removed, on average, 58 (38–127) days after the fracture.

The inclusion criteria for this study were at least 18 months of follow-up after the fracture to permit recovery of muscle function, remodeling

Copyright © Taylor & Francis *2003. ISSN 0001–6470. Printed in Sweden – all rights reserved.*

of the femur and overgrowth. Of the 70 children, 19 did not meet the criteria of at least 18 months of follow-up and 14 lived in other parts of the country. Of the remaining 37 patients, 3 declined to participate in the study, 1 had bilateral fractures, and 2 had a slight mental dysfunction and could not cooperate during various tests. Thus 31 patients with as many fractures were available for evaluation (Table 1).

The fractures were classified as transverse, oblique, spiral or comminuted. The location of the fractures was divided into upper-, middle- and distal third of the shaft from the inferior edge of the lesser trochanter to 2 cm above the distal physis. Displacement of the fracture was measured as a percentage of the diameter of the shaft at the fracture site. Leg length discrepancy at 1 year was measured radiographically with standardized orthograms (Green et al. 1946, Morscher and Figner 1972). Thigh circumference was measured 10 cm proximal to the proximal edge of the patella.

The 31 patients (22 boys) were 7 (3–15) years old at the time of fracture. At the time of testing, their median age was 11 (5–17) years. The median time after the fracture was 34 (18–62) months. None of them received any specific physiotherapy after discharge from the hospital.

To estimate the muscle strength of normal children, we chose a control group from the same school population in the same county. It was healthy children with no history of fractures to the lower limb. They were asked at random through their parents to participate by the physiotherapist who did the test. Our aim was to obtain one matched control for each patient. The most important factors for comparing muscle strength and physical performance between individuals are gender, weight, height and age (Molnar and Alexander 1973). These variables were therefore used during the matching procedure. We found no statistical difference as regards these variables (paired t-test). The median age of 31 controls was 11 (5–17) years. Dominance of the leg was determined by which foot the child used to kick a ball (Hennrikus et al. 1993).

The hop-index test was used to assess strength in the quadriceps muscle and the patient's confidence in the function of the injured limb. 3 one-leg hops were done on each leg after which the average hop distance was calculated and used for comparison. The hop-index was defined as the average distance for the leg with a "fracture" as a percentage of the distance for the uninjured leg. In children, a hop-index of 90% or more is considered normal (Sachs et al. 1989).

The study was approved by the Ethics Committee of Uppsala University. The parents of the children gave their informed consent and the study was done in compliance with the Helsinki declaration.

Cybex testing

Muscle strength during flexion and extension of the knee was measured with a Cybex 6000 extremity testing and rehabilitation system (Cybex Division of Lumex Inc, Ronkoma, NY). Two physiotherapists experienced in treating children and familiar with the system did the tests in a standardized way (Montgomery et al. 1989). After warming up and performing the hop-index test, the Cybex test was done at 2 test speeds of 60° and 180° per second. The uninjured leg was tested first. The child was allowed 5 sub-maximum contractions at each speed to become familiar with the system. During the test, each child performed 5 consecutive repetitions at each test speed with a 3-minute rest between them. The peak torque (maximum voluntary torque output) was measured in both the extensors and flexors of the knee. The difference between the involved and uninvolved legs was given as a percentage and had to be at least 15% to be considered a true deficit (Montgomery et al. 1989). The torque to body weight ratios (peak torque as a percentage of body weight) was used to compare muscle strength between patients and controls. The average range of motion of the 5 consecutive repetitions at each test speed was recorded and compared with the maximum range of motion (0–90 degrees). The results should not differ by more than 5 degrees and they were used as a control of the child's ability to perform the test.

Statistics

SPSS was used for the statistical calculations (Version 10.0 for Windows, SPSS, Chicago, IL). A 2-sided paired Student's t-test was used to determine whether there were any statistically significant dif-

Table 1. Clinical data of 31 patients treated for displaced femoral fractures by external fixation and early weight bearing and 31 sex-, age- and weight-matched controls

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Patients																		
1	m	4;1	6;6	S	r	71	2	0.8	34	109	11	11	9	9	11	19	11	14
2	m	3;7	5;11	S	l	76	2	0.3	42	98	23	14	27	9	22	20	46	9
3	m	3;5	4;11	S	l	80	2	0.8	53	128	11	14	7	11	19	19	14	12
4	m	4	8;8	C	l	176	2	2.2	83	86	27	35	23	23	52	50	35	34
5	m	7	8;11	S	l	69	2	0.7	50	93	31	28	26	24	43	27	33	34
6	m	6;9	9;3	T	l	65	1	–0.5	47	99	26	27	16	20	39	43	30	33
7	m	8;7	12;1	T	l	66	2	1.1	70	102	38	46	34	43	64	53	52	45
8	m	7;1	11;9	O	r	45	2	–0.8	67	99	56	46	49	39	100	87	64	62
9	m	10;1	11;11	C	r	110	2	2.2	53	112	52	42	38	33	76	77	46	45
10	m	7;9	10;8	O	l	93	1	2.1	61	91	33	41	33	34	53	61	50	49
11	m	7;1	11;11	C	r	60	2	0.3	62	109	49	45	35	20	91	87	58	49
12	m	3;1	5;11	S	r	41	2	0.1	43	117	22	19	20	15	28	38	22	18
13	m	8;11	11;7	C	r	100	2	0.9	50	93	49	41	41	47	80	83	68	72
14	m	8;7	12;11	S	r	59	2	0.3	48	101	68	69	56	46	106	118	66	77
15	m	9;7	12;8	O	r	131	2	–0.4	55	95	60	56	45	42	87	100	69	65
16	m	6;5	9;7	O	l	45	3	0.6	47	100	49	41	27	27	79	71	52	42
17	m	9;11	12;9	O	r	108	2	–0.4	56	90	68	56	45	41	89	89	68	68
18	m	9;7	13	S	r	95	2	0	63	89	64	66	60	64	103	117	71	84
19	m	11;1	14;2	T	l	72	2	0.7	63	102	85	88	56	52	141	129	91	72
20	m	11;8	16;2	C	r	52	2	–0.4	127	99	56	72	60	56	111	102	61	72
21	m	12	15;9	T	l	40	2	0.5	68	97	111	107	96	95	156	183	111	126
22	m	12;6	14;7	C	r	102	2	–0.8	62	100	115	118	94	87	199	178	136	118
23	f	4;3	6;9	T	l	50	1	–0.5	39	85	11	12	9	11	22	22	16	15
24	f	6;3	8	C	r	60	3	0.1	46	113	26	8	16	14	34	23	23	26
25	f	6;4	9;4	T	r	236	1	1.2	46	88	22	15	15	14	45	41	30	28
26	f	10;6	12;1	S	l	75	2	–1.2	68	102	54	68	43	49	79	94	64	66
27	f	4;4	6;11	T	l	128	2	0.3	60	82	23	26	11	14	47	43	30	27
28	f	15;4	17;7	C	l	155	2	0	67	100	35	45	20	19	50	72	35	33
29	f	6;1	11;3	C	l	87	2	0.6	48	95	39	35	23	22	76	92	54	49
30	f	10;8	12;6	S	l	106	2	1	58	100	73	8	57	46	140	142	85	98
31	f	14;4	17;11	C	r	45	2	–1.1	83	105	57	69	38	43	91	104	47	66
Controls																		
1	m		5;3							88	18	15	7	5	20	22	11	14
2	m		5;11							101	18	15	4	11	30	19	16	22
3	m		6;6							92	27	14	3	7	43	27	18	18
4	m		6;1							83	5	7	7	8	26	20	20	14
5	m		6;11							92	20	20	14	5	38	34	23	20
6	m		11;6							108	10	23	11	14	23	46	23	24
7	m		10;6							100	39	37	31	28	53	60	39	34
8	m		12;5							98	43	41	30	32	79	81	54	49
9	m		9;6							78	33	37	22	27	61	61	43	45
10	m		9							81	38	34	34	31	56	68	58	53
11	m		13;9							101	47	54	38	46	92	89	65	65
12	m		7;10							97	38	42	28	30	52	60	41	42
13	m		10;11							109	50	57	43	31	81	47	66	34
14	m		12;6							97	53	56	38	53	98	121	68	72
15	m		12;8							101	76	88	62	69	127	121	92	89
16	m		11;11							97	56	57	45	45	98	92	71	66
17	m		11;5							87	58	50	47	46	81	75	57	53
18	m		14;3							105	75	83	61	69	141	155	107	108
19	m		12;1							96	60	30	46	47	98	98	73	73
20	m		15;8							101	85	89	71	80	140	152	107	107
21	m		15;2							102	89	92	77	92	178	159	129	118
22	m		12;5							113	58	49	46	37	127	113	84	77
23	f		5;1							92	12	12	14	9	30	31	23	20
24	f		6							82	19	12	14	16	28	22	23	19
25	f		9;8							96	19	28	15	23	53	47	37	31
26	f		7;9							129	38	42	28	30	52	60	41	42
27	f		9;3							99	27	19	11	11	62	47	18	33
28	f		14;6							100	54	68	45	49	68	103	53	77
29	f		11;7							98	42	41	35	33	80	75	61	57
30	f		17;1							93	75	79	43	65	144	119	84	76
31	f		17;9							94	50	42	49	37	122	100	87	71

Legends for Table 1

A. Patient case number and Control case number.
B. Gender: m= male; f= female
C. Age at fracture (years; months)
D. Age at cybex testing (years; months)
E. Fracture type: S=spiral, O=oblique, T=transverse, C=comminuted
F. Fracture side: r=right. l=left
G. Displacement at the time of fracture (%)
H. Fracture location: 1= upper third. 2= middle third. 3= distal third
I. Difference in leg length at one year follow up. cm. plus = overgrowth. minus = shortening
J. Duration of treatment, days
K. Hop–index: average distance of 3 one–leg–hop for the fractured leg as a percentage of the distance for the uninvolved leg
L. Peak torque at 60 degrees flexion for the fractured leg in patients and the non–dominant leg in controls. Nm
M. Peak torque at 60 degrees flexion for the non–fractured leg in patients and the dominant leg in controls. Nm
N. Peak torque at 180 degrees flexion for the fractured leg in patients and the non–dominant leg in controls. Nm
O. Peak torque at 180 degrees flexion for the non–fractured leg in patients and the dominant leg in controls. Nm
P. Peak torque at 60 degrees extension for the fractured leg in patients and the non–dominant leg in controls. Nm
Q. Peak torque at 60 degrees extension for the non–fractured leg in patients and the dominant leg in controls leg. Nm
R. Peak torque at 180 degrees extension for the fractured leg in patients and the non–dominant leg in controls. Nm
S. Peak torque at 180 degrees extension for the non–fractured leg in patients and the dominant leg in controls. Nm

ferences between the patients and controls as regards demographic data and muscle strength. Chi-Square with exact significance and 2-sided tests were used to compare muscle strength to various clinical parameters. The independent samples test was used to compare muscle strength in boys and girls.

The chosen level of significance was $p < 0.05$.

Results

Clinical parameters

Boys were slightly stronger than girls at the same age, although the difference was not statistically significant. We found no statistically significant differences in muscle strength as regards various fracture types, different locations of the fracture or between those with a displacement at the time of fracture above or below 100%. There was a reduction in circumference of the thigh after 1 year in 13 of 31 patients, but no statistically significant difference in muscle strength between patients whose fractured leg was smaller and those whose fractured leg was equal or larger in circumference. The average duration of treatment was 58 days with no significant difference in muscle strength between those treated for more or less than 58 days. Moreover, there was no statistically significant difference in muscle strength was detected between those with residual shortening of the fractured leg and those with lengthening of the fractured leg at the 1-year follow-up. None of the patients had a side difference in range of motion in the knee joints, which exceeded 5°.

At the time of testing muscle strength, patients and parents were asked if there was any subjective feeling or sign of residual weakness in the fractured leg. Only one boy reported persistent weakness, although his previously injured leg was not weaker than his uninvolved leg during the test.

Hop-index

The fracture was in the dominant leg in 16 of the patients and in the nondominant leg in 15. 30 patients had the right leg as the dominant leg. 5 had a slight deficit in the hop-index (range 82–89%), while 13 had a hop-index > 100% (range 101–128%)—i.e., their average hop distance was longer with the previously fractured leg than the uninvolved leg. The average in those with a fracture in the nondominant leg was 97% (SD 10), and in those with a fracture in the dominant leg the average was 101% (SD 8.9) ($p = 0.3$).

In the controls, the right leg was dominant in 29 subjects, while 2 children used both legs equally. 6 controls had a slight deficit in the hop-index (81–88%), while 12 had a hop-index > 100% (101–129%). The average was 97% (SD 10).

A comparison of the hop-index in patients and controls showed no statistical difference ($p = 0.42$).

We found no association between a slight reduction in hop-index and muscle strength.

Table 2. Mean peak torque of both legs in 31 patients and 31 controls at various angular velocities

Direction	Velocity °/sec	Patients				Controls			
		Fractured leg		Unfractured leg		Dominant leg		Nondominant leg	
		mean [a]	95% CI [b]	mean	95% CI	mean	95%CI	mean	95%CI
Flexion	60	47	37–56	44	34–54	43	34–52	43	34–51
Flexion	180	36	28–45	34	26–42	35	27–43	33	25–40
Extension	60	75	59–92	77	60–93	75	60–90	77	61–92
Extension	180	53	42–63	52	41–63	52	42–63	55	43–66

[a] Mean, measured in Newton meter Nm
[b] Confidence interval

Table 3. Peak torque to body weight ratios in patients and controls. Fractured leg in patients compared to nondominant leg in controls and non-fractured leg in patients compared to dominant leg in controls

Direction	Velocity °/sec	Patient Fract. leg [a] Mean [b]	Control Nondom. l. [c] Mean	Differ-ences in means	95%CI [d]	Patient Unfract. l. [e] Mean	Control Dom. leg [f] Mean	Differ-ences in means	95%CI
Flexion	60	110	102	7.8	-23–7	104	103	1.5	-20–17
Flexion	180	86	75	12	-25– 2	80	79	0.5	-15–14
Extension	60	176	184	7.6	-13–29	178	178	0.7	-18–20
Extension	180	128	128	0.4	-18–19	122	124	2.9	-14–19

[a] Fractured leg
[b] Mean of peak torque to body weight ratios
[c] Nondominant leg
[d] 95% Confidence interval for the mean differences
[e] Unfractured leg
[f] Dominant leg

Muscle strength

The muscle testing was done, on average, 34 (18–62) months after the fracture. The findings in those tested between 18–34 months after the fracture (17 patients) did not differ statistically from those tested between 35–62 months after the fracture (14 patients).

In knee flexion at 60°/sec, the mean peak torque was 47 (37–56, CI 95%) Nm in the fractured leg and 43 (34–51, CI 95%) Nm in the nondominant leg in the controls. In the unfractured leg, the mean peak torque was 44 (34–54, CI 95%) Nm and 43 (34–52, CI 95%) Nm in the dominant leg in the controls (Table 2).

We found no statistically significant difference betwen the means in the fractured and unfractured legs in patients and the means in the dominant and nondominant legs in the controls onflexion (paired t-test). The fractured leg was equal or stronger in 25 patients and weaker in 6 while in the controls, the dominant leg was equal or stronger in 27 children and weaker in 4.

No statistically significant differences in the means were detected between the legs in the patients or controls on extension (paired t-test) (Table 2). The fractured leg was equal or stronger in 25 patients and weaker in 6. In controls, the dominant leg was equal or stronger in 27 children and weaker in 4.

We found no statistically significant difference as regards torque to body weight ratios between the fractured leg in patients and the nondominant leg in the controls or the unfractured leg in the patients and the dominant leg in the controls (paired t-test) (Table 3).

The patients and controls showed no statistically significant difference in hamstring to quadriceps power ratios between the involved and uninvolved legs at either of the test speeds.

The average range of motion differed between 0–6 degrees from the maximal range of motion at all test speeds.

Discussion

One of the goals of our treatment protocol—early mobilization to avert long-standing muscle weakness that might follow when a leg is kept in traction or a cast for a long time (Neel and Glancy 1990)—was fulfilled.

A potential limitation when performing maximal muscle testing after a fracture is that patients may be afraid to put their full weight on the previously fractured leg. We addressed this problem in several ways. The hop-index test was used mainly to assess the child's confidence in the injured leg, but this test seemed to be of no value for evaluating quadriceps strength, a finding in accordance with Hennrikus et al. (1993). We needed at least 1.5 years after the fracture until testing to permit recovery of muscle strength (Neel and Glancy 1990, Hennrikus et al. 1993). Moreover, all tests were done by the same physiotherapists to reduce any differences caused by inter-observer variation. None of the children had any adverse symptoms from the legs during the tests. The most important factor to have them do their best was the encouragement from the physiotherapist and their parents. The small difference between an average range of motion and a maximal range of motion showed that they had done well, even the youngest children who were 5 years old. In Molnar et al.'s (1979) study of normal children, the youngest were 7 years old. Technical and behavioral aspects of test performance are not an important source of inaccuracy (Molnar and Alexander 1974).

The testing of muscle strength with the Cybex machine may not be an exact metod in children. Molnar et al. (1974) studied 500 normal boys and girls and found that isokinetic testing could be done to assess for quantitative strength of knee flexors and extensors in children. The main factors that affected the results were age, height, weight and gender. We therefore used those parameters when matching our patients with the controls. In Molnar's study, boys were stronger than girls of the same age. Those results accord with our findings although the overall average muscle strength in both groups did not differ statistically. Furthermore, muscle groups in the dominant side were stronger. Molnar et al. (1979) found that the magnitude of peak torque increases with age, but the differences between the legs and the ratios are distributed equally in various age groups. This agrees with our findings.

In normal children without a previous injury, the differences in isokinetic strength of the 2 limbs may be as great as 20% or more (Henderson et al. 1992). The side difference in peak torque must exceed the inherent variation of repeated testing reported to range from 2% to 14% (Montgomery et al. 1989). In view of these studies, we chose a difference in peak torque of at least 15% between the legs as a lower limit for true muscle strength deficit. Torque decreases as angular velocity increases. Therefore, it is important to analyze torque data at various speeds (Montgomery et al. 1989). We chose a 2-speed protocol with one slow speed torque set (60°/second) and one mid-speed torque set (180°/second).

Like Hennrikus et al. (1993), we found no relationship between muscle weakness and fracture of the dominant leg. In normal children, Howes et al. (1991) found no relationship between weakness and dominance of the leg. This is similar to our findings—i.e., it is of no importance whether the fracture is in the dominant or nondominant leg.

The normative ratios for torque to body weight and opposing muscle group torque (hamstring/quadriceps) have been calculated in studies on adults (Giove et al. 1983, King et al. 1986, Morrissey 1987). Normative ratios for torque to body weight for the quadriceps are 80–100% in males and 60–80% in females. In hamstrings, the ratios are 45–60% in males and 40–60% in females. The normal ratio for opposing muscle groups is 50–70% in males and females. Our findings suggest that the normative ratios for torque to body weight and opposing muscle group torque (hamstring/quadriceps) in children are similar to those in adults.

Early weight bearing could mean a risk of malunion. However, the external fixator is stable and prevents re-dislocation of the fracture. Apart from restoring muscle function, early weight bearing makes the child more mobile and independent during treatment.

We thank physiotherapists Helena Jonspers and Karin Gillblom for participating in the Cybex and hop-index testing

of the children. We also thank statistician Jan Ifver for help with the statistical analysis.

This research was financially supported by grants from the Olaisson's Foundation, Falun Hospital, Dalarna Research Institute and the Swedish Medical Society.

No competing interests declared.

Damholt V, Zdravkovic D. Quadriceps function following fractures of the femoral shaft in children. Acta Orthop Scand 1974; 45: 756-63.

Giove T P, Sayers J M, Kent B E. Non-operative treatment of the torn anterior cruciate ligament. J Bone Joint Surg (Am) 1983; 65: 184-92.

Green W T, Wyatt G M, Anderson M. Orthoroentgenography as a method of measuring the bones of the lower extremities. J Bone Joint Surg (Am) 1946; 28 (1): 60-5.

Henderson R C, Kemp G J, Campion E R. Residual bone-mineral density and muscle strength after fractures of the tibia or femur in children. J Bone Joint Surg (Am) 1992; 74: 211-8.

Hennrikus W L, Kasser J R, Rand F, Millis M B, Richards K M. The function of the quadriceps muscle after a fracture of the femur in patients who are less than seventeen years old. J Bone Joint Surg (Am) 1993; 75: 508-13.

Howes C L, Erickson K L, Heere L M, Henderson R C, DeMasi R A. Isokinetic measurements of knee flexion-extension strength in children. Physical Therapy (Suppl) 1991; 71 (6): l.

King S, Butterwick D J, Cuerrier J P. The anterior cruciate ligament: A review of recent concepts. J Orthop Sports Phys Ther 1986; 8: 110-20.

Molnar G E, Alexander J. Objective, quantitative muscle testing in children: a pilot study. Arch Phys Med Rehabil 1973; 54: 224-8.

Molnar G E, Alexander J. Development of quantitative standards for muscle strength in children. Arch Phys Med Rehabil 1974; 55: 490-3.

Molnar G E, Alexander J, Gutfeld N. Reliability of quantitative strength measurements in children. Arch Phys Med Rehabil 1979; 60: 218-21.

Montgomery L C, Douglass L W, Deuster P A. Reliability of an isokinetic test of muscle strength and endurance. J Orthop Sports Phys Ther 1989; 2: 315-22.

Morrissey M C. The relationship between peak torque and work of the quadriceps and hamstrings after meniscectomy. J Orthop Sports Phys Ther 1987; 8: 405-8.

Morscher E, Figner G. Die Messung der Beinlängen. Orthopäde 1972; 1: 9-13.

Neel A B, Glancy G L. Residual quadriceps weakness following childhood femur fractures. Orthop Trans 1990; 14: 292.

Sachs R A, Daniel D M, Stone M L, Garfein R F. Patellofemoral problems after anterior cruciate ligament reconstruction. Am J Sports Med 1989; 17: 760-5.