Isometric measurement of wrist-extensor power following surgical treatment of displaced lateral condylar fracture of the humerus in children

Po-Hsin Chou · Chi-Kuang Feng · Fang-Yao Chiu ·
Tain-Hsiung Chen

Received: 22 March 2007 / Revised: 20 April 2007 / Accepted: 23 April 2007 / Published online: 30 May 2007
© Springer-Verlag 2007

Abstract Muscle disability is a common sequel after fracture management. Previous research has shown divergent results concerning muscle-power recovery after bone healing. This study has investigated the muscle function of wrist extensors after lateral condylar fracture in children, as evaluated by a hand-held dynamometer and compared with sex- and age-matched children. From 1999 to 2004, 20 patients (13 boys and seven girls; mean age: 9 years and 4 months) with displaced lateral condylar fracture of the humerus were treated by open reduction and internal fixation with Kirschner wires (K-wire). The duration of K-wire fixation was 35 days and the mean follow-up time was 50 months. A total of 180 healthy age-, sex- and weight-matched children were used as control groups. A paired Student's test was applied for the analysis of statistical significance. The range of motion of the elbow and radiographic findings were not significantly different between the injured limb and normal control groups. The maximum isometric power of wrist-extensor muscles after surgical treatment of lateral condylar fracture of the humerus in final follow-up was not statistically different from that in the normal control children. Muscle power therefore recovers to its normal status after the healing of lateral condylar fracture of the humerus in children.

Résumé Les troubles fonctionnels musculaires sont une séquelle relativement fréquente après le traitement d'une fracture. Les résultats des recherches faites de façon à évaluer la fonction musculaire, montrent, une fois l'os guéri, des résultats divergents. Cette étude de la fonction musculaire a été réalisée au niveau des extenseurs du poignet après fracture du condyle externe du coude, en utilisant un dynamomètre et en comparant les résultats en fonction du sexe et de l'âge. De 1999 à 2004, 20 patients (13 garçons, 7 filles; l'âge moyen: 9 ans et 4 mois) ont présenté une fracture déplacée du condyle externe de l'humérus traitée par réduction sanglante et brochage. Le temps de fixation par broche a été de 35 jours et le suivi moyen a été de 50 mois. Une analyse comparative de 180 critères a été réalisée. Il n'y a pas eu de différences significatives en ce qui concerne le résultat sur la fonction du coude, la mobilité et la consolidation. De même, il n'y pas eu de différences significatives en ce qui concerne la tension isométrique des extenseurs du poignet comparés au membre contro latéral, comparé sur une série d'enfants contrôle. On peut en conclure que le muscle retrouve une fonction complète après guérison d'une fracture déplacée du condyle externe chez l'enfant.

Introduction

Muscle wasting and joint stiffness are well-known “fracture diseases”. Post-traumatic muscle atrophy may result from disuse, immobilisation and the nociceptive reflex [9, 11–13, 16, 18, 21].

Hennrikus et al. (1993) [13] reported that persistent weakness of the quadriceps in patients younger than 17 years and managed for closed femoral shaft fracture was found 18–56 months after injury. McKee et al. (2000)

P.-H. Chou · C.-K. Feng (✉) · F.-Y. Chiu · T.-H. Chen
Department of Orthopedics and Traumatology,
Taipei Veterans General Hospital,
No. 201, Sec.2, Shih-Pai Road,
Taipei 11217, Taiwan
e-mail: ckfeng@vghtpe.gov.tw

P.-H. Chou · C.-K. Feng · F.-Y. Chiu · T.-H. Chen
School of Medicine, National Yang-Ming University,
Taipei, Taiwan

[16] quantified a decrease in the range of motion (ROM) and muscle strength of patients (mean age: 47 years) following surgical treatment of intra-articular distal humerus fracture after a 37-month follow-up, whereas Stamatis and Paxinos (2003) [19] reported that, after 39–50 months, the muscle strength of the major muscle groups of the operated elbow was equal to that of the uninjured elbow tested clinically in patients treated for coronal shear fractures of the distal humerus.

These diverse reports have stimulated this research to evaluate muscle function quantitatively after fracture healing in long-term follow-up patients. The lateral condylar fracture of the humerus is the second most common elbow fracture in children [3, 14, 20], the injured area being the origins of the wrist-extensor muscles, and is therefore a good candidate for investigating the relationship between muscle performance and fracture healing.

This study retrospectively evaluated the clinical results, radiographic examination and isometric strength of the wrist-extensor muscles in displaced lateral condylar fractures of the humerus following surgical fixation. The muscle strength of the wrist-extensor muscles was measured in age-, sex- and weight-matched children for comparison.

Materials and methods

From 1999 to 2004, 35 cases younger than 17 years presented with displaced humeral lateral condylar fracture treated by open reduction with two K-wires and plaster casting in our institution. Patients with complete medical history records, physical examinations, pre-operative radiography and series images, who revealed bony union without post-operative complications and who completed isometric wrist-extensor muscle strength measurements with a hand-held dynamometer in their final follow-up were included in this study.

Reliability test of measurement of hand-held dynamometer

Eleven six-year-old children participated in the preliminary testing but were not included in the control groups. The scores of maximum isometric wrist-extensor muscle strength were recorded (in pounds but given here also in kilograms) by a Microfet II hand-held dynamometer (Hoggan Health Industries, West Draper, Utah, USA) in triplicate on three separate occasions and the same procedure was repeated one week apart by the same author. The inter-score correlation was tested by the Pearson product-moment method. The test/re-test reliability was determined by a one-way analysis of variance. The statistical procedures were managed electronically by the Statistical Package for Social Science 12.0 (SPSS for Windows, Chicago, Ill., USA). All correlations revealed good to high reliability (Table 1) and we could perform the next stage of measurement with confidence in both control and patients groups.

Patient evaluation

The ROM and carrying angle of both elbow joints were assessed using an international standard pocket goniometer [5]. Standard biplanar radiographical films were evaluated pre-operatively and in a series of follow-ups. The fracture type was classified by the Milch and Jakob methods, respectively [14, 17]. Bauman's angles were measured bilaterally at the final examination.

All the quantitative muscle-strength measurements were obtained by use of the Microfet II hand-held dynamometer, which was calibrated and operated in the range of 0.8–100 pounds. The subjects were placed in a sitting position, arm dependent at the side and neutrally rotated, elbow flexed at 90°, forearm pronated and supported, and the tested wrist unsupported. Resistive contact force was applied perpendicularly and centrally located on the dorsum of the hand (metacarpal region) under the dynamometer. The subjects were instructed to exert an instantaneous effort against the resistive contact for three consecutive trials for both wrists and the average result was recorded as the score of the maximum isometric wrist-extensor muscle strength [1, 2, 6,

Table 1 Test/re-test reliability for wrist-extensor muscle power (NS non-significant)

Week	Number	Force produced in pounds (in kg)						Pearson correlation			Repeated measures analysis of variance	
		Test 1		Test 2		Test 3		Test 1-2	Test 2-3	Test 1-3	F	P
		Mean	SD	Mean	SD	Mean	SD					
First	11	6.5 (3.0)	1.4	6.6 (3.0)	1.6	6.7 (3.0)	1.6	0.897	0.903	0.939	0.431	NS
Second	11	6.5 (3.0)	1.5	6.5 (3.0)	1.6	6.6 (3.0)	1.5	0.947	0.972	0.981	0.431	NS

18] (Fig. 1). Three scores were generated in tests five minutes apart.

Under general anaesthesia, the displaced lateral condylar fracture of the humerus (Fig. 2a) was approached laterally. Gentle and minimal dissection of the underlying muscle tissue were performed and the fracture fragments were aligned anatomically with respect to the visualised articular surface contour. Two K-wires were inserted percutaneously, assisted by fluoroscopy (Fig. 2b). The injured limb was immobilised in a long-arm plaster cast in the functional position of the elbow and wrist joint. The K-wires were removed in an out-patient service after radiographic evidence of a periosteal bridge over the fracture site and viewed later at follow-up (Fig. 2c). No specific scheduled rehabilitation program for the injured limb was conducted in the authors' institution.

Control group

Fifteen (from a total of 180) healthy children who were age-, sex- and weight-matched with each study patient were collected prior to a full explanation of the purpose and procedures of the study and with parental consent. The mean muscle strength in each healthy group was compared with the corresponding value for each patient (Table 2).

Statistical analysis

Maximum isometric wrist-extensor muscle strength for patients and control-group children were compared by the paired Student's *t*-test. The Mann-Whitney U test was used to investigate the relationships between the fracture types and final muscle strength. Univariate and multiple linear regression analysis were applied to analyse the factors of age and dominant/non-dominant sites related to functional outcome. A *P*-value of <0.05 was considered significant.

Fig. 1 Subject position and tester stance for wrist-extensor muscle power testing with a hand-held dynamometer

The measurement of both control and patients groups was not started until a good reliability of the preliminary test was noted. All measurements including those in the preliminary test and of control and patients groups were undertaken by the same person to avoid individual bias.

Results

Twenty cases completed all the criteria in this study. They were thirteen boys and seven girls with the mean age of 9 years and 4 months (5–17 years old). The mean follow-up time was 50 months (32–90 months). The duration of K-wire fixation was 35 days (range: 28–42 days). All patients were right-handed (defined as dominant side). The right elbow (dominant side) was involved in 11 cases (seven boys) and left elbow (non-dominant side) were involved (eight boys) in nine cases in this series. Demographic data are shown in Table 3.

The mean Baumann's angle corresponding to the left and right involved elbows in the patients was 72.0 and 71.5 degrees, respectively. The mean ROM and carry angle for left-handed patients was 148 and 7.6 degrees, whereas the right-handed cases was 145 and 7.8 degrees, respectively (Table 4).

Statistical analysis showed no significant differences between the affected-limb side compared with the same side of the control group with respect to maximum isometric wrist-extensor muscle strength ($P=0.562$). Muscle strength was significantly associated with age ($P=0.001$) and less significantly related with dominant and non-dominant sides ($P=0.483$).

Discussion

To our knowledge, routine neuro-muscular functional assessment based on objective measurements is more accurate and clinically meaningful than those based merely on clinical estimations. This is especially true when evaluating treatment programs, the progress of a pathological process or the effect of training. The hand-held dynamometer provides reliable assessments [8, 10, 15] and detects all situations mentioned above. Inconsistent reports have been presented regarding muscle strength after fracture healing following conservative treatment or surgical repair [13, 16, 19]. Objective data are available in the literatures related to muscle power post-surgical fixation of the fracture in the elbow area [16, 19]. As far as we know, our study provides the first objective data quantifying the isometric power of wrist extensors of children who have suffered from displaced lateral condylar fracture of the humerus and who have been treated by surgical repair.

Fig. 2 Treatment of right lateral condylar fracture of humerus with K-wires ($\times 2$) at age of 6 years and 2 months (case 2). **a** Pre-operative. **b** Post-operative. **c** Bilateral roentgenograms of the elbows; 36 months post-operative. The X-ray revealed lateral spur formation

Some limitations should be pointed out with respect to our investigation. First, this is a retrospective study and its potential bias lies in that some data, which might be different from current results, have been missed because all patients could not be followed up and the sample size of this study is relatively small. Secondly, manual testing, hand-held dynamometry and the use of the Cybex machine and Baltimore Therapeutic Equipment (BTE) work-stimulator are known different methods with regard to the objective measurement of muscle strength. In our study, we prefer the hand-held device, which is more reliable than manual testing [8, 10, 15] and much easier to operate than the Cybex and BTE work-stimulators when children are examined. The drawback of a hand-held device is that variation in angular velocity is a potential source of variability in serial strength measurements [7]. Thirdly, in the studies of Bowman et al. (1984) [2], Backman et al. (1989) [1] and Andrew et al. (1996) [5], at least 30 volunteers participated at each age. Only 15 children

participated as volunteers in each age-, sex- and weight-matched control group and so extreme values could have had a large influence on the average muscle strength, which may in turn result in different consequences.

Immobilisation appeared to have no significant effect on the strength of wrist extensors and a post-operative vigorous rehabilitation program was not supported by this study. Our findings are similar to those of Henderson et al. [12] who noted that the duration of immobilisation had no apparent relationship with muscle strength after fractures of the tibia or femur in children.

A systemic review of the standard protocol for the measurement of isometric wrist-muscle strength shows a negative result [4]. In our study, the test position was uniform and we considered the test/re-test reliability to be good. The same test was applied to the control group by the same author. The normative data were reliable.

The clinical results for ROM and carrying angle and the radiographic findings were consistent with other studies of

Table 2 Control group data (*F* female, *M* male, *ROM* range of motion, *L* left, *R* right)

Age	Sex	Number	Mean height in cm	Mean body weight in kg	ROM				Mean muscle strength in pounds (in kg)			
					L	SD	R	SD	L	SD	R	SD
5	F	15	114.4	21.3	144	5	146	4	7.5 (3.4)	1.7	7.6 (3.5)	1.3
6	F	15	119.2	22.5	146	4	146	4	6.5 (3.0)	1.1	6.7 (3.0)	1.4
6	M	15	119.6	23.6	150	6	150	5	7.5 (3.4)	1.0	7.9 (3.6)	1.2
7	F	15	121.5	23.2	148	3	148	3	7.4 (3.4)	0.8	7.5 (3.4)	0.8
7	M	15	123.3	24.6	148	4	148	3	7.7 (3.5)	1.7	7.9 (3.6)	1.2
8	F	15	127.4	27.1	148	3	148	3	7.2 (3.3)	0.7	7.3 (3.3)	0.7
8	M	15	128.3	28.3	148	3	147	3	7.8 (3.5)	1.1	8.1 (3.7)	1.3
9	M	15	132.6	32.3	146	4	148	5	8.0 (3.6)	1.0	8.5 (3.9)	1.0
10	F	15	138.6	34.1	146	4	148	3	8.6 (3.9)	1.3	8.8 (4.0)	1.4
13	M	15	161	52	145	3	147	3	21.2 (9.7)	2.8	22.8 (10.4)	3.5
14	M	15	167	54	145	4	146	4	23.4 (10.6)	5.4	24.2 (11.0)	4.8
15	M	15	167.8	58.7	144	5	144	5	23.3 (10.6)	5.5	24.1 (10.9)	5.6
16		15	158.8	51.8	144	5	144	5	16.8 (7.6)	3.1	17.6 (8.0)	2.5
17	M	15	172	69	144	5	143	6	25.0 (11.4)	5.3	26.4 (12.0)	5.4

Table 3 Patient profiles (*F/U* follow up, *F* female, *M* male, *L* left, *R* right)

Case	Sex	Injury	F/U interval (months)	Current age (years+months)	Milch classification	Interval of fixation (days)
1	F	R	32	5+7	II	32
2	M	R	36	6+2	II	35
3	F	R	38	6+11	II	28
4	M	R	32	7+6	II	35
5	M	R	40	7+8	II	32
6	M	L	34	8+4	II	37
7	F	L	39	8+7	II	40
8	M	R	43	8+10	II	37
9	F	L	41	9+2	II	40
10	F	L	50	9+4	II	42
11	M	L	58	9+11	II	32
12	F	R	76	10+7	II	32
13	M	R	54	10+8	II	34
14	M	L	68	13+6	II	35
15	M	L	61	13+6	II	31
16	M	L	64	14+2	II	37
17	M	R	48	15+7	II	32
18	M	L	60	15+10	II	35
19	F	R	54	16+6	II	36
20	M	R	90	17+6	II	36

surgical fixation of lateral condylar fracture of the humerus in children [13, 20]. The muscle performance of wrist extensors was not significantly different after bone healing in the different severity fracture types. The possible reasons were anatomical repair by surgical fixation and the remodelling and regenerative capacity of children. However,

the muscle power was positively correlated with the age. This research supports the conclusion that the isometric power of the wrist extensors returns to normal status compared with age-, sex- and weight-matched subjects after anatomical reduction of the displaced lateral condylar fracture of the humerus in children.

Table 4 Muscle strength of patients and radiographic findings (*ROM* range of motion, *L* left, *R* right)

Case	Sex	Injury	Carrying angle (degrees)		Buaumann's angle (degrees)		ROM		Muscle strength in pounds (in kg)			
			L	R	L	R	L	R	L	Duration (s)	R	Duration (s)
1	F	L	8	6	70	72	140	145	5.2 (2.4)	1.6	6.4 (2.9)	1.8
2	M	R	6	5	72	72	149	145	6.5 (3.0)	1.9	7.7 (3.5)	1.8
3	F	R	4	3	69	70	166	168	6.9 (3.1)	1.8	6.3 (2.9)	1.7
4	M	R	12	12	73	68	147	140	7.3 (3.3)	1.7	8.1 (3.7)	1.8
5	M	L	7	5	70	71	150	140	8.8 (4.0)	1.9	8.6 (3.9)	1.8
6	F	L	3	4	68	67	154	154	7.6 (3.5)	1.9	6.8 (3.1)	2
7	M	R	0	0	68	67	125	125	9.3 (4.2)	1.9	10.7 (4.9)	2
8	F	L	10	10	74	72	150	150	7.6 (3.5)	1.7	9 (4.1)	1.7
9	F	L	10	10	77	78	155	155	8.0 (3.6)	1.8	9.5 (4.3)	1.8
10	M	L	6	6	72	73	138	140	7.9 (3.6)	1.7	8.5 (3.9)	1.6
11	F	R	7	6	76	74	158	155	9.0 (4.1)	1.9	8.8 (4.0)	1.9
12	M	L	7	7	74	73	160	151	14.8 (6.7)	1.7	15.6 (7.1)	1.6
13	M	L	6	6	74	75	149	141	17.8 (8.1)	1.5	21.3 (9.7)	1.4
14	M	L	6	6	76	74	150	150	25.0 (11.4)	1.4	26.5 (12.1)	1.4
15	M	L	10	10	73	70	145	145	27.3 (12.4)	1.3	26.7 (12.1)	1.1
16	F	R	18	22	73	71	155	143	19.0 (8.6)	1.5	17.9 (8.1)	1.4
17	M	R	10	16	66	69	132	134	28.8 (13.1)	1.4	24.4 (11.1)	1.3

Conclusion

The isometric power of the wrist extensors returns to normal status compared with age-, sex- and weight-matched individuals after anatomical reduction of the displaced lateral condylar fracture of the humerus in children.

References

- Andrews AW, Thomas MW, Bohannon RW (1996) Normative values for isometric muscle force measurements obtained with hand-held dynamometers. *Phys Ther* 76:248–259
- Backman E, Odenrick P, Henriksson KG, Ledin T (1989) Isometric muscle force and anthropometric values in normal children aged between 3.5 and 15 years. *Scand J Rehabil Med* 21:105–114
- Badelon O, Bensahel H, Mazda K, Vie P (1988) Lateral humeral condylar fractures in children: a report of 47 cases. *J Pediatr Orthop* 8:31–34
- Bialocerkowski A, Grimmer KA (2003) Measurement of isometric wrist muscle strength—a systematic review of starting position and test protocol. *Clin Rehabil* 17:693–702
- Boone DC, Azen SP, Lin CM, Spence C, Baron C, Lee L (1978) Reliability of goniometric measurements. *Phys Ther* 58:1355–1360
- Bowman OJ, Katz B (1984) Hand strength and prone extension in right-dominant, 6 to 9 years olds. *Am J Occup Ther* 38:367–376
- Burns SP, Spanier DE (2005) Break-technique handheld dynamometry: relation between angular velocity and strength measurements. *Arch Phys Med Rehabil* 86:1420–1426
- Docherty CL, Moore JH, Arnold BL (1998) Effects of strength training on strength development and joint position sense in functionally unstable ankles. *J Athl Train* 33:310–314
- Gaston P, Will E, McQueen MM, Elton RA, Court-Brown CM (2000) Analysis of muscle function in the lower limb after fracture of the diaphysis of the tibia in adults. *J Bone Joint Surg* 82B:326–331
- Gregory TC (1997) Rehabilitation management in neuromuscular disease. *J Neuro Phys Rehab* 11:69–80
- Hedin H, Larsson S (2003) Muscle strength in children treated for displaced femoral fractures by external fixation: 31 patients compared with 31 matched controls. *Acta Orthop Scand* 74:305–311
- Henderson RC, Kemp GJ, Campion ER (1992) Residual bone-mineral density and muscle strength after fractures of the tibia or femur in children. *J Bone Joint Surg* 74A:211–218
- Hennrikus WL, Kasser JR, Rand F, Millis MB, Richards KM (1993) 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* 75A:508–513
- Jakob R, Fowles JV, Rang M, Jassab MT (1975) Observations concerning fractures of the lateral humeral condyles in children. *J Bone Joint Surg* 57B:430–436
- Kilmer DD, Abresch RT, Fowler WM Jr (1993) Serial manual muscle testing in Duchenne muscular dystrophy. *Arch Phys Med Rehabil* 74:1168–1171
- McKee MD, Wilson TL, Winston L, Schemitsch EH, Richards RR (2000) Functional outcome following surgical treatment of intra-articular distal humeral fractures through a posterior approach. *J Bone Joint Surg* 82A:1701–1707
- Milch H (1964) Fractures and fracture-dislocations of humeral condyles. *J Trauma* 4:592–607
- Paula TK, Damien WA, Terry LG, Shane LK, Stephen CA, Jean MB, et al (1999) Effect of the forearm support band on wrist extensor muscle fatigue. *J Orthop Sports Phys Ther* 29:677–685
- Stamatis E, Paxinos O (2003) The treatment and functional outcome of type IV coronal shear fractures of the distal humerus: a retrospective review of five cases. *J Orthop Trauma* 17:279–284
- Van Vugt AB, Severijnen RV, Festen C (1988) Fractures of the lateral humeral condyle in children: late results. *Arch Orthop Trauma Surg* 107:206–209
- Zacharova G, Knotkova-Urbancova H, Hnik P, Soukup T (1997) Nociceptive atrophy of the rat soleus muscle induced by bone fracture: a morphometric study. *J Appl Physiol* 82:552–557