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EVALUATION OF GRIP STRENGTH MEASUREMENTS AFTER COLLES' FRACTURE: A METHODOLOGICAL STUDY

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ABSTRACT. Maximal isometric grip strength during short and sustained contractions was registered in 28 females and five males with displaced Colles' fracture involving the distal radio-ulnar joint. After reduction the patients were immobilized with plaster cast or with external fixation. The reliability of the measurements of the uninjured side was high and stable over a two-year follow-up period. The between-occasion reliability of the injured side was lower than that of the uninjured side. At each session the intensity of pain was measured. There was a reduction in pain after two years. The discriminatory ability of the measurements was satisfactory. It is suggested that the measurement methods and the present findings may serve as guidance in physiotherapy for these patients, especially if the uninjured side is used as reference.

Key words: Colles' fracture; physiotherapy; isometric grip strength; measurement method; reliability; discriminatory ability.

INTRODUCTION

Grip strength is an important function in activities of daily living, and is often used as an outcome measure of the functional recovery of patients with Colles' fracture (8, 12, 15, 17, 18). Methods for measuring maximal isometric grip strength during short maximal voluntary contraction (MVC) and sustained maximal voluntary contraction (SMVC) (9, 11) have previously been evaluated showing high inter- and intra-observer reliabilities when applied in healthy subjects. It is important to study whether comparable reliability is achieved with injured subjects. To compensate for changes resulting from the biological variation over time, comparison with the uninjured side is important.

The aims of this investigation were (i) to apply our previously developed methods for measuring MVC and SMVC (11) in patients with Colles' fracture, and (ii) to determine intra-observer reliability and discriminatory ability during two years, especially for use in physiotherapy.

MATERIAL AND METHODS

Design and patients

This investigation included 33 patients, mean 58.3 SD 8.4 years, with unilateral displaced Colles' fractures involving the distal radio-ulnar joint, immobilized either with a plaster cast ($n = 16$ females), or with an external fixator ($n = 12$ females and 5 males). Apart from Colles' fracture they showed no other symptoms or signs of disease or injury. The patients were a part of a prospective investigation (10). After the first measurement occasion six weeks after the fracture, one patient refractured, and another patient no longer wanted to participate.

There were no significant differences between the women and men concerning age. The men were, however, significantly taller and heavier than the women (10). According to the method described by Saltin & Grimby (16), the patients reported light to moderate workloads and spare-time activities. All patients with the exception of one woman were self-reported right-hand dominant.

Treatment

Surgical treatment. Disregarding the immobilization method, treatment was standardized and equal for primary orthopaedic treatment, and clinical follow-ups. The immobilization period was six weeks from the day the fracture was finally treated.

Physiotherapy started the same day or the day after the fracture had been immobilized. The programme, consisting of basic information and active exercises, was identical for all patients ($n = 33$).

Measurement procedures

Grip strength measurements. MVC and SMVC were measured bilaterally with the Grippit® (11, 13, 14), a device consisting of an elliptical handle with electronic force transducers based on strain gauges, and a wooden base on

which an arm guide is mounted. Grip strength (Newton, N) was recorded every half-second, and connected to a computer, grip versus time curves could be visualized.

The instrument was calibrated against known weights through the measuring range in 50- to 100-N increments before and after the testing period, as has previously been described (11). The instructions, the verbal encouragement, and the position of the instrument and of the patients were standardized. The Grippit® handle was mounted on the wooden base. The use of the forearm guide ensured that the wrist and the hand were placed in a position that was minimally affected by gravity (11).

All measurements were performed bilaterally, the uninjured side first. After instructions and a trial with submaximal effort, the multitrial procedure of measuring MVC (9), continuously exerted for 4 seconds, was carried out. Each series ranged between 3 and up to 5 trials. The condition was that the last trial was not the highest. The last three trials comprised one session, and were used for analysis of the MVC. In order to minimize artefacts, the registrations for the second to the fourth second of the grip versus time curves were used as representative of the MVC.

SMVC was measured as the maximal contraction continuously exerted for 40 seconds and expressed as the area below the grip versus time curve (Newtonseconds; Ns). For this measurement there was one trial for each hand on each occasion. The intervals between MVC trials were $\geq$30 seconds. Between tests of MVC and SMVC and between two SMVC sessions there were $\geq$2 minutes. In order to reduce errors caused by fatigue or practice, the sequence of the measurements was identical on all occasions. All tests were performed at approximately the same time of the day for each patient.

All measurements were performed by the same investigator (C. L.) on six occasions starting on the same day as the immobilization device had been removed: 6, 10, 14, 18 weeks and 1 and 2 years after the fracture.

Pain measurement. Immediately after each session, the patients were asked to report any pain or discomfort in connection with the measurement. The intensity of pain was measured with a 10-cm visual analogue scale (7). The endpoints were "No pain" and "The strongest pain I have ever perceived".

Statistical analysis

Missing values for injured and uninjured sides were substituted by interpolation for nine patients (MVC: 16 values; area: 11 values; perceived pain: 9 values).

As the grip strength values of this sample were fairly normally distributed, parametric statistics were performed. Descriptive statistics, correlation coefficients, paired *t*-tests and analyses of variance were calculated according to standard routines. Differences were considered significant if the *p*-value was < 0.05. In order to estimate the reliability of the measurement methods, intra-individual standard deviations ($s = \sqrt{(\sum d_i^2/2)/n}$) were used for calculating coefficients of repeatability, referring to short-term, within-session variations, and of reproducibility, referring to long-term, between-occasion variations (C_R for both = $1.96 \times \sqrt{2} \times s$). These coefficients have the same unit of measure as the observed variables (N; Ns). Coefficients of variation (C_V; %) were computed to express the variation in relation to the magnitude of the observed values (1–3).

RESULTS

Accuracy of the instrument

On calibration before and after the measurement period the correlation coefficients between applied forces and the measurement values indicated by the Grippit® were both $r = 0.9999$ (11).

Within-session reliability of MVC

Four patients, immobilized with the external fixator, could not perform MVC measurements for the injured side on the day the immobilization device was removed. The average within-session MVC values (N) are presented in Table I. There were significant within-session differences for both uninjured and injured sides on all but one measurement occasion [mean differences all occasions included: uninjured side: 0.48–13.19 N (0.2–5%); injured side: 0.50–13.27 N (1–6%)]. The first or the second trial was highest equally often for the uninjured side. For the injured side the MVC at the second trial was significantly higher than at the first one on almost all occasions. Intra-class correlations were between 0.98 and 0.99 for the uninjured side. The within-session C_R and C_V for uninjured and injured sides are presented in Table II.

Test–retest reliability of MVC and area

MVC determined as the mean of all three trial values was significantly lower for both sides than that determined as the highest value of three on all except one measurement occasion. Thus, the maximal values were chosen to represent the patients' MVC in all analyses. One plaster-casted and 12 externally fixated patients were unable to perform the SMVC test for the injured side on the day the immobilization device was removed. Therefore, the results from this measurement occasion were not analysed. The area below the grip versus time curve of uninjured and injured sides for the remaining five measurement occasions are presented in Table III.

There were no significant differences between measurement occasions for MVC or area in the uninjured side apart from a significant increase in area between the measurements at 10 and 14 weeks. Intra-class correlations were 0.99 and 0.98 for MVC and area, respectively. C_R and C_V for uninjured and injured sides are presented in Table IV.

Table I. *Within-session values (Newton; N) of maximal voluntary isometric contractions for uninjured and injured sides in patients with Colles' fracture, recorded on six measurement occasions during 2 years after fracture treatment*

		Trial 1			Trial 2			Trial 3		
Side	Wks	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Uninjured	6	32	272.3	90.1	32	271.4	87.1	32	259.1	89.1
	10	31	270.1	86.2	26	259.6	66.4	26	248.7	64.1
	14	31	280.7	87.8	28	261.5	65.4	28	252.1	61.2
	18	31	272.7	86.7	29	261.4	76.2	29	249.4	68.2
	52	31	270.5	85.8	29	261.4	71.1	29	250.1	72.3
	104	31	268.2	80.6	31	271.2	87.7	31	258.8	85.3
Injured	6	29	45.3	33.4	28	55.7	40.2	28	46.2	35.3
	10	30	102.2	53.6	28	111.3	58.6	28	102.1	55.5
	14	31	145.5	68.6	31	149.9	67.8	31	144.2	66.9
	18	31	168.5	69.4	30	182.8	67.7	30	173.1	64.9
	52	31	229.1	83.8	30	238.4	83.6	30	225.1	77.7
	104	31	241.1	90.8	31	248.1	85.9	31	232.6	84.7

Wks = no. of weeks after fracture treatment.

Table II. *Within-session reliability. Coefficients of repeatability (C_R) and of variation (C_V) of the within-session maximal voluntary isometric contraction values on six measurement occasions 6, 10, 14, 18, 52 and 104 weeks after treatment of Colles' fracture*

	Uninjured side			Injured side		
Wks	*n*	C_R (N)	C_V (%)	*n*	C_R (N)	C_V (%)
6	32	42.96	5.8	28	26.11	19.0
10	26	41.00	5.8	29	27.50	9.6
14	28	38.97	5.4	31	27.28	6.7
18	29	48.09	6.7	30	32.10	6.6
52	29	40.36	5.6	30	32.87	5.1
104	31	41.02	5.6	31	39.14	5.9

Wks = no. of weeks after fracture treatment; N = Newton.

Table III. *Area, below grip versus time curve (Newtonseconds), for uninjured and injured sides in patients with Colles' fracture, recorded on five measurement occasions during 2 years after fracture treatment*

	Uninjured side			Injured side		
Wks	*n*	Mean	SD	*n*	Mean	SD
10	30	6,728.1	2,153.5	30	3,130.1	1,613.7
14	30	7,091.4	2,207.4	31	4,302.8	2,001.8
18	30	7,210.6	2,153.0	31	5,168.7	2,155.4
52	30	6,968.7	2,232.4	31	6,260.1	2,406.4
104	28	7,291.6	2,185.0	30	6,555.8	2,610.5

Wks = no. of weeks after fracture treatment.

Discriminatory ability

The differences between the injured and uninjured sides were significant for MVC and area during the total follow-up period. With the exception of the area between the one- and two-year measurement occasions, both variables increased significantly on the injured side.

Table IV. *Test–retest reliability. Coefficients of reproducibility (C_R) and of variation (C_V; %) from comparisons of maximal voluntary isometric contraction values (MVC; Newton) and of area (Newtonseconds) on six and five measurement occasions, respectively, after treatment of Colles' fracture*

		Uninjured side			Injured side		
	Intervals (weeks)	*n*	C_R	C_V	*n*	C_R	C_V
MVC (N)	6–10	30	43.75	5.6	27	151.63	65.3
	10–14	31	44.86	5.7	30	102.66	27.5
	14–18	31	43.32	5.5	31	68.89	14.8
	18–52	31	47.03	6.2	31	140.08	24.3
	52–104	31	34.12	4.4	31	94.75	14.0
Area (Ns)	10–14	30	1,452.24	7.6	30	2,900.64	28.1
	14–18	30	1,394.46	7.0	31	2,141.98	16.2
	18–52	30	1,374.43	7.0	31	3,014.86	19.0
	52–104	28	1,378.00	6.9	30	1,711.61	9.6

Intervals = test–retest intervals; N = Newton; Ns = Newtonseconds.

Perceived pain during grip strength measurements

Ratios of the number of patients perceiving pain and the total number of patients measured on each occasion were calculated. During measurement of MVC the ratio was 0.8 on the day the immobilization device was removed, and 0.6 during SMVC measurement at the 10-week follow-up. After two years the corresponding ratios were 0.2 and 0.1. Perceived pain during measurements of MVC and SMVC is presented in Table V. An analysis of within-session variation and difference between injured and uninjured sides was performed for individuals with the highest intensity of pain ($\geq$3.9 cm during MVC; $\geq$2.7 cm during SMVC). Neither the standard deviation between trials nor the difference between sides was greater for those with strong pain than for those with little or no pain during measurements.

DISCUSSION

The accuracy of the instrument

The Grippit® had very high precision. It showed calibration coefficients above the minimum level of tolerance for recalibration and readjustment of Jamar® dynamometers, suggested by Fess (5, 11).

Methodological aspects

Evaluation of grip versus time curves from an earlier study (9) showed that most healthy subjects had reached their peak value and a plateau of the subsequent decrease of strength within 30 seconds. SMVC measured as the maximal contraction exerted for 40 seconds showed satisfactory test–retest reliability in healthy subjects (11). Therefore, this same duration was chosen in the present investigation.

Table V. *Perceived pain measured with a visual analogue scale (cm; median (Md) and range) during measurements of maximal isometric grip strength during short (MVC) and sustained (SMVC) contractions after Colles' fracture on six and five measurement occasions, respectively*

	MVC measurement			SMVC measurement		
Wks	*n*	Md	Range	*n*	Md	Range
6	29	1.5	0–7.0	–	–	–
10	30	0.05	0–6.4	30	0.4	0–6.6
14	31	0	0–4.0	31	0	0–4.1
18	31	0	0–3.9	31	0	0–2.5
52	31	0	0–1.9	31	0	0–2.0
104	31	0	0–5.0	30	0	0–2.5

Wks = no. of weeks after fracture treatment.

In general, there were no difficulties in performing the MVC and SMVC measurements. On the day the immobilization device was removed, however, many patients who had been immobilized with the external fixator could not grasp the Grippit® handle correctly due to lack of range of motion in the wrist, possibly caused by the firm fixation of the wrist joint in palmar and ulnar flexion during the immobilization period.

Within-session reliability of MVC

The need of more than three trials for some patients to reach their MVC in a session, and the difference between the uninjured and injured sides in the precedence of the within-session trial values support our previous findings in favour of the multi-trial procedure (9).

In the early part of the follow-up period the C_R was much lower for the injured side than for the uninjured side, but increased over time and was about equal with that of the uninjured side at two years (Table II). In contrast, at first the C_V was higher for the injured than for the uninjured side but then decreased over time, and was about equal with the uninjured side from 14 weeks onwards. The within-session repeatability of both sides was equal to or better than those reported in our two previous studies on grip strength in healthy subjects (9, 11). The variability of the measurements of the injured side was high at 6 and 10 weeks after fracture treatment. This implies that the within-session reliability of the injured side was lower than that of the uninjured side during the first two months of the follow-up but equally high for both sides at two years.

Test–retest reliability of MVC and area

Measurements of MVC and area showed high reliability for the uninjured side between measurement occasions, which was in accordance with our results in healthy subjects (11). The MVC reproducibility was even higher in the uninjured side of the patients. Thus, MVC and area of the healthy uninjured side can be used as reliable references for the injured side after Colles' fracture.

C_R and C_V for the injured side were higher than for the uninjured side between all measurement occasions but the difference became less pronounced with time (Table IV). The coefficients decreased except between the 18- and the 52-week follow-ups. The high coefficients of reproducibility and of variation for the injured side could be expected as a consequence of the on-going grip strength recovery. It is noticeable that the between-occasion reliability of the injured side was still lower than that of the uninjured side after two years.

Discriminatory ability of MVC and area measurements

The measurement methods showed good ability to discriminate between impaired and unimpaired sides regarding MVC and area. They could identify changes in these two variables over time on the injured side.

Pain during grip strength measurements

About 25% of patients with distal radius fracture have residual dysfunction (6) including pain when exerting grip strength (4). In this investigation the degree of pain was rather low (Table V). It was most pronounced on the first measurement occasion for both MVC and SMVC, and decreased over time, but 19% of the patients had persistent pain after two years. The degree of pain perceived during a measurement session did not seem to influence the magnitude of the within-session trials.

In summary, the measurement methods, applied in patients with Colles' fracture, appear to be acceptably reliable, and sensitive to long-term changes in MVC and area. Thus, they are applicable to following the natural course and the effect of treatment in physiotherapy and for other healthcare professionals. Our findings of differences in within-session and test–retest reliability of grip strength measurements during recovery after Colles' fracture could be helpful in differentiation between changes in strength due to recovery and due to measurement errors.

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REFERENCES

1. Altman, D. G. & Bland, J. M.: Measurement in medicine: the analysis of method comparison studies. Statistician *32:* 307–317, 1983.
2. Bergfeldt, L., Melander, H. & Schenk-Gustafsson, K.: Time-dependent variation in the cardiac conduction system assessed in young healthy individuals at weeks' interval: implications for clinical trials. J Am Coll Cardiol *18:* 792–800, 1991.
3. Bland, J. M. & Altman, D. G.: Statistical methods for assessing agreement between two methods of clinical measurement. Lancet *1:* 307–310, 1986.
4. Ekenstam af, F. & Jonsson, U.: Active treatment of distal radius fractures is the only way to decrease the number of disturbing persisting dysfunctions. (In Swedish). Läkartidn *83:* 3254–3257, 1986.
5. Fess, E. E.: A method for checking Jamar dynamometer calibration. J Hand Ther *1:* 28–32, 1987.
6. Frykman, G.: Fracture of the distal radius including sequelae – shoulder-hand-finger syndrome, disturbance in the distal radio-ulnar joint and impairment of nerve function. A clinical and experimental study. Acta Orthop Scand *Suppl 108:* 1967.
7. Huskisson, E. C.: Measurement of pain. Lancet *Nov 9:* 1127–1131, 1974.
8. Kongsholm, J. & Olerud, C.: Plaster cast versus external fixation for unstable intra-articular Colles' fractures. Clin Orthop *241:* 57–65, 1989.
9. Lagerström, C. & Nordgren, B.: Methods for measuring maximal isometric grip strength during short and sustained contractions, including intra-rater reliability. Upsala J Med Sci *101:* 273–286, 1996.
10. Lagerström, C., Nordgren, B. & Rahme, H.: Recovery of isometric grip strength after Colles' fracture: a prospective two-year study. Scand J Rehab Med *31:* 55–62, 1999.
11. Lagerström, C. & Nordgren, B.: On the reliability and usefulness of methods for grip strength measurement. Scand J Rehab Med *30:* 113–119, 1998.
12. Millet, P. J. & Rushton, N.: Early mobilization in the treatment of Colles' fracture: a 3-year prospective study. Injury *26:* 671–675, 1995.
13. Nordenskiöld, U.: Elastic wrist orthoses. Reduction of pain and increase in grip force for women with rheumatoid arthritis. Arthritis Care Res *3:* 158–162, 1990.
14. Nordenskiöld, U. & Grimby, G.: Grip force in patients with rheumatoid arthritis and fibromyalgia and in healthy subjects. A study with the Grippit instrument. Scand J Rheumatol *22:* 14–19, 1993.
15. Roysam, G. S.: The distal radio-ulnar joint in Colles' fractures. J Bone Joint Surg *75B:* 58–60, 1993.
16. Saltin, B. & Grimby, G.: Physiological analysis of middle-aged and old former athletes. Comparison with still active athletes of the same ages. Circulation *38:* 1104–1115, 1968.
17. Solgaard, S.: Function after distal radius fracture. Acta Orthop Scand *59:* 39–42, 1988.
18. Villar, R. N., Marsh, D., Rushton, N. & Greatorex, R. A.: Three years after Colles' fracture. A prospective review. J Bone Joint Surg *69B:* 635–638, 1987.

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