Measuring the Strength of the Intrinsic Muscles of the Hand in Patients with Ulnar and Median Nerve Injuries: Reliability of the Rotterdam Intrinsic Hand Myometer (RIHM)

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Purpose: To determine the reliability and measurement error of measurements of intrinsic muscle strength of a new hand-held dynamometer (the Rotterdam Intrinsic Hand Myometer [RIHM]).

Methods: With the RIHM we obtained repeated measurements of the intrinsic muscle strength of the hand in 27 patients with peripheral nerve injury of the ulnar and/or median nerve in different stages of rehabilitation. The average time period after injury was 4.4 years (range, 99 days–11 years).

Results: Differences between 2 measurements greater than 6.3 N were interpreted as a real change in assessing the strength of the abduction of the little and index finger; for the median innervated muscles of the thumb this value was 16 N.

Conclusions: In patients with nerve injuries the muscle strength is usually assessed with manual muscle strength testing and grip- and pinch-strength dynamometers. Preferably the intrinsic muscle strength should be measured in isolation and quantitatively. The RIHM is a new dynamometer that allows for measurements of the intrinsic muscle strength in isolation with reliability comparable to grip and pinch measurements. (J Hand Surg 2004;29A:318–324. Copyright © 2004 by the American Society for Surgery of the Hand.)

Key words: Evaluation, dynamometry, intrinsic muscle strength, median nerve, ulnar nerve.

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Ulnar and/or median nerve pathology (eg, injury, compression, infection [leprosy]) causes a strength deficit of the intrinsic muscles that may result in severe loss of hand function. In addition, several neuromuscular diseases (eg, Charcot-Mary-Tooth, Guillain-Barré) can cause loss of intrinsic hand muscle function.

Muscle strength measurements are made frequently in patients with hand injuries and other hand problems and they are an integral part of the physical examination and provide information for diagnosis and for the outcome of surgery and therapy.[1–4] The most commonly used classification scale for manual muscle strength testing (MMST) is the Medical Research Council (MRC) scale.[5] The MRC scale uses a 6-point numeric scale (grades 0–5) and suggests a constant distance between points. Because it is an ordinal scale with disproportional distances between grades, however, it might have been more appropriate to use terms such as normal, good, fair, trace, and paralyzed, instead of the numbers.

With this 6-point ordinal scale for MMST it would be too difficult to identify those factors that may have small but additive beneficial effects and those that may have negative effects on nerve regeneration.[6] In contrast with the MMST, measurements with a dynamometer are more sensitive to change and render outcome on a continuous scale (eg, kilogram force, newton). An additional advantage of such measurement methods is that the strength of the uninjured hand can serve as the reference value for normal for that person.[7]

In the evaluation of peripheral nerve function grip- and pinch-strength measurements with dynamometers have often been recommended as a measure of outcome.[8–10] An important caution in using these dynamometers was made by Strickland et al,[9] who argued that grip- and pinch-strength data may be used only as an indirect measurement of nerve recovery. It is commonly overlooked that grip-strength measurements provide information on the combined function of all the intrinsic and extrinsic muscles of the hand. We have observed frequently that patients with weak intrinsic muscles of the hand after ulnar and/or median nerve lesion have a considerably strong grip. The strength of the intrinsic muscles of the hand affect the grip strength only to a certain level. Improvement in grip strength can merely be a reflection of compensatory strengthening of the uninvolved extrinsic musculature. Therefore, grip-strength measurements do not provide decisive information about the motor function of the ulnar and median nerves in the lower arm. Hand surgery literature, however, is replete with grip-strength data used to measure the outcome after nerve repair.

To accurately evaluate the outcome of motor function after nerve repair we need to distinguish between extrinsic and intrinsic muscle strength. This can be done clinically only with a precision instrument that measures the strength of the intrinsic muscles in isolation. Several methods to measure the muscle strength of the hand have been developed.[6,11-15]. A number of these instruments can measure the strength of the ulnar innervated muscles that produce abduction of the index and little fingers. Some instruments can measure the strength of the abduction of the thumb; however, when measuring the abduction strength of the thumb the wrist position needs to be controlled to minimize the action of the radial-innervated abductor pollicis longus muscle.[3]

A new hand-held dynamometer, the Rotterdam Intrinsic Hand Myometer (RIHM) (Experimental Medical Instrumentation, Rotterdam, the Netherlands) meets the specific needs of measuring the intrinsic muscle strength of the hand in isolation. The RIHM allows measurement of little finger and index finger abduction. In addition the opposition and palmar abduction of the thumb can be measured, making 2 measurements available for both median-and ulnar nerve–innervated intrinsic muscles.

The aim of the present study is to assess the reliability of measurements with the RIHM in patients with ulnar and/or median nerve injury. Several indexes of measurement error were assessed for intraexaminer applications of strength measurements with this new device and compared with those of reliability studies on grip- and pinch-strength measurements.

Materials and Methods

Subjects

All patients had a laceration of the ulnar and/or median nerve in the forearm between the elbow and wrist. They were operated on by surgeons of the plastic and reconstructive surgery department and received their hand therapy at the rehabilitation department of the Erasmus Medical Center. The therapy protocol consisted of 3 to 4 weeks of protection for the sutured nerve with a thermoplastic splint, which in case of combined flexor tendon injuries of the fingers is a splint with the wrist in 30° flexion and the metacarpophalangeal (MCP) joints in 60° flexion. All patients followed a rehabilitation program consisting of exercises to maintain the range of motion, strengthening exercises, and instruction on how to prevent injuries due to loss of protective sensation. At regular time intervals muscle strength was assessed.

The patients included in this study were in different phases of the rehabilitation process. A total of 27 patients (22 male, 5 female; mean age, 35.4 years; range, 16–70 years) with peripheral nerve lesions who were able to exert maximum strength against resistance were included in this study. There were 11 ulnar nerve injuries, 9 median nerve injuries, and 7 combined ulnar and median nerve injuries. Two patients had an isolated nerve injury; all others had a combined nerve-tendon injury. The average time period after injury was 4.4 years (range, 99 days–11 years). The majority of injuries were due to sharp objects (eg, glass or knife) causing injury to the forearm between the elbow and wrist.

The measurement protocol was explained to the patients and all gave written informed consent. The ethical board of the Erasmus MC—University Medical Center Rotterdam approved this study.

Instruments

Measurements were taken with the RIHM. Compared with a generic industrial dynamometer the RIHM has the advantage of an easy-to-hold, ergonomic handgrip and a different method of giving resistance (ie, by means of pulling) in which the angle of the applied strength is easy to control. Another advantage of the RIHM is that opposition of the thumb can be tested. This provides 2 tests for both the ulnar and median nerve–innervated muscles, which is valuable when comparing the muscle strength recovery of both nerves.

The RIHM was developed because in a previous study we found that with a generic industrial dynamometer only relatively large changes in muscle strength measurement of the thumb, index, and little fingers could be adequately detected.[16]

Testing Protocol

The measurements were taken in the clinical setting of a rehabilitation department. The examiner and patient were seated at opposite sides of a table. The patient was shown how to hold the finger or thumb and instructed that he/she should try to keep the finger or thumb in that position with maximum strength. The strength on the finger or thumb was slowly increased while the examiner verbally encouraged the patient to hold the finger or thumb in place, which is known as a break test.[17] The places at which the strength was applied were similar to the anatomic reference points of the MMST as described by Brandsma et al.[3,18]

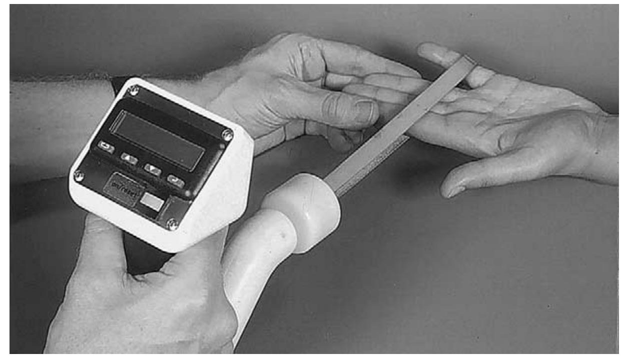

Figure 1. Measuring the strength of the abduction of the little finger with the RIHM dynamometer. The sling is attached to the RIHM pulled at proximal interphalangeal level of the little finger.

Ulnar nerve–innervated muscles.

Ulnar abduction of the little finger. The patient's hand was in supination while the index, middle, and ring fingers were held by the examiner's hand. The patient's little finger was placed in maximum abducted position with the MCP joint in slight flexion. The patient was told to keep the finger in that position while the sling of the dynamometer was applied at the proximal interphalangeal joint of the little finger. The pull was always perpendicular to the little finger in a straight line with the palm of the hand (Fig. 1).

Radial abduction of the index finger (mainly the index first dorsal interosseus muscle). The patient's hand was in pronation and the middle, ring, and little fingers were held by the examiner. The point at which the sling was applied was at the radial side of the proximal interphalangeal joint of the index finger. The pull was always perpendicular to the finger parallel to the palm of the hand.

Median nerve innervated muscles.

Palmar abduction of the thumb (or anteposition[19]). The lower arm was in supination with the elbow resting on the table and the wrist manually supported by the examiner in extension. The sling was applied at the MCP joint level of the thumb. The patient was asked to move the thumb away from the palm of the hand. The strength was in one line with the flexion-extension axis of the MCP joint of the thumb (Fig. 2).

Opposition of the thumb. The lower arm was supinated and all fingers of the hand were fixed flat on the table by the examiner. The pull was at the

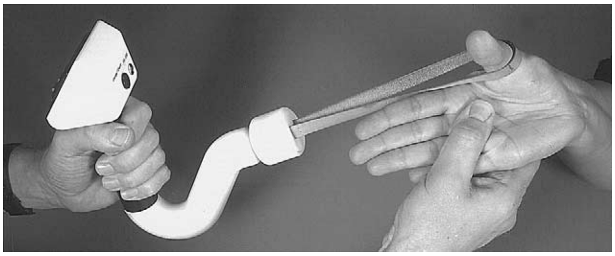

Figure 2. Measuring the strength of the abduction of the thumb with the RIHM dynamometer. The wrist is positioned in extension and the sling is at the MCP level of the thumb.

MCP joint, where the sling was applied, in a horizontal plane in line with the palm of the hand. The patient was instructed not to flex the interphalangeal joint of the thumb.

All movements were tested 3 times within 1 session; after a short break in which the patient left the testing position the same examiner performed a second session. All measurements were completed within 30 minutes.

Statistics

The reliability indexes intraclass correlation coefficients (ICCs) and the standard errors of measurement (SEMs) were calculated. Although both of these measures are related they define different properties. The magnitude of the ICC defines a measure's ability to discriminate among subjects whereas the SEM quantifies measurement error in the same unit as the original measurement (newton).[20–26]

An analysis of variance was performed with statistical software (SPSS/PC+ version 10.1; SPSS, Chicago, IL) to determine the multiple sources of measurement error. The variances attributed to differences between patients, differences between sessions, and the interaction between these factors, including some residual error from unspecified error sources, were calculated. The total variance minus the variance between patients constitutes the error variance, the square root of which is the SEM.

The magnitude of change between tests that is required to detect a real change in a subject's performance is indicated as the smallest detectable difference (SDD). The SDD represents the magnitude of the measured difference, of which the examiner can be 95% confident that a genuine change of strength has taken place rather than a change due to measurement error. The SDD can be calculated by multiplying the SEM with $1.96 \times \sqrt{2}$. The smaller the measurement error, the better the measure.[23]

Because no clear criteria to judge the SDD are available for such measurements we compared our findings with a previous study investigating grip- and pinch-strength measurements in a group of patients with hand injuries. For this comparison we expressed the SDD in relation to the standard deviation (SD) of the measurements, which was labeled as the SDD/SD ratio.[27]

Results

Table 1 gives the mean value and SD of all measurements (2 ulnar and 2 median nerve measurements). The strength of the thumb measurements was considerably greater than those of the little finger and index finger. Results of the 2 measurement sessions of the index finger, little finger, thumb abduction, and opposition of the thumb are shown in 4 scatterplot diagrams (Figs. 3–6). These figures show a high level of correspondence between the 2 sessions.

Table 2 gives data on ICCs, SEMs, and SDDs for the intraexaminer measurements of all 4 tests. The ICCs of all measurements were greater than or equal to 0.94. For the ulnar innervated muscles the SEM for abduction of the little finger and index finger were 2.2 N and 2.3 N, respectively, and the SDDs were 6.1 N and 6.3 N, respectively. The SEM for the median nerve–innervated muscles of abduction and opposition of the thumb were 5.8 N and 5.5 N, respectively, and the SDDs were 16 N and 15.3 N, respectively.

Only differences between 2 measurements greater

Table 1. Two Sessions of Muscle Strength Measurements of 4 Movements of the Hand With a Hand-Held Dynamometer in Patients (n = 27) With an Ulnar and Median Nerve Injury

	Session 1			Session 2		
	Mean	SD	Range	Mean	SD	Range
Abduction small finger	22.8	14.5	5.6–68.2	22.6	13.1	5.9–56.8
Abduction index finger	27.3	18.0	4.7–60.6	28.5	17.9	7.1–61.7
Abduction thumb	55.0	24.2	13.5–101.0	55.3	23.0	13.9–101.7
Opposition thumb	86.9	25.6	50.8–144.2	85.9	24.8	41.7–142.5

All values are given in newtons.

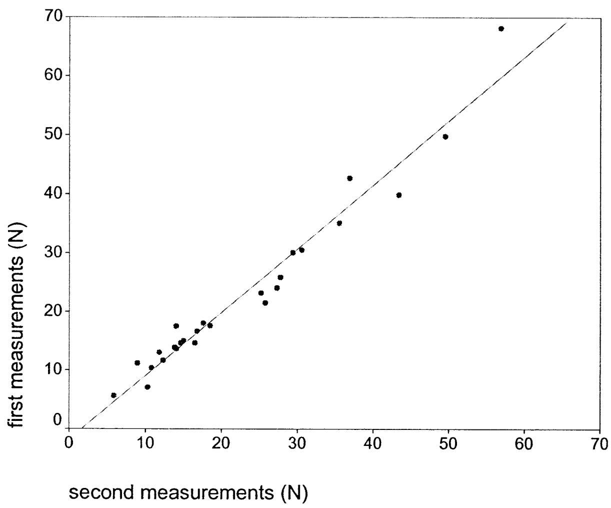

Figure 3. Scatter plot of 2 sessions of measurements of the strength of the abduction of the little finger.

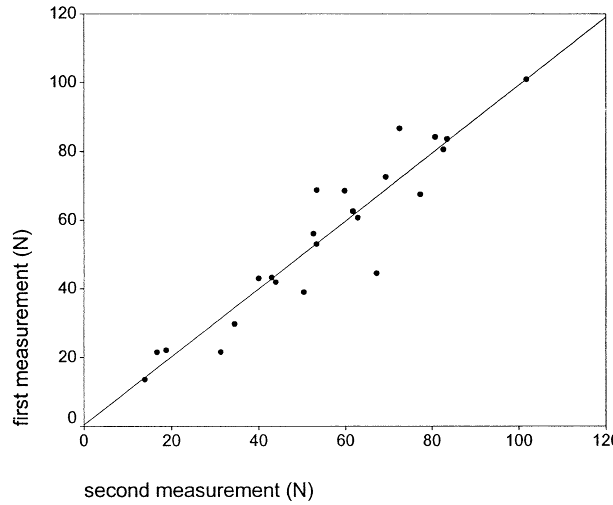

Figure 5. Scatter plot of 2 sessions of measurements of the strength of the abduction of the thumb.

than 6.3 N can be interpreted as a real change in assessing the strength of the abduction of the little and index fingers; for the median innervated muscles of the thumb this value is 16 N.

To allow comparison with the results of the present study, Table 3 gives data on grip- and pinch-strength measurements from a study of 33 patients with hand injuries.[27] The RIHM has similar reliability with regard to ICC and error measurement compared with the grip- and pinch-strength measurements. The ICCs for the RIHM measurements were between 0.94 and 0.98 compared with 0.93 to 0.97 for the grip- and pinch-strength measurements, which according to the scale suggested by Shrout and Fleiss[28] should be classified as excellent. The SDD/SD ratios for the RIHM were between 0.4 and 0.7 and for the grip and pinch measurements they were comparable: between 0.5 and 0.7.

Discussion

The intrinsic muscles of the hand have their origin and insertion within the hand. There are 4 dorsal interosseous muscles, 3 palmar interosseous muscles, 2 ulnar lumbrical muscles, and the adductor pollicis muscle innervated by the ulnar nerve. The intrinsic muscles innervated by the median nerve are the abductor pollicis brevis muscle, the opponens pollicis muscle, and 2 radial lumbricals. The flexor pollicis brevis muscles usually innervated by both ulnar and median nerves. Many valuable studies on the function of the intrinsic muscles of the hand have been performed.[17,29–34]

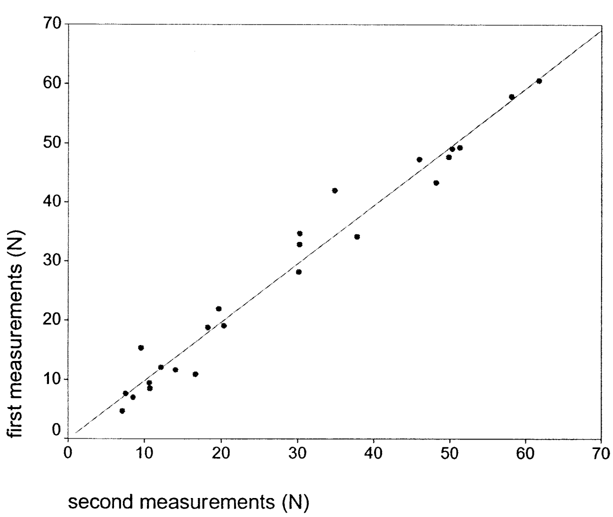

Figure 4. Scatter plot of 2 sessions of measurements of the strength of the abduction of the index finger.

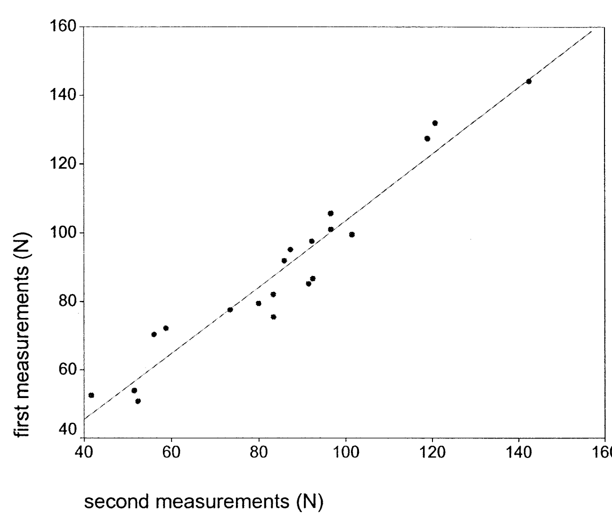

Figure 6. Scatter plot of 2 sessions of measurements of the strength of the opposition of the thumb.

Table 2. Reliability Indexes for Measurements with a Hand-Held Dynamometer in 27 Patients With Ulnar and Median Nerve Paralyses

Nerve	Movement Tested	ICC	SEM (N)	SDD (N)	SDD/SD Ratio*
Ulnar	Abduction small finger	0.97	2.2	6.1	0.4
	Abduction index finger	0.98	2.3	6.3	0.4
Median	Abduction thumb	0.94	5.8	16.0	0.7
	Opposition thumb	0.95	5.5	15.3	0.6

*SDD/SD ratio is presented for comparison of SDD with grip- and pinch-strength measurements.

The widely used MMST, grip-strength measurements, and pinch-strength dynamometers provide important information on the recovery of muscle strength after peripheral nerve injury but also have considerable limitations. Grip strength is a vital function of the hand in general because it is essential to activities of daily living. In our opinion, however, it is a less adequate parameter to evaluate the muscle strength of the intrinsic muscles of the hand. Grip strength is not only a reflection of both the extrinsic and intrinsic flexor musculature of forearm and hand[35] but is also dependent on the strength of the extensor muscles.[36] When measuring grip and pinch strength, the question will remain as to what the intrinsic muscles contribute to grip and pinch strength. Consequently an instrument that is capable of measuring the intrinsic muscle strength in isolation is preferable in evaluating the recovery of muscle strength in the ulnar and median nerve injuries.[16]

In this study we tested the reliability of measurements with the RIHM for the intrinsic muscle strength measurements in 27 patients with ulnar and/or median nerve injury. The results show that the reliability of the RIHM, as determined by the ICC, was excellent. We have examined only the intraexaminer reliability because this is the most frequently occurring situation of these measurements in clinical practice.

The SDDs for the ulnar and median nerve–innervated muscles were 6.3 N and 16 N, respectively. The amount of measurement error considered to be acceptable is a matter of clinical judgment. One useful approach is to judge the SDD in relation to the SD of the measurements. We have applied the same method and compared these with data from our reliability study of grip- and pinch-strength measurements (Table 3).

To determine the clinical value of a particular measurement in a specific population it is essential to know in which range the changes of muscle strength take place. For example, in patients with hand injury the grip strength will have weakened shortly after the trauma. In later rehabilitation phases the increase of muscle strength will generally reach a plateau after many months. If the difference in the grip strength between the start and end of the rehabilitation is, for example, 100 N an SDD of 80 N will show that the measurements are inadequate to detect changes. If the range in which the strengths change is as wide as 300 N an SDD of 30 N is certainly sufficient to detect changes during the rehabilitation process. In this latter example a virtual scale of 10 steps is achieved.

It can be seen that both ICC values and SDD/SD ratios are very similar for intrinsic muscle strength measurements and grip- and pinch-strength measurements.

Until now manual muscle strength testing and pinch- and grip-strength measurements with dynamometers are the most widely used tools to assess the muscle strength of the hand after nerve injuries, although both have important limitations in determining the strength of the intrinsic muscles. The RIHM allows for measurements of the intrinsic muscle strength in isolation. The reliability of measurements with the RIHM is comparable to grip- and pinch-strength measurements and is acceptable to study the recovery and function of the intrinsic muscles

Table 3. Reliability Study of 33 Patients With Hand Injuries (Intraexaminer, Experienced Examiner)

	Mean (N)	SD (N)	ICC	SEM (N)	SDD (N)	SDD/SD Ratio
Grip strength (2nd handle position)	250	123	0.97	22	61	0.5
Grip strength (4th handle position)	231	110	0.95	25	70	0.6
Tip pinch strength	39	17	0.93	4	12	0.7
Key pinch strength	64	22	0.97	4	11	0.5

of the hand in isolation. The measurements with the RIHM are a valuable addition to the existing instruments for the evaluation of nerve function of the hand.

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