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ORIGINAL RESEARCH

Ultrasonographic Quantification of Intrinsic Hand Muscle Cross-Sectional Area; Reliability and Validity for Predicting Muscle Strength

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Abstract

Objective: To investigate whether ultrasonographic measurement of the cross-sectional area (CSA) of the intrinsic hand muscles can be used to predict muscle strength in a valid and reliable manner, and to determine if this method can be used for follow-up of patients with peripheral nerve injury between the wrist and elbow.

Design: Repeated-measures cross-sectional study.

Setting: Clinical and academic hospital.

Participants: Healthy adults (n=31) and patients with ulnar and median nerve injuries (n=16) between the wrist and elbow who were visiting the Erasmus Medical Center or Maasstad Hospital were included in the study (N=47).

Interventions: Not applicable.

Main Outcome Measures: Correlation between measured muscle CSA and strength and assessment of inter- and intrarater reliability. Ultrasound and strength measurements of the intrinsic hand muscles were conducted bilaterally. To establish validity, the CSA of 4 muscles (abductor digiti minimi, first dorsal interosseus, abductor pollicis brevis, opponens pollicis) was compared with strength measurements of the same muscles conducted with the Rotterdam Intrinsic Hand Myometer. Repeated measures were conducted to assess inter- and intrarater reliability.

Results: The assessed CSA strongly correlated with strength measurements, with correlations ranging from 0.82 to 0.93 in healthy volunteers and from 0.63 to 0.94 in patients. Test-retest reliability showed excellent intrarater reliability (intraclass correlation coefficient range, 0.99−1.00) in patients and volunteers and good interrater reliability (intraclass correlation coefficient range, 0.88−0.95) in healthy volunteers.

Conclusions: We found that ultrasound is a valid and reliable method to assess the CSA of specific muscles in the hand. Therefore, this technique could be useful to monitor muscle reinnervation in patients suffering from peripheral nerve injury as a valuable addition to strength dynamometers. Archives of Physical Medicine and Rehabilitation 2015;96:845-53

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Peripheral nerve injury is disabling and has a prevalence of approximately 3% in trauma patients.[1] As a direct result of median or ulnar nerve injury, muscles are denervated and atrophy consequently occurs in the weeks after injury. This can result in severe loss of hand function. The outcome with or without surgery is often unpredictable and disappointing. Most patients suffer considerable posttraumatic psychological stress because of the daily confrontation with their inability to use the injured hand and the uncertainty concerning the functional outcome. This psychological stress is believed to adversely affect functional recovery.[2,3] To provide patients and surgeons with more information concerning the outcome of surgery and therapy, muscle strength measurement has become an integral part of the physical examination and longitudinal follow-up after nerve injury.[4-7]

The methods most frequently used to evaluate outcome of motor function of the hand are manual muscle testing introduced by the British Medical Research Council (MRC) and grip and

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pinch strength dynamometers.[8,9] In addition, more recently, the Rotterdam Intrinsic Hand Myometer (RIHM) has been developed to measure individual finger or thumb strength, allowing more direct assessment of intrinsic muscle strength.[10]

However, manual muscle testing and dynamometers have a number of limitations. First, the MRC scale used for manual muscle testing is an ordinal scale with disproportional distances between grades and provides little information on recovery in the 4 to 5 segment.[11] Second, strength measurements generally assess several muscles at the same time and do not allow the examiner to measure individual muscles. Because the assessed muscles are rarely innervated by the same nerve, strength measured is not a direct representation of regeneration of one specific nerve. Third, strength measurement is often influenced by other factors than muscle strength alone (eg, injuries of associated soft tissues and tendons, pain inhibition, patient motivation, malingering). Another limitation specific to dynamometers is that they cannot be used by patients who score <3 on the MRC scale. Hence, dynamometers do not allow detection of early muscle recovery.[10,12,13] Therefore, new methods that can tackle these limitations are necessary to provide patients and clinicians with more detailed and specific information.

Clinical studies have shown ultrasounds to be highly reliable for measurement of muscle cross-sectional area (CSA) and to have a strong correlation with magnetic resonance imaging findings.[14,15] Ultrasonography has also been described as a useful tool in the diagnosis of neuromuscular disorders and for the documentation of the course of muscle atrophy and mesenchymal abnormalities in neurogenic muscle lesions in a rabbit model.[16,17] Additionally, a previous study conducted by our research group showed high correlations between the gastrocnemius muscle index and muscle thickness measured with ultrasound in a rat sciatic nerve transection model.[18] Muscle atrophy and regeneration, objectified by repeated measurements of the muscle CSA in time, may therefore serve as a monitoring tool to evaluate muscle reinnervation, even in the early stages of recovery.

The purpose of this study was to determine whether ultrasonographic measurement of the CSA of the intrinsic hand muscles can be used as a valid and reliable method to predict muscle strength and whether it can be used to monitor muscle reinnervation in patients suffering from nerve injury.

Methods

Participants

Ethical approval for this study was obtained in the Erasmus Medical Center and Maasstad Hospital. Subjects visiting either hospital were approached for inclusion. After signing informed consent, 47 subjects participated in this study. A short questionnaire was used to determine hand dominance and the presence of known upper-extremity problems or factors that could influence hand strength. We excluded all subjects with preexisting deformities or myopathies of the hand. Subjects unable to use the RIHM[a] because of insufficient strength or pain and subjects aged <18 years were also excluded. Subjects were divided into 2 groups: a group of healthy volunteers and a group of patients with nerve injuries of the ulnar or median nerve or both nerves combined (table 1).

Table 1 Group characteristics

Characteristic	Healthy Volunteers		Patients	
Sex	15 male	16 female	12 male	4 female
Hand dominance	26 right	5 left	14 right	2 left
Damaged nerve	NA		8 median nerve	10 ulnar nerve
Mean age (range) (y)	27.5 (21–54)		35.9 (19–61)	

Abbreviation: NA, not applicable.

Thirty-one healthy volunteers (15 men, 16 women; mean age, 27.5y; age range, 21–54y) were included for normative reference. Sixteen patients (12 men, 4 women; mean age, 35.9y; age range, 19–61y) had a laceration of the ulnar nerve (n=8), median nerve (n=6), or both nerves (n=2) in the forearm between the elbow and wrist. The patients were operated on by hand surgeons and received hand therapy at the rehabilitation department of one of the participating hospitals. All patients had combined nerve and tendon injuries, except for 1 patient who only had an isolated ulnar nerve injury. The average time period after injury was 15 months (range, 6–39mo). Most injuries were caused by sharp objects causing injury to the forearm between the elbow and wrist.

Ultrasound measurements

The ultrasonographic evaluation was conducted using a SonoSite TITAN ultrasound system,[b] with a 5- to 10-MHz broadband linear array probe. We used 2 examiners who were blinded to each other's measurements. The first examiner also performed a second measurement with a pause of at least 15 minutes to minimize the recall bias. The examiner and patient were seated at opposite sides of a table. The patient was asked to rest the arms on the table in a relaxed position, with the dorsal aspect of the hand and forearm in contact with the examination table. The thumb was held at a 45° angle to the midline of the hand. The array probe was placed directly onto the skin using sufficient transmission gel.[c] All scans were made from the palmar surface of the hand.

We assessed the CSA of 2 intrinsic hand muscles, abductor digiti minimi (ADM) and first dorsal interosseus (DI), which are innervated by the ulnar nerve, and 2 muscles innervated by the median nerve, abductor pollicis brevis (APB) and opponens pollicis (OP). The positions used to measure the CSA of the muscles were standardized to find the most reproducible measure of the intrinsic hand muscles at, or close to, their thickest point (fig 1). The scan planes were determined before the start of the study by pilot ultrasound evaluation of the intrinsic hand muscles in healthy volunteers, and the positions were validated using cadaver models.

All ultrasound measurements were conducted bilaterally followed by strength measurements using the RIHM. In the patients,

List of abbreviations:

ADM abductor digiti minimi
APB abductor pollicis brevis
CSA cross-sectional area
DI dorsal interosseus
ICC intraclass correlation coefficient
MRC Medical Research Council
OP opponens pollicis
RIHM Rotterdam Intrinsic Hand Myometer
SDD smallest detectable difference

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