Key Recommendations for Outcome Evaluation

1. **International Classification of Functioning Category**: b7300 (power of isolated muscles and muscle groups).

2. **Measures**:
   - MMT using the 6-level Medical Research Council (MRC) grading should be used to assess neuromuscular functioning when a nerve lesion is suspected or known.
   - MMT will not be considered a valid measure to evaluate progression of muscular strength once grade 4 has been achieved.
   - Quantitative measures, such as hand-held dynamometry, can be used to measure the progression of intrinsic and extrinsic strength using the same principles of positioning/resistance to isolate muscles. The evidence on tests, methods, and tools is emerging but insufficient to suggest a single device or approach. Comparability of results across methods should be done with caution.

3. **Procedures**: The examiner will use positioning and resistance to isolate the primary mover innervated by the nerve of interest (as outlined in this chapter and text/papers that have been validated through electrodiagnostic and other basic studies). The use of specific and consistent handling, positioning, point of application of resistance, verbal instruction, documentation of any potential factors limiting the validity of the measure, and format for documentation are essential to comparability across occasions and examiners.

4. **Interpretation**: The MRC grades will be used. Documentation of potential factors that might confound results should be performed (e.g., pain, abnormal muscle tone, limited joint range of motion, confusion, abnormal sensation, or lack of cooperation to produce a maximum performance).
Clinical Assessment Recommendation

Manual Strength Testing of the Muscles of the Hand and Wrist

Overview of Testing

Conceptual Basis for Testing
Manual muscle strength testing (MMST) is the process of assessing muscle strength and answers the question defined by the Medical Research Council (MRC): Can a muscle or muscle group move a joint segment through its full range of motion, with or without gravity eliminated, or is there only a palpable contraction?¹ (Table 1)

<table>
<thead>
<tr>
<th>MEDICAL RESEARCH COUNCIL (MRC) SCALE</th>
<th>MODIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 grades</td>
<td>9 grades</td>
</tr>
<tr>
<td>5 Full range of motion; full resistance</td>
<td>4+ Moderate resistance</td>
</tr>
<tr>
<td>4 Full range of motion; some resistance</td>
<td>3+ Minimal resistance</td>
</tr>
<tr>
<td>3 Full range of motion; no resistance</td>
<td>2+ Nearly full range</td>
</tr>
<tr>
<td>2 Decreased range of motion</td>
<td></td>
</tr>
<tr>
<td>1 Muscle flicker</td>
<td></td>
</tr>
<tr>
<td>0 Complete paralysis</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Medical Research Council Grading System

The MRC scale originally grades 4-5 against gravity and 0-3 with gravity eliminated. For muscle grading of small muscles, the effect of gravity is negligible and need not be taken into account, save maybe the wrist.⁷

The main purpose of muscle testing is to determine the continuity and integrity of the motor unit and strength of specific muscles. Therefore, MMST of the hand and wrist enables the examiner to assess impairments in strength, which may yield valuable information regarding nerve/muscle function and neuromuscular disease processes. These findings can then be used as baseline data against which changes in neuromuscular function can be evaluated and their effects on hand function researched.

Apart from the main purpose as stated earlier, muscle (strength) testing also has a place in detecting if there is discontinuity in the muscle-tendon unit or whether there are adhesions of a tendon that may prevent or limit the muscle from transmitting its force, although there is little empirical evidence on this role. These “secondary” indications will not be further discussed in this document; the focus of this document will be on MMST in relation to assessment of motor nerve function.

Muscle Weakness/Paralysis and Hand Function in the Context of the International Classification of Functioning
The International Classification of Functioning (ICF) was developed to create uniformity in language to describe and evaluate health conditions. Grading individual muscle strength can be conducted using the MRC scale (0-5) or by using hand-held dynamometers. Both types of testing/grading fall under ICF category b7300 (power of isolated muscles and muscle groups).

The consequences of muscle weakness or paralysis of the hand can be reflected at the activity level in fine hand use (d440), hand and arm use (d445), and carrying, moving, and handling objects (d449). Hence, muscle strength testing and grading, both manual and with dynamometers, can be useful to establish relationships between strength and function with the use of validated questionnaires and hand activity tests.

Tests and Subtypes/Variations of Measurement
All manual muscle strength tests for the intrinsic and extrinsic muscles of the hand and wrist will be described in detail. Multiple grading systems have been described for MMST. Grip and pinch strength measurements with grip/pinch dynamometers are presented elsewhere in the manual but some issues are also discussed in this chapter.

Understanding MMST
The first publications about MMST appeared about 100 years ago when poliomyelitis was very prevalent.² A practical clinical system was needed to assess the extent of paralysis and to monitor possible recovery. In 1936, Florence Kendall developed a percentage grading system that first introduced the factor of fatigue in grading.³ The classic document developed after World War 2 was the Aids to the Investigation of Peripheral Nerve Injuries.¹ This manual illustrates the major actions of limb muscles and how they should be tested; defines the concepts of prime movers, synergists, and antagonists; and includes the muscle grading scale familiar...
Manual Strength Testing of the Muscles of the Hand and Wrist

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to all therapists and doctors. A modified (fourth) version of
this manual, *Aids to the Examination of the Peripheral Nervous System*, was published in 2000.4

Because the MRC system was intended to be used to grade
recovery from total paralysis (grade 0), the greatest emphasis is
placed on severe degrees of weakness (grades 1, 2, and 3). The
grading system is ordinal, with differences between the grades
not assumed to be equal.5 Hence, it was designed to measure
motor nerve functionality. Other grading systems have been
developed. Several important ones will be described in this
chapter.

For a further review of the history of MMST and other
relevant aspects, the reader is referred to other articles.3,6-12

Construct Being Measured

MMST assesses the ability of the neuromuscular unit to exert
force using active muscular contraction if not limited by other
factors, e.g., joint mobility, muscle excursion (shortening or
adhesions), pain, and coordination. It requires the synergy of
several muscles of the upper extremity because few muscles
can be tested in isolation, needing synergistic contractions
of other muscles to stabilize joints to make a required
movement/test possible.

Applying MMST

MMST is mainly used in the orthopedic, neurological,
medical, chiropractic, and physical therapy areas to assess
muscle strength and to determine a patient’s progress or
deterioration over time.

The main purpose of MMST in hand therapy is to evaluate
and monitor the function of the motor neuron in peripheral
nerve pathology, e.g., peripheral or nerve root lesions,
entrapments and infections, and (poly)neuropathies such as
hereditary motor and sensory neuropathy (HMSN) or
Charcot-Marie-Tooth disease, amyotrophic lateral sclerosis
(ALS, Lou Gehrig’s disease), and Guillain-Barré syndrome,
among others. Additionally, MMST may be used in:

- establishing muscle/tendon (dis)continuity
- determining full excursion of muscle/tendon unit, e.g.,
  are there adhesions along its pathway?
- determination of suitable donors in connection with
tendon transfer surgery (these issues will not be part of
this chapter)

A relative contraindication for MMST is the presence of pain.
Naturally, in all other acute and chronic joint conditions
(e.g., fractures, sprains, and inflammation), MMST is not
indicated. MMST is also not indicated in the first few weeks
following tendon repair, tendon transfers, or other surgical
procedures in which healing structures must be protected.
Further, MMST was not designed to measure progression in
strength once full innervation and anti-gravity strength has
been obtained because grades 4 and 5 will cover a wide range
of muscle capability.

In the following sections, MMST will mainly be discussed in
the context of peripheral nerve pathology, neuropathy, and
nerve lesions.

Conceptual/Theoretical Basis

for the Construct

The function of a muscle can be divided into three aspects:
force or strength (N), endurance (time in seconds), and
velocity (m/sec). However, in most muscle strength tests,
only the first aspect, strength, is tested, which sometimes is
referred to as the maximum voluntary contraction (MVC).
In strength measurements, the MVC is generally determined
by asking the patient to squeeze or push “as hard as you can.”
In case of full ROM in MMST, the therapist will then (try
to) break the resistance. In activities of daily living (ADL),
these maximum muscle contractions are rarely used, except
for some specific activities, e.g., when lifting a heavy suitcase
or opening a tight jar. Usually, a much lower level of strength
is sufficient to perform most of our ADL, especially in white-
collar workers. The second aspect, endurance or rather lack of
it (fatigue), is probably particularly relevant in patients with
impaired muscle function due to, e.g., multiple sleroses, ALS
or HMSN.13

According to Cuthbert and Goodheart, to achieve accurate
results, muscle tests must be performed according to a
protocol.14 They state that the following factors must be
carefully considered when testing muscles in clinical and
research settings:

- proper positioning so the test muscle is the prime mover
  as much as possible
- adequate stabilization of other joints
- observation of the manner in which the patient or
  subject assumes and maintains the test position, trying,
  unwittingly, to compensate/substitute for weakness/
  paralysis
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Manual Strength Testing of the Muscles of the Hand and Wrist

- observation of the manner in which the patient or subject performs the test
- consistent timing, pressure, and position
- non-painful contacts (non-painful execution of the test)

Muscle Grading

The MRC grading system is universally accepted. All published reliability studies on MMST use this system. The grades are defined by three variables: ROM, resistance, and gravity (Table 1).

In both early and current publications, gravity is also mentioned as a factor that may influence the muscle performance. In the experience of the authors of this chapter, the effect of gravity is not important when testing the muscles of the fingers and possibly also the wrist.8

Smith et al. developed a numerical index for clinical research in muscle testing, adding a plus (+) and minus (–) to the standard grades.15 Paternostro et al. suggested a 9-point scale,16 Florence et al. have used an 11-point scale in the assessment of children with Duchenne dystrophy,17 and Bohannon and Walsh defined a 13-point scale.12 Such detail is not always possible or practical for the muscles of the hand. For the hand, a 9- or 6-point scale may suffice when manually evaluating the strength of the muscles of the hand.7,8,18

In many conditions seen by the hand therapist in which MMST is indicated, the problem is unilateral, allowing the contralateral hand to be the normative reference hand. Testing the unaffected hand for comparison may be especially important in the subnormal, or weak, range (grades 5– and 4+), when the therapist really wants to be certain that there is definite motor function impairment. The authors feel that hand dominance is not a factor of importance in MMST.

Studies by MacAvoy and Green19 and van der Ploeg et al20 (Figure 1) show that, with less than 10% of MVC, you can move a joint though its full ROM. This study was about the elbow but the same finding may apply to MMST for muscles of the hand and wrist, i.e., that minimal MVC is needed for grade 3, leaving disproportional large “room” for grade 4. Grade 4 is clinically the most relevant grade: Is motor function impairment present?

Factors That May Compromise Test Results

Five important factors may influence the validity of MMST:

1. Pain: The presence of pain may inhibit MVC.
2. Lack of sensation might cause higher than expected values because the absence of pain will help the hand to deliver power beyond physiological limits.
3. Joint contractures may limit maximum ROM. Muscle grading according to MRC scale is defined by ROM (grade 3 and above). Note that normal strength-resistance can be present with reduced range.
4. Lack of control due to spasticity.
5. Cognitive: A lack of ability to understand the procedure may produce involuntary lack of adherence to test demands.
6. Motivational: A subject may be voluntarily non-adherent to test demands, purposely showing weakness/paralysis.
### Assessing/monitoring muscle strength

**MMST**

<table>
<thead>
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<th>ULNARIS</th>
<th>Date</th>
<th>Date</th>
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<th>Date</th>
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<td>Low Abd. Little finger</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abd. Index</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Intr. Pos. I and M</td>
<td></td>
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<tr>
<td>Intr. Pos. R and S</td>
<td></td>
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| High FDP      | Date | Date | Date | Date |
|               |      |      |      |      |
| FCU           |      |      |      |      |

**MEDIAN**

| Low Abd. Thumb | Date | Date | Date | Date |
|               |      |      |      |      |
| Opp. Thumb     |      |      |      |      |

| High FPL      | Date | Date | Date | Date |
|               |      |      |      |      |

**RADIAL**

| Wrist extension | Date | Date | Date | Date |
|                |      |      |      |      |
| Finger extension|      |      |      |      |

**DYNAMOMETRY**

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<tbody>
<tr>
<td>Abd. Thumb</td>
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</table>

The form allows for adding additional muscle(s) (groups) if required

Assessment: Evaluation Form for MMST of the Wrist and Hand
Reliability

The skills of the examiners conducting studies on MMST and their skills in interpreting the derived information will affect the usefulness of MMST data. Reliability studies have been published that focus on the intrinsic muscles of the hand (Table 2).7, 18

<table>
<thead>
<tr>
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<th>Brandsma, 1995</th>
<th>Brandsma, 1998</th>
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<tr>
<td></td>
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<td>0.79</td>
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<tr>
<td>Little</td>
<td>0.83</td>
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</tbody>
</table>

Table 2. Brandsma, 1998: Three testers involved. Results shown are for AB pair. BC and AC results are very similar.

In the first study, the inter- and intrater reliability coefficients were presented for 10 intrinsic muscle tests. The study reported good reliability with better reliability coefficients when the test was repeated by the same tester. This is a common finding in observer/tester reliability studies.

The second study reported the intertester reliability from a larger patient population (n = 72) with 3 experienced testers for 9 of the 10 tests in the first study (adduction of the little finger was omitted). In this study, the MRC 6-point grading scale was refined to a 9-point scale. The calculated reliability coefficients (Kw: weighted kappas) were all good (Altman, 1991) but direct agreement was very poor. It was therefore recommended that, in the hospital where the study was conducted, only the whole numbers/grades are “valued” until acceptable direct intertester agreement can be shown on an expanded (9-point) scale. In this case, clinical decisions in the management of neuritis, changing dose of corticosteroids, are based on reported nerve assessment outcomes and therefore need to have a high degree of reliability.

Roberts et al found that reliability (Kw) for muscles predominantly supplied by ulnar nerve ranged from 0.71 upward, indicating good to very good agreement. For these tests, the percentage of agreement to within 1 grade ranged from 89% upward. For the median nerve-supplied muscles, 5 testers achieved Kw values of 0.87 or higher, and all 9 testers graded at least 97% of assessments within 1 grade of the gold standard, a senior therapist with more than 15 years of experience in daily muscle testing.

A systematic review on manual muscle testing or manual muscle test showed good reliability and validity in the use of MMST for patients with neuromusculoskeletal dysfunction. Twelve randomized controlled trials were reviewed that were used by chiropractors, physical therapists, and neurologists. In this review on muscle testing mainly in larger muscle groups like hip, shoulder, and back muscles, it was concluded that the levels of agreement, based upon a margin of one grade, were high, ranging from 82% to 97% agreement for interexaminer reliability and from 96% to 98% for test-retest reliability. The results of these studies indicate that, in order to be confident that a true change in strength has occurred, MMST scores must change more than one full grade. In the 11 studies, the coefficients ranged from 0.63 to 0.98 for individual muscle groups, and from 0.57 to 1.0 for a total MMST score (comprised of the sum of individual muscle grades).

Florence et al reported acceptable reliability on an 11-point scale but only weighted kappas were reported. Proximal muscle groups showed higher reliability than distal groups. The reliability coefficients for the two tests of two hand movements in this study, wrist extension and thumb abduction, were 0.69 and 0.71, respectively. However, in this study, only one movement relevant to hand therapists was tested.

Validity

Buschbacher determined in a prospective study (n = 217) the sensitivity and specificity of MMST in detecting weakness of the ulnar and median innervated muscles and compared the results with “confrontational strength testing.” In confrontational testing, a muscle (group) is tested against its contralateral counterpart, e.g., abducting the little fingers against each other. He found a significantly higher sensitivity
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for confrontational testing as compared to MMST: 82% and 14%, respectively, for abduction of the little finger. For abduction of the thumb, the difference was much less: 16% and 6%, respectively. Specificity was 100% in all tests. In this test, however, the outcome is nominal, positive-negative, whereas in MMST testing, the grading is ordinal.

van Brakel et al concluded that, in a prospective study in which electroneurophysiological tests such as nerve conduction and warmth perception threshold testing were used, “… changes in muscle testing scores (and monofilament testing), confirm their validity as screening tools.”31

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Muscles vs Movements

It has been emphasized that prime movers and synergists are often tested together, not individual muscles. However, it should be pointed out that every muscle is a prime mover in some specific action. MMSTs are designed to replicate the primary vector of motion of a muscle while minimizing the contribution of secondary mover muscles. During an “isolated” muscle test (individual MMST), the designated primary mover muscle should have the highest level of activity, compared with the secondary mover or synergist muscles, with minimal contribution of secondary muscles.36

Most of the intrinsic and many of the extrinsic muscles cannot be tested “in isolation.” This has been confirmed by electromyography studies.37,38 Brunnstrom and Dennen (1941), based on their experience with polio patients before World War II, stated that, in many instances, movements were graded rather than individual muscles. For example, in testing the motor function of the ulnar nerve, the therapist would test abduction of the little finger rather than the abductor digiti minimi muscle.8

Muscle testing evaluates the strength of response of the muscle, not the speed of response. Muscle testing is an art in which the force applied to the patient is increased at a constant rate until the tester senses the muscle begin to give way. The classic “break test” used by physical therapists tests this phenomenon as well.

Clinical changes are expressed in grade changes that either result from change in ROM 1-2 > 3, or increase in force that can be overcome 3 > 5, i.e., mild (3+), moderate (4–, 4+), strong (5).

A new system of grading for MMST should retain the advantages of the MRC: wide acceptability, ease of use, usefulness for most muscles, and applicability to motor recovery from all types of nerve injury (e.g., deterioration based on progressive neuromuscular disorders).

Useful potential modifications of the MRC include a grade for a muscle that achieves strength against resistance but not against gravity and a standardized subdivision of grade 4: mild (4–), moderate (4), good (4+), and normal/strong (5).

Intrinsic Hand-Held Dynamometer

Instruments such as the RIHM are now available to perform quantitative measurements of the intrinsic muscles of the hand.39

The RIHM was designed such that it can measure a wide range of muscle groups, such as the abduction and adduction strength of the little finger and index finger and the opposition, palmar abduction (anteposition), and opposition strength of the thumb and intrinsic muscles of the fingers.
Manual Strength Testing of the Muscles of the Hand and Wrist

Reliability of RIHM measurements in nerve injury patients was comparable to grip and pinch strength measurements and is appropriate to study the functional recovery of the intrinsic muscles of the hand in isolation. In clinical evaluation and research studies on patients with hand problems, muscle strength is often based on grip and pinch strength dynamometry. It has been shown that changes in grip-pin$\text{ch}$ strength are not necessarily related to changes in intrinsic muscle strength because of the dominant contribution of the extrinsic hand muscles to these measurements.40,41

In a study comparing the strength of the hand muscles in 46 patients with neuropathies like HMSN, in which the correlations between the different strength measurements of intrinsic and extrinsic muscles and hand function measured with the modified Sollerman test and the DASH questionnaire,32 it was found that intrinsic muscle strength was positively correlated with the Sollerman test, which specifically measures fine motor tasks. In contrast, extrinsic muscle strength was more strongly correlated with the DASH, which is a more global measure of upper extremity function.

In a review on CTS outcome measures, Geere et al concluded that, in theory, MMST should be more specific when testing the thenar musculature, whereas dynamometry may be more sensitive if assessed using a hand-held dynamometer like the RIHM.42

Tests for Intrinsic Muscles

Testing the intrinsic muscles serves to assess and monitor the motor function of peripheral nerves and cervical nerve root function. It is assumed that, in neuropathies, most of the muscles in the same nerve distribution will be weak/paralyzed to the same degree and extent. In such instances, it is therefore not necessary to test each and every muscle that is innervated by the nerve whose function is compromised.8

Some suggestions for quick testing are Froment sign and “confrontational testing” for ulnar palsy.53 In the latter test, the patient is asked to put the adducted little fingers against each other on their ulnar borders while holding the fingers in full extension. The patient is then asked to abduct the little fingers against one another. Abduction of the little finger in the affected hand will be weak or not possible. The same can be done with the thumbs to test for integrity of the median nerve.

In cases of nerve laceration and repair, more movements/muscles should be tested and graded. In cases of suspected nerve entrapment, detailed testing is needed to determine at which site the nerve may be compressed.

Prior to the actual muscle testing, the examiner has demonstrated the required movement and has verified that full ROM is available and that pain is not a possible inhibiting factor.

Abduction of the Little Finger

Primary muscle: abductor digiti minimi, but all hypothenar muscles are active; flexor digiti minimi, opponens digiti minimi.

The therapist supports the patient’s hand, palm up, holding the middle, ring, and index fingers. The little finger is passively fully abducted while keeping the metacarpophalangeal (MCP) joint in slight flexion to observe the full ROM, and the patient is asked to hold the finger in that abducted position (Figure 2). If the little fingers maintain this position, they must exert a force equivalent to grade 3. If the patient is able to hold the fingers into abduction, manual resistance is applied at the ulnar side of the proximal phalanx of the little finger in a direction toward the ring finger. If the patient is not able to maintain the abducted position, then the contraction of the hypothenar is assessed to determine the grade 0, 1, 2, or 3.

Figure 2. Abduction of the little finger.
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Abduction of the Index Finger
Primary muscle: first dorsal interosseous.

With the forearm of the examinee in neutral position, the therapist asks the patient to abduct the index finger while keeping the MCP joint flexed. The thumb of the supporting hand of the therapist is resting in the first web space to feel for possible muscle contraction in case of severe weakness. If there is full ROM, manual resistance is given on the radial aspect of the base of the proximal phalanx of the index finger in an ulnar direction (Figure 3).

![Figure 3a. Abduction of the index finger.](image)

There may be considerable or full strength of the first dorsal interosseous muscle accompanied by paralyzed hypothenar muscles (abduction of the little finger) in a high ulnar nerve lesion. In those cases, a Martin-Gruber anastomosis should be suspected. With a Martin-Gruber anastomosis, the first dorsal interosseous muscle will often be innervated from the median nerve through the ulnar nerve at the mid-forearm level. Local pathology at the level of the wrist, in Guyon’s canal or distal to it where the ulnar nerve branches, may also result in weakness or paralysis of the ulnar innervated muscles, which is different from the muscle loss seen in ulnar involvement proximal to the wrist.

Intrinsic-Plus Position
Primary muscles: interosseous and lumbral muscles.

The patient is asked to place the fingers in the so-called “intrinsic-plus”: flexion of the MCP joints and extension of the interphalangeal (IP) joints. If the patient is able to move to this position, active resistance is applied on the volar side of the proximal phalanx toward extension (Figure 4). The suggested grading for this movement is for grades 3, 4, and 5 as per MRC scale. Grade 2: When asking for the intrinsic position, the finger is less than 30 degrees short of full extension at the proximal IP (PIP) joint. Grade 1 does not apply.

![Figure 4. Combined Interosseous and Lumbrical.](image)

This test gives additional information about ulnar innervated muscles, specifically the interosseous muscles. Contrary to what most textbooks on anatomy and MMST state, this intrinsic-plus test is a function of the interosseous muscles.

Unlike the interosseous muscles, there are no clinical tests in which the activity of the lumbral muscles can be graded on an ordinal scale.
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The terms lumbrical-splint and lumbrical-replacement could be considered misnomers. The interossei are the primary active muscles for MCP flexion in the so-called lumbrical position. In tendon transfer procedures described as lumbrical-replacement procedures transfers, it is the function of the interossei that is replaced.

Two major clinical findings support this view: In low median palsy, there is no weakness in the lumbral test of the index and middle fingers. Second, in ulnar palsy, there is usually always weakness or overt clawing of the index and long fingers.8,44

**Thumb Adduction**

**Primary muscle:** adductor pollicis; **secondary muscles:** extensor pollicis longus (EPL) and flexor pollicis longus (FPL).

The adductor pollicis muscle is the most powerful intrinsic hand muscle. Adduction of the thumb is obtained by several muscles, including the extrinsic EPL and FPL muscles. The muscles cannot be tested in isolation; the EPL and FPL are also strong adductors of the thumb. Thumb adduction strength is best evaluated with a pinch dynamometer in the key pinch. Grading of individual palmar and dorsal interossei (except first dorsal interosseous) is not needed for most common conditions, and would also be difficult to grade with MRC grades and would be superfluous with the tests already given.

**Thumb Palmar Abduction**

**Primary muscle:** abductor pollicis brevis (APB); **secondary muscles:** the opponens pollicis (OP), flexor pollicis brevis (FPB), and abductor pollicis longus (APL).

With the forearm in supination and the hand in slight extension at the wrist, the patient is asked to lift the thumb away from the palm so the thumb is at a right angle to the plane of the palm. When this full movement is possible, resistance is given proximally on the radial aspect of the thumb, MCP level, in a direction toward the palm. Resistance is applied perpendicular to the plane of the palm of the hand (Figure 5). Wrist extension eliminates contribution of the APL toward thumb abduction.45

**Thumb Opposition**

**Primary muscles:** OP-APB and FPB.

For testing thumb opposition, the person is asked to put the hand in the same position as the test for thumb abduction. Resistance is provided on the palmar surface of the patient’s thumb over the head of the first metacarpal, parallel to the plane of the palm of the hand. The finger providing resistance rotates 90 degrees from the abduction test (Figure 6). The patient is not allowed to flex the IP joint of the thumb.
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Figure 6a. Thumb Opposition.

Figure 6b. Thumb Opposition.

Figure 7. MCP Flexion of Thumb.

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Figure 6a. Thumb Opposition.

Figure 6b. Thumb Opposition.

Figure 7. MCP Flexion of Thumb.

Testing FPB strength is (too) difficult as: 1) It requires coordination flexing the MCP joint while maintaining extension at the IP joint. 2) It requires sufficient range of motion of the MCP joint, which is not always present. Again, for assessment and evaluation of most clinical conditions, the MMST test for MCP flexion would be redundant. 3) The muscle may be innervated by ulnar, median, or both.

Tests for Extrinsic Muscles

As stated earlier, MMST of the intrinsic and extrinsic muscles often is performed to assess and monitor the motor function of the ulnar, median, and radial nerves in (mono) neuropathies, nerve lacerations and repairs, and nerve root lesions of the cervical spine. The testing of the extrinsic muscles is also often performed to check for continuity or discontinuity of the tendon or adhesions that prevent full tendon excursion.

Thumb MCP Flexion Muscles

Primary muscle: FPB.

MCP flexion of the thumb can be graded, provided there is a good range of joint motion. In this movement, the adductor pollicis and abductor pollicis contribute to flexion along with the FPB. The patient is asked to flex the thumb MCP joint while keeping the IP joint extended (Figure 7). Resistance is given at the base of the proximal phalanx toward extension.

Wrist Extension: Extensor Carpi Radialis Longus (ECRL) and Extensor Carpi Radialis Brevis (ECRB)

With the forearm in pronation and supported by the examiner, and the elbow flexed to 90 degrees, the person is asked to extend the wrist with the fingers in a fist. This decreases possible contribution of finger extensors to wrist extension. Resistance is given on the dorsum of the hand in a palmar-ulnar direction (Figure 8).
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The ECRL and ECRB tendons insert at the bases of the second and third metacarpals, respectively, and can be palpated there. In a slender hand, the individual tendons may be visible. A palpable and visible groove may be seen between the two muscle bellies in the upper forearm. Differentiation between the two muscle contractions may be possible by changing the elbow position: first testing with the elbow flexed and then with the elbow extended. The differentiation between the two muscles is especially important in tetraplegia when the transfer of one of these tendons may be considered to enhance hand function.

Wrist Extensions: Extensor Carpi Ulnaris (ECU)
The ECU is tested by asking the patient to extend the wrist, with forearm pronated and supported by the therapist. Resistance is given on the dorso-ulnar side of the hand in a volar-radial direction (Figure 9). The tendon can be palpated distal to the ulnar styloid process.

Finger Extension: Extensor Digitorum Communis (EDC)
The EDC muscle is tested by asking the person to hyperextend the MCP joints while flexing the IP joints. The wrist is kept in extension by the examiner (Figure 10). All fingers may be tested simultaneously.

Finger Extension: Extensor Indicis Proprius (EIP) and Extensor Digiti Minimi (EDM)
To test and grade the EIP and EDM, the subject is asked to only extend the index and little fingers from the closed hand position. Resistance is given on the dorsal side of the proximal phalanx in a direction toward flexion. If the connection between the EDC of the index and the middle finger is loose enough, isolated extension of the index finger is possible without the EIP.
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**Wrist Flexion: Flexor Carpi Ulnaris (FCU)**
To test the FCU muscle, the patient positions the forearm in supination and the therapist asks the patient to flex and ulnar deviate the wrist. Resistance is applied toward radial extension. The FCU tendon can easily be palpated (Figure 11a, 11b). With normal integrity of the ulnar-innervated muscles, the FCU tendon is also palpable with little finger abduction as the pisiform bone migrates. Both the FCU and the hypothenar muscles insert into the pisiform. Contraction of the FCU stabilizes the pisiform, allowing more efficient contraction of the hypothenar muscles. Strength grading of the FCU may be difficult as other muscles contribute to wrist flexion.

**Wrist Flexion: Palmaris Longus (PL)**
The patient positions the forearm in supination and the therapist asks the patient to flex the wrist without deviation. Because many individuals do not have a PL tendon, one may only be able to see and palpate the FCR. When present, the PL tendon can be clearly visualized in the center of the wrist, especially when the therapist asks the patient to simultaneously oppose the thumb tip to the little finger tip (Figure 12). This motion may or may not be possible given the possible underlying pathology.

**Wrist Flexion: Flexor Carpi Radialis (FCR)**
During wrist flexion, the FCR tendon is also easily palpated near the center of the wrist just radial to the PL. To test the FCR muscle, the patient positions the forearm in supination and the therapist asks the patient to flex the wrist. Resistance is applied toward extension (Figure 13).
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**Finger and Thumb Flexion: Flexor Digitorum Profundus (FDP)**

The FDP is responsible for distal IP (DIP) joint flexion. The muscle has a dual innervation: The ring and little fingers are usually innervated by the ulnar nerve, and the index and long fingers by the median nerve. The individual finger flexor muscles are difficult to test in isolation, as the FDPs have strong connections at the wrist level. In testing the individual fingers, the therapist holds all finger IP joints extended, allowing only the DIP joint of the finger to be tested free. Resistance is applied toward extension (Figure 14). In the group test, the therapist asks the patient to flex all fingers and then provides resistance on the palmar surface of the fingertips to the flexed DIP joints in the direction of extension. This test can be used to determine high and low median nerve pathology. If the FDP of the little finger is weak in high ulnar nerve pathology, the FDP of the index is weak in high median nerve pathology. The test may be useful to determine possible lesions of individual FDP tendons.

**Finger and Thumb Flexion: Flexor Digitorum Superficialis (FDS)**

Individual FDS muscles are tested with all other fingers held in extension by the examiner. The examiner asks for flexion of the PIP joint, and resistance is applied toward extension (Figure 15). Many people have a normally weak FDS to the little finger and, in some cases, this muscle may even be absent. In such cases, isolated PIP flexion will not be possible. Also, in some patients, the ring finger must be allowed to move with the little finger in order to see adequate movement of the FDS in the little finger.

**Finger and Thumb Flexion: FPL**

The FPL muscle is the only muscle that flexes the IP joint of the thumb. Therefore, testing IP flexion of the thumb is the ideal test of the integrity of the median nerve if a lesion proximal to the wrist is suspected. The therapist grasps the patient’s thumb, stabilizes the carpometacarpal joint in neutral and the MCP joint in extension, and asks the patient to flex the thumb IP joint. Resistance is applied toward extension (Figure 16).

Confrontational testing has been discussed earlier for intrinsic muscles but could also be done to diagnose nerve function impairment and differentiate between high and low lesions. For the ulnar nerve, the DIPs of both little fingers could be “hooked,” distal phalanges interlaced, and strength assessed. Likewise, the same could be done with FPL (thumb IP flexion) to assess high median nerve motor integrity.
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Thumb Extrinsic Muscle Test: EPL
The EPL is the primary extensor of the thumb IP joint. The EPL is tested by asking the subject to place the palm on a table surface and lift the thumb above the plane of the hand (Figures 17a, 17b).
The thenar muscles, except for the OP, have an insertion into the extensor apparatus of the thumb. This insertion is similar to the insertion of the lumbrical and interosseus muscle in the fingers so that these muscles can assist in thumb IP extension. In cases of complete EPL rupture or radial palsy, thumb IP extension may still be complete. Usually IP extension in this circumstance will be accompanied by adduction of the thumb as the intrinsic thumb muscles that insert into the extensor apparatus that try to substitute for loss of EPL function also exert their primary function.

The clinical significance of this “trick” movement is obvious: Do not conclude there is normal EPL function or returning radial nerve function when thumb IP extension is possible.

Thumb Extrinsic Muscle Test: Extensor Pollicis Brevis (EPB) and APL
Specific movements that isolate EPB and APL function are difficult. In clinical practice, the grading of these muscles in cases of nerve pathology is not needed. We refer to main textbooks on MMST in case the reader should be interested in testing these muscles.

The three thumb extensor tendons are all easily palpable and, in most hands, they are also visible as the patient moves (circles) the thumb. The tendons are the borders of the anatomical snuffbox on the radial aspect of the thumb.

References
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Additional References

ErasmusMC video on muscle testing

Web album for figures

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