Protocol Isometric Strength Testing

Clarification of terms used

Isometric Contraction

In an isometric contraction, the length of the muscle remains the same. As a consequence the muscle exerts strength without a change of angle in the joint.

Hand Held Dynamometer (HHD)

With a HHD, the isometric strength of different muscle groups can be determined. In this protocol, the MicroFET 2 is used. This device contains a power cell which can measure the peak force that is exerted by a certain muscle group.

Proximal

An anatomical term to indicate that the body part/area is located closer to the centre of the body.

Distal

The opposite of proximal. This term is used to indicate that the body part is situated farther away from the centre of the body.

Machine set up

Select Newton for measurement results

The desired unit of measurement can be selected prior to the measurement. Hold down the 'threshold'-button for 5 seconds. A dash will appear behind the current unit setting in the 'peak force'-display. It is now possible to switch between the different units by briefly pressing the 'threshold'-button. Once the desired unit of measurement has been selected, press the 'reset'-button to confirm.

Threshold settings

The threshold sets a High (H) or Low (L) threshold for the minimal force to start the test. The setting of the MicroFET2 for this protocol is at High (H).

Reset the device after each measurement

By pressing the reset button all measurements are set at zero. Only after this reset can a new test be initiated.

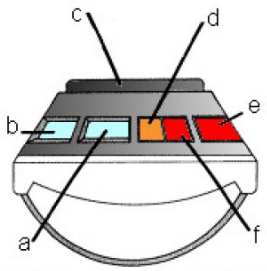


Figure 1: microFET2 Features

a. Duration display
b. Peak Force display
c. Transducer pad
d. Threshold button
e. ON/OFF switch
f. Reset button

Testing procedure

1. Install the lunar-shaped pad by screwing it onto the MicroFET2.
   Attention! For the First Dorsal Interosseous the finger pad is installed.
2. Set up threshold on High (H)
3. Reset the HHD
4. Perform the first measurement
5. Note the measurement on the form
6. Reset the HHD
7. Perform the second measurement
8. Note the measurement on the form

1. Introduction

The necessity for standardized muscle strength testing as an evaluation method in ALS effect studies.

ALS leads to progressive muscle weakness that spreads throughout the entire body. This muscle weakness is for a large part responsible for functional loss over time. To understand the effect of new therapies on functional level, it is therefore essential to include muscle strength in trial designs. However, the measurement of muscle strength yields various problems, such as lack of standardization and low intra- and inter- rater reliability. Consequently, the data is often of poor quality leading to suboptimal reliability of test outcomes. An example of these problems is outlined in the following case.

Mr. Jones (62), has had a dropping foot for two years. He is experiencing increasing difficulty in climbing the stairs. Two months ago, he was diagnosed with ALS. Mr. Jones is participating in a trial. His isometric muscle strength will, therefore, be assessed monthly.

At the time of the first trial measurement, Mr. Jones is sitting in a chair. The evaluator notes that the arm of the chair is in the way and so she cannot grip the right elbow while measuring elbow flexion. She, therefore, allows Mr. Jones to rest his elbow on the chair. During the test, the evaluator stands in front of the patient. Later, the evaluator notes that she is not able to break the power of the knee extension with gentle force. To resolve this, she pushes against the lower leg using her full body weight, without noticing that she has actually pushed the hip down on the chair and the knee was still extended during the test.

One month later, Mr. Jones visits the same evaluator for his monthly muscle strength test. This time the evaluator positions the elbow away from the body slightly so that she can grip the elbow to test the flexural strength. She performs the test while standing alongside rather than in front of the patient. After the previous monitoring visit, Mr Jones experienced pain in his knee. He, therefore, now chooses to exert submaximal power. On this occasion, the evaluator succeeds in gently breaking through the power of the extensor muscles of the knee. Test scores show that the measured strength in the knee extensors is much lower than it was the previous month.

In our daily practice, the approach used for measurement of isometric muscle strength often varies. However, in order to compare the results, it is important that every muscle strength measurement is carried out in exactly the same way by each of the investigators. Had the measurement in the above case been standardized, the execution of the measurements would have been as follows:

The strength of arms and legs is measured on a treatment table while Mr. Jones is lying down. Thus, Mr. Jones' body acts as a fixation for the strength test and the evaluator has both hands free to perform the test. This makes it much easier to break through the exerted force using gentle pressure. When testing the flexural strength of the elbow, the evaluator stands in axis of the movement according to the protocol and exerts a pulling movement to extend it.

To test the strength of the knee, the evaluator asks Mr. Jones to sit on edge of the bed. Because the treatment table is at a high setting, the feet do not touch the floor and the lower legs can dangle in relaxed fashion. When testing the extension force of the knee, the evaluator can exert resistance in the direction of knee flexion by pushing with two hands. Because of the sitting position on the treatment table, the possibility of the muscles around the patient's hip affecting the strength test of the knee extensor muscles is minimised. The test results are now much more reliable because there is less variability. This means that isometric strength testing is of huge added value for the desired effect evaluation.

Why do we test isometric strength with a HDD and not with the MRC scale?
The use of the MRC scale is debatable because of the subjectivity. What is normal strength for a man of 39, or a woman of 62? Furthermore, the MRC score is not sensitive. This is problematic for the detection of small changes. Regarding this issue, the non-linear nature of the scale is also a stumbling block (see Figure 2). Because of these factors, the reliability of the MRC scale for an effect study is low.

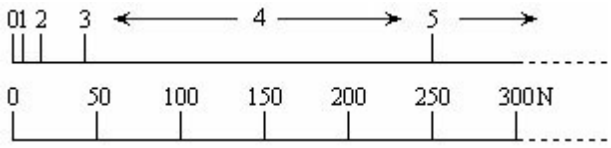


Figure 2: Comparison between the Medical Research Council (MRC) scale (upper line) and the dynamometer scale (lower line) in the case of the elbow flexors of a man. Clearly, the ability of the MRC-scale to grade a large range of force application is inadequate, in particular in the range 3 to 5.

A portable and inexpensive way of solving these problems is by using a Hand Held Dynamometer (HHD) to test isometric muscle strength. This device can provide a reliable and objective representation of the strength, provided that the test is performed in a standardized way by all evaluators. We make the quality of the measurements as high as possible by instructing all the investigators to test isometric muscle strength in the same way, with the same instrument. This is not only beneficial to our patients, but it also contributes to the quality and usefulness of the research data.

This course introduces you to the standardized test procedures, so that you can then apply them yourself. Practicing the protocol is essential in order to meet the requirements of an accredited evaluator.

2. Conditions for measuring isometric strength

Break method
For this protocol, the so-called 'break method' is used. This means that the evaluator not only offers resistance in the opposite direction to the force exerted by the subject, but also gently breaks through the power exerted by the patient. This form of testing is aggravating for the muscles and joints of the patient. It is, therefore, recommended that movement is gentle and only pushes slightly through the power exerted by the patient to limit the load on the tested muscle as much as possible. Make sure that the tested body part never touches the ground before the end of the test. The ground offers extra resistance, and so touching it would result in an overestimation of the observed power.
If 'breaking' through the exerted power of the subject was not possible, it is very important to note this on the designated place on the score form.

Starting position of the subject
The strength measurements are carried out on a treatment table. The body itself can serve as fixation strength for strength measurements. This fixation strength is highest in the supine position. Therefore, this position greatly improves the reproducibility of the data. The head of the treatment table is usually set at a 45 degree upward incline. A small pillow can be placed under the head/neck region for extra comfort. In general, it is recommended that treatment table paper or mattress covers are removed in order to create as much friction as possible at the table surface.
An exception in starting position is only made for knee extension and flexion. For these tests, the patient sits on the treatment table in upright position with the lower legs hanging down relaxed. While testing, compensatory movements in the trunk of the patient should be avoided if possible.

It is important to adhere to the starting positions specified in the protocol (see Technique, Section 3). You also have the option of checking the corners of limbs with a goniometer. Shoes and any orthotics are taken off during muscle strength testing.

Starting position of the evaluator
It is possible that an evaluator has difficulty breaking through the power of the patient. This happens when the subject is stronger than the assessor. In order to provide as much resistance as possible, the evaluator always stands in the "groove" of motion and therefore is always exerting a pushing or pulling movement. It is important to not only use the arms but also the trunk to provide sufficient resistance for a break.

Placement of the HDD
The exact location of the HDD has a large influence on the final test score. The higher the leverage, the lower the force being measured. Always place the HHD just proximal to the articulation of the joint. If the HHD is positioned too far distally, this may cause a movement in the joint, or result in an improper test of the muscle group. These factors have a considerable adverse influence on the strength score.

Duration of contraction
To give the subject the opportunity to exert maximum strength, but to prevent unnecessary overexertion, the isometric contraction is sustained for 2 seconds, followed by a break.

Encouragements
The subject should be encouraged to push against the HHD with all of his/her strength. The effect of encouragement on maximal strength has been proven. The encouragement has, therefore, been standardized. During muscle strength measurement, the evaluator says in an encouraging voice (level): "contract!" (1 second), followed by "maximum!" (1 second) followed by a gentle break.

Number of repetitions
Each measurement is repeated twice. Both scores are written down. If the value of the second measurement deviates by more than 15% from the first measurement, the measurement is repeated a third time. The value of the third measurement is also included on the test form.

Handgrip strength
The Jamar dynamometer is used to measure hand grip strength. Hand grip strength is measured and recorded in pounds. For this protocol, the standard grip setting is at the second notch and should not be adjusted.

3. Technique (see Appendix 1 for supportive images)

Shoulder Flexion
Subject in supine position. Shoulder flexion 90 degrees relative to the trunk. Elbow extended; the forearm is in neutral position (thumb is pointing towards the ceiling). HHD is placed proximal to the humeral epicondyles, i.e. just above the elbow joint. Movement evaluator: pull.

Elbow Flexion
Subject in supine position. Elbow is flexed to 90 degrees; the forearm is in neutral position (thumb is pointing towards the ceiling). Important: during the test, the upper arm and elbow rest on the mattress of

the treatment table. HHD is placed on the distal radius, just proximal to the wrist joint. Movement evaluator: pull.

Elbow Extension
Subject in supine position. Elbow is flexed to 90 degrees; the forearm is in neutral position (thumb is pointing towards the ceiling). Important: during the test, the upper arm and elbow rest on the mattress of the treatment table. HHD is placed on the distal ulna, just proximal to the wrist joint. Movement evaluator: push.

Wrist Extension
Subject in supine position. Elbow is flexed to 90 degrees, the forearm is in neutral position (thumb is pointing towards the ceiling) and the back of the hand lies in the extension of the forearm. Important: during the test the upper arm and elbow rest on the mattress of the treatment table. The fingers are bent into a fist if possible. The evaluator grasps the palmar side of the forearm with the contralateral hand. The HHD is placed just below MTP 2,3 and 4 on the back of the hand. Movement evaluator: push.

First Dorsal Interosseous
Pay attention! The finger pad has to be installed to test this muscle group. Subject in supine position. Forearm in pronation; the back of the hand is pointing upwards. During the test, the upper arm and elbow rest on the mattress of the treatment table. Using his contralateral hand (the hand not holding the HHD), the evaluator fixes the ulnar side of the subject's hand, just below MTC 5. The subject is asked to spread the fingers maximally. The HHD is placed on the lateral side of the index finger, just proximal to the PIP joint of the index finger. Movement evaluator: push.

Hip Flexion
Subject in supine position. Raise knee until hip is flexed 90 degrees relative to the trunk. The knee of the raised leg hangs loosely in flexion. Important: the foot does not touch the treatment table. HHD is placed suprapatellar to the flexed knee at the end of the upper leg, towards the knee. Movement evaluator: push.

Ankle Dorsiflexion
Subject in supine position. The ankle is in neutral dorsiflexion (0 degrees; foot perpendicular to the lower leg). HHD is placed just proximal to the metatarsal joints. Movement evaluator: pull.

Knee Extension
Subject is sitting on the edge of the treatment table, the back of the knees just not touching the edge. The height of the treatment table is set so that the feet float at least 20 centimetres above the ground. The subject should not move the trunk forwards or backwards during the test. The hands can lean on the treatment table next to the thighs, but must not hold on to the treatment table. The backs of the knees do not touch the edge of the table. The knees are in 90 degrees of flexion, the lower legs hang down relaxed. HHD is placed on the ventral side of the lower leg just proximal to the malleoli. Movement evaluator: push.

Knee Flexion
Subject is sitting on the edge of the treatment table in the same position as during the knee extension test. HHD is placed on the dorsal side of the lower leg just proximal to the malleoli, right on the Achilles tendon. Movement evaluator: pull.

Grip strength

Subject in sitting position on the edge of the treatment table. The subject's feet are touching the ground. Grip strength is measured with a Jamar grip dynamometer. The standard grip setting is at the second notch. The elbow is flexed at 90 degrees. The dynamometer is placed in the hand to be tested with the dial facing towards the evaluator. The subject is instructed to squeeze the dynamometer (with his or her hand) as hard as possible. Subjects should be prevented from moving into pronation and from extreme wrist flexion. The evaluator may stabilize the dynamometer at the ends.

4. FAQ's

1. A limb cannot be placed in the desired starting position because of a shortened muscle, joint restriction or pain.
   If the limb can be tested without letting it touch the surface, the test can still be carried out using a different joint angle. This deviation is recorded on the score sheet.

2. My subject is unable to breath properly in the prescribed position (headrest elevated 45 degrees).
   This can often occur, particularly in patients with a bulbar onset. You can adjust the headrest. A higher position of the headrest will often help to increase the level of comfort for the patient. If the position of the headrest is not 45 degrees, please do note the exact position (number of degrees) on the score sheet.

3. My subject does not have enough strength to adopt the correct starting position
   A score of 0 is noted on the score form.

4. My subject cannot (safely) sit unsupported on the treatment table while testing knee flexion and extension.
   If necessary, the subject may lean on the treatment table with the hands next to the thighs, but the hands are not allowed to hold the table because this would affect the score. If, despite arm support, the subject cannot maintain the sitting position, the evaluator must ask an assistant to stabilize the subject's trunk from behind.

5. My subject is sliding on the treatment table during muscle strength testing.
   If the subject is sliding on the surface of the treatment table during muscle strength testing, the subject should be stabilized properly. The recommendation is that the evaluator stabilizes the subject manually, and that straps or other types of external fixation are avoided. It is recommended that paper or mattress covers are removed.

6. Is a quick and robust break the best alternative if I'm not able to make a small and gentile break?
   No. If a small and gentile break was not possible the evaluator notes an N under 'Able to break' on the score form. A robust brake generates an unreliable score which has a negative effect on the quality of the data.

5. Criteria for passing practical examination 'Isometric strength testing in ALS patients'

During the exam 4 muscle groups will be tested: 2 muscle groups of the upper extremity, 2 muscle groups of the lower extremity.

The exam will be awarded if
- at least 3 of 5 'technique' criteria are passed.
- both criteria 6 and 7 of the 'variability' section are passed. Note: the inter and intra rater variability will only be assessed for measurements in which the student was able to make an adequate break.

Technique	Passed (Y/N)
1. Excellent starting position of the participant.	
2. Excellent placement of the HHD.	
3. Uses body weight and not only arm strength to perform a break.	
4. Performs a gentile and small break.	
5. Adequate judgment of 'able to break'.	
Sub score technique (minimal score to pass 'technique': 3)	
Variability	
6. Intra rater variability within 10% in at least 2 of 4 tested muscle groups.	
7. Inter rater variability within 20% in at least 2 of 4 tested muscle groups.	
Sub score variability (minimal score to pass 'variability' : 2)	
Total (1-7)	
Conclusion (passed/not passed)	

6. Score form 'Isometric strength testing in ALS patients'

RIGHT SIDE	Trial 1 (Newton)	Trial 2 (Newton)	Trial 3 (if necessary)	Able to break (Y/N)	Other deviations from the protocol
Neck flexion					
Shoulder Flexion					
Elbow Flexion					
Elbow Extension					
Wrist Extension					
1st D. Interosseous					
Hip Flexion					
Ankle Dorsiflexion					
Knee Extension					
Knee Flexion					
	Trial 1 (Pounds/lbs.)	Trial 2 (Pounds/lbs.)	Trial 3 (if necessary)		
Grip strength					

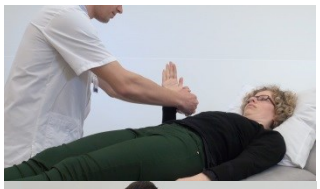
LEFT SIDE	Trial 1 (Newton)	Trial 2 (Newton)	Trial 3 (if necessary)	Able to break (Y/N)	Other deviations from the protocol
Neck flexion					
Shoulder Flexion					
Elbow Flexion					
Elbow Extension					
Wrist Extension					
1st D. Interosseous					
Hip Flexion					
Ankle Dorsiflexion					
Knee Extension					
Knee Flexion					
	Trial 1 (Pounds/lbs.)	Trial 2 (Pounds/lbs.)	Trial 3 (if necessary)		
Grip strength					

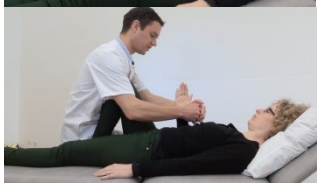
Appendix 1: Quick reference Isometric Strength Test Protocol

Shoulder Flexion

The arm is lifted so the shoulder is flexed in 90 degrees relative to the trunk. The elbow is extended and the thumb is pointing upwards. The hand held dynamometer is placed just above the elbow joint on the lateral epicondyle of the humerus.

Elbow Flexion





The elbow is flexed to 90 degrees and the thumb is pointing upwards. The distal radius is palpated and the hand held dynamometer is placed lateral on that point, just proximal to the wrist joint. The evaluator is exerting a pulling movement. During this specific measurement is often occurs that the subject is sliding on the treatment table.
In this case the subject should be stabilised to ensure a reliable measurement. This can be done by asking the subject to bent the knee en rest with the foot on the treatment table. The evaluator can now stabilise the subject with his trunk and still perform the measurement as previously described.

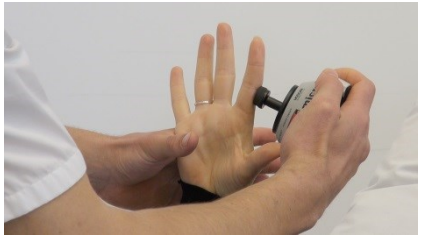
Elbow Extension

The elbow is flexed to 90 degrees and the thumb is pointing upwards. The distal ulna is palpated and the hand held dynamometer is placed lateral on that point, just proximal to the wrist joint. The evaluator is exerting a pushing movement.
It is important that during the test the upper arm and elbow rest on the mattress of the treatment table.

Wrist Extension

Just as during the previous tests the elbow is flexed to 90 degrees and the thumb is pointing towards the ceiling. The back of the hand lies in the extension of the forearm. The fingers are bent into a fist if possible. With the contralateral hand -that is the hand that is not holding de hand held dynamometer- the evaluator grasps the palmar side of the forearm. The hand held dynamometer is placed just below the knuckles of the fingers on the back of the hand and the evaluator exerts a pushing movement.

First Dorsal Interosseous



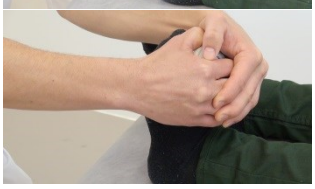
Pay attention! The finger pad has to be installed to test this muscle group. The elbow is flexed to 90 degrees. The forearm is placed in pronation so the back of the hand is pointing upwards. The subject is asked to spread the fingers maximally. Using his contralateral hand the evaluator fixes the ulnar side of the subject's hand just below MTC 5, the knuckle of the little finger. The hand held dynamometer *with the finger attachment* is placed on the lateral thumb side of the index finger, just proximal of the interphalangeal joint.

Hip Flexion

The knee is raised until the hip is flexed 90 degrees relative to the trunk. It is important that the foot does not touch the treatment table. The hands rest at the sides of the thighs. The knee of the raised leg hangs loosely in flexion. The subject is asked to move the knee in the direction of the chest. The hand held dynamometer is placed suprapatellar to the flexed knee. That is at the end of the upper leg, towards the knee.
The evaluator exerts a pushing movement and stands in line of the motion.

Ankle Dorsiflexion

The ankle is placed in neutral dorsiflexion so the foot is perpendicular to the lower leg. Just like during the other measurements, it is important that the hand held dynamometer is placed accurately. In this case, the hand held dynamometer should be placed between the cuneiform bones and the metatarsal joints, so on the metatarsal bones. The evaluator exerts a pulling movement.
It is quite possible that during this test the subject is sliding on the treatment table. In that case the evaluator stabilises the contralateral foot of the subject with his knee, still performing the measurement as previously described.



Knee Extension

The subject is asked to sit on the edge of the treatment table with the back of the knees just not touching the edge. The height of the treatment table is set so that the feet float at least 20 centimetres above the ground. The knees are in 90 degrees of flexion. The hand held dynamometer is placed on the ventral side of the lower leg just proximal to the malleoli. The evaluator squats in front of the subject and exerts a pushing movement, using the weight of his body to exert enough resistance.

Knee Flexion

The subject is sitting on the edge of the treatment table in the same position as during the knee extension test. The hand held dynamometer is placed on the dorsal side of the lower leg just proximal to the malleoli, right on the Achilles tendon. The evaluator squats in front of the subject and exerts a pulling movement. The upper leg of the subject should keep contact with the treatment table during the test.

Grip strength

The subject is sitting on the edge of the treatment table with the feet touching the ground. Grip strength is measured with a Jamar grip dynamometer. The elbow is flexed at 90 degrees an touching the flank. The dynamometer is placed in the hand to be tested with the dial facing towards the evaluator. The subject is instructed to squeeze the dynamometer as hard as possible.