Table of contents

Introduction

With the CITEC dynamometer, the maximal voluntary contraction (MVC) can be measured. This instrument can be used in many different circumstances, from consulting hours to intensive care and at home.

This manual is divided in two parts:

I. A manual explaining how to use and operate the CITEC dynamometer
II. A manual explaining how to maintain the CITEC dynamometer

For safe and effective use of the CITEC, knowledge and skills of manual muscle strength tests are needed. Part II of this manual offers information about measurement techniques and photo illustrated examples how the CITEC dynamometer can be used in practise. These instructions are based on information from the publication “Handheld Dynamometry” (Ploeg, R.J.O. van der – Groningen: Dijkhuizen Van Zanten BV, 1992), and is intended as a tool to learn how to use the CITEC dynamometer.

Part I – operating instructions

The CITEC is a hand held dynamometer that facilitates a quick, objective and reliable measurement of the quantitative muscle strength. This light and ergonomically designed tool can be used with nearly all clinically relevant muscle groups.

How to start the CITEC

On the CITEC, you find only one button: the [on/reset]-button. Press this button once to turn on the CITEC. In the display the base level is shown.

First use of the CITEC: setting the base level

The first time you use the CITEC, the base level needs to be adjusted to zero.
Start by pressing the [on/reset] button. The display shows the base level. Do not put pressure on the installed applicator.
At the right side of the CITEC you'll find the adjustment wheel.
Adjust the base level by carefully and slowly turning the adjustment wheel with a little, sharp object (such as the point of a pen).

Normal use of the CITEC

Press the [on/reset]-button to turn on the CITEC; the display lightens.
Your CITEC now is ready to measure.
Press the installed applicator. In the display, the measured strength (peak force) is shown. Force is shown in Newton; 1 kilogramme is ca. 10 Newton (9.80665 Newton).
After 15 seconds, the CITEC shuts off automatically; during this period, the peak force remains visible in the display.
To start a new measurement right away, please press the [on/reset] button for min. 1,5 seconds. The CITEC will reset and is ready for a new measurement.

Changing applicators

An applicator can be removed by simply pulling them off the CITEC. Another applicator is installed the other way around: press to adjust the applicator.

Pinch grip applicator (optional)

Installing the pinch grip applicator is slightly different.

First, remove the applicator installed. Then, screw off the round handle by turning it to the left. Slide the pinch grip applicator over the battery and push it through the rubber ring. Adjust the applicator by turning it to the right.

The pinch grip applicator passes on the measured strength in a 1:2 ratio. Therefore, the displayed strength needs to be multiplied by 2 (as indicated on the applicator).

Changing batteries

The CITEC uses two 544 6.2 volt batteries, obtainable at photographic dealers, etc.. As battery power weakens, the [low battery]-indication will show. You can keep using the CITEC by adjusting the base level. Once the [low battery] indication is shown constantly it is necessary to replace **both** batteries. The lifetime of the batteries is subject to usage. For most users, the batteries will last for about 6 months.

To replace the batteries, remove the applicator installed. Screw off the button at the bottom of the CITEC by turning it to the left. Remove the old batteries and place the new ones. Please note the instructions at the back of the CITEC as to how to place the batteries.

We advice to remove batteries if the CITEC is not used for more than 30 days. This will reduce possible damage as a result of leakage and corrosion of the batteries

Maintenance

The CITEC does not require any special treatment.
For cleaning the CITEC you can use a soft cloth with eventually a non aggressive detergent. Avoid liquid seeping into the interior of the CITEC.

Ordering accessories

Accessories, e.g. applicators, battery button, etc., can be ordered at C.I.T. Technics:

C.I.T. Technics BV Rijksstraatweg 384 NL-9752 CR HAREN The Netherlands	Tel.: +31 50 - 406 17 54 Fax: +31 50 - 406 15 58 e-mail: info@citec.nu internet: www.citec.nu

Important

The CITEC measures up to 500 Newton.
Do not exceed this range: this can cause damage to the load cell.
Avoid heavy shocks, extreme low or high temperatures, moist and aggressive detergents.

For technical specifications, please refer to appendix 1

Part II - Description of test procedure and technique in practice

The CITEC dynamometer is a medical device that can be used to measure the maximal voluntary contraction (MVC). Proper use of the CITEC dynamometer demands a lot of knowledge and skills of the of the examiner.
Our body counts many muscles, which cannot be investigated separately. In clinical practice, one is always testing muscle groups. Therefore it is better to use the muscle groups terms (e.g. elbow flexors rather than biceps muscle).
Precise standardization of the position of the subject, the dynamometer and the examiner are of vital importance for a correct and reliable measurement. These standard positions, for 13 muscle groups, are listed in this document.
Disrobing is not necessary in these positions, except of taking off the shoes in the case of the foot dorsal- and plantar flexors.

Measurement technique

As stated, the measurement process asks knowledge and skills of the examiner.
A measurement is conducted as follows:

- Press the on-reset button to turn the CITEC dynamometer on. The device is ready to measure start.
- The examiner checks the position and settings of the measurement and equipment.
- The examiner instructs the patient to contract the muscle group in a controlled way within for a couple of seconds and then to stop contraction on the signal of the examiner.
- The examiner holds the dynamometer in position (see descriptions below)
- With the CITEC in position, the examiner tells the patient to contract the muscles in a controlled way; not too fast, not too slow.
- After app. 2 – 3 seconds, the examiner asks the patient to exert maximal effort (verbal encouragement can be helpful).
- Then, in app. 1 – 2 seconds, the examiner slowly overcomes the strength and stops the measurement on the moment the patient gives away.
- After the measurement, the CITEC display shows the measured strength for 15 seconds. Then, the devices shuts off automatically.
- When the on-reset button is pressed, the CITEC is ready for a new measurement.

The process as described above follows the ‘break technique’. An alternative method is the ‘make technique’. A brief description:

Break technique

In a careful break test, the examiner slowly overcomes the strength and stops on the moment the subject gives away. In practice, this means a movement of the segment of ± 1 cm (wrist extensors) to ± 5 cm (hip flexors, elbow flexors) in ± 1 second. In fact, there is an eccentric movement and therefore it is essential to ascertain that the velocity of the moving segment is always low.

Make technique

An alternative is the make test, which is strictly isometric. The examiner just holds the dynamometer in position and the subject is pressing against the applicator of the dynamometer in otherwise exactly the same standard position and conditions.
With the make test, it is more difficult to determine whether there has been a MVC and suboptimal cooperating persons are less willing to exert maximal effort.
A break test, as it were, forces them to produce a real MVC. With the break test, the examiner feels a characteristic tight elastic resistance, which is called “follow through”.
Moreover, the results in cooperative normals and patients show only minor differences between make and break (3% more force with break).

Measurement variables

Repetitions

During a single session it is advisable to carry out 3 measurements and to average these three values. Under normal circumstances with cooperative persons, these values differ <15%. The minimum rest period between the contractions should be about 5 seconds. Furthermore it is advisable to always start with a test measurement.

Feedback

During the tests the subject does not receive instantaneous feedback. Of course the subject is, in most cases, informed afterwards about his performance.

Instruction to the subject

In a break test, the subject is instructed to increase to maximum exertion, without jerk, in about one to two seconds and to maintain this effort until the examiner gives the command to relax. The subject is informed about the test purpose and procedures.

Encouragement

Verbal encouragement is given, especially on the moment the examiner perceives that the subject is giving way, e.g. “hold, hold”.

Rewards

Goal setting, competition and non-medical spectators are to be avoided.

Test room

There are no special requirements for a test room. A patient can be investigated in an outpatient’s department, a clinic or at home. It is self-evident that not all 13 muscle groups can be tested in an intensive treatment unit, but in a supine position still 7 muscle groups can be measured, for instance in a Guillain-Barré patient.

Pain

Complaints about pain, especially when elicited by the contraction, can disturb a correct measurement. The result will be probably too low. The patient gives away abruptly and the examiner does not observe a follow through contraction.
Some patients can proceed after having received extra explanation and encouragement. However, sometimes it is impossible to give a proper judgment in these cases.
Discomfort caused by the applicator of the dynamometer when pushed against bony surfaces (e.g. dorsum of hand) can be prevented by extra padding, for instance additional high density foam.

Indications

What is the purpose of muscle strength quantification?

In the first place, muscle strength quantification with a dynamometer offers a more objective measurement than manual tests with so called ordinal data. This offers enhanced possibilities to evaluate therapies with larger sensitivity. The development of the patient in time can be followed more accurately. Also, measuring results can be compared to reference values for normal functioning muscle groups.

For which patients the dynamometer can be used?

Periodical muscle group strength measurement is used for patients with neuromuscular disorders, e.g. polymyosities, muscle dystrophy and Guillain Barré syndrome. Results of physiotherapy, medication therapy and other kinds of treatment can be evaluated more accurately.

Reference values

In appendix 2, you'll find a table with reference values. These values are based on measurements with 50 normal women and 50 normal men in the age of 20 – 60 years. For quick practical clinical purposes, the 5th and 50th centile values will suffice. For experienced examiners, results of repeated measurements will differ between 10% and max 20%.

Measurement position

Below, you find some useful measurement tips and details for measuring 13 clinically relevant muscle groups. The reference values are a result of measurements conducted as described below.

The information is based upon research, medical literature and experience. Variation is possible, as long as a standardized method is used for repetitions.

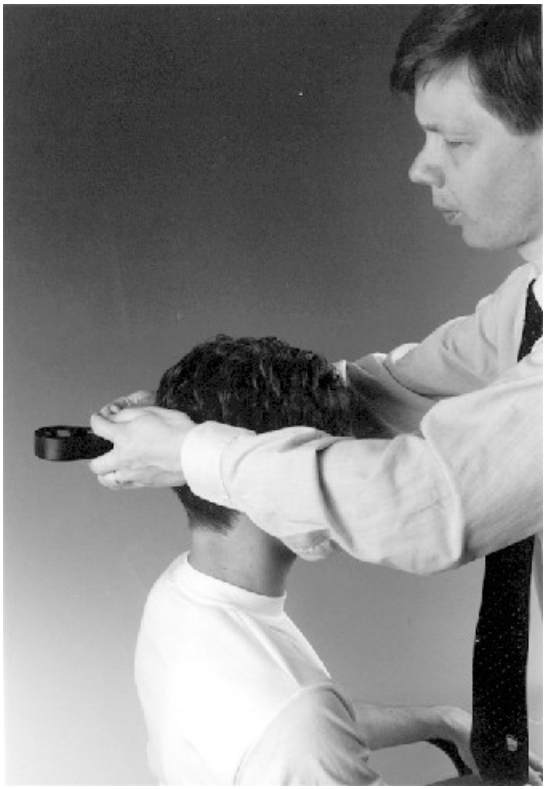
When choosing the position, the examiner should consider the comfort of the patient as well as the characteristics of the particular muscle group. Measurement should not be conducted when contraction of the muscle group is impeded.

Muscle group 1: Neck extensors

position of subject	Sitting upright in a chair with a firm back; head up at 90º from horizontal
position of dynamometer	Back of the head, lower rim of applicator just above ear shelf level
position of examiner	Standing behind subject
fixation	Both hands fixate the elbow-rests

Additional remarks

Some patients experience pain in their neck extensors (in my experience notably patients with tension headache), which will influence MVC and reliability.



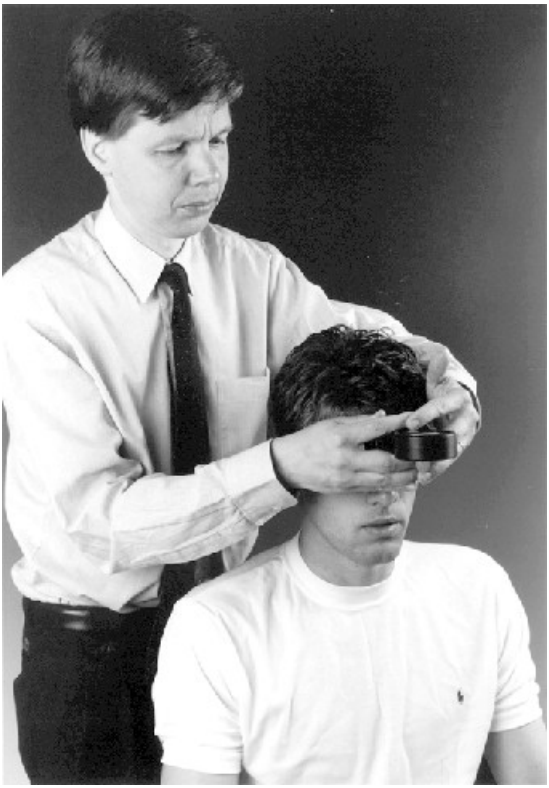
The tendency of the subject to elongate these muscles by bending the trunk backwards is prevented by the chair. In the described examiner position, it is not possible to measure beyond +/- 125N. Most normal subjects are stronger than this value. For males a value <125 N must be regarded as subnormal.

Muscle group 2: Neck flexors

position of subject	Sitting upright in a chair with a firm back; head up at 90º from horizontal
position of dynamometer	Centre of forehead, lower rim of applicator just above eyebrows
position of examiner	Standing behind subject
fixation	Both hands fixate the elbow-rests

Additional remarks

Some patients experience pain in their neck flexors, which will influence MVC and reliability. Not infrequently pain is caused by pressure of the dynamometer on the forehead. This difficulty can be removed by a small soft pad between the applicator and the forehead.



The subject will have a natural tendency to elongate these muscles by bending the trunk forward, which cannot be prevented totally, but a fast movement must be avoided, because this will result in a fast eccentric contraction and a higher value.

Muscle group 3: Shoulder abductors

position of subject	Sitting upright in a chair sitting upright; shoulder 90º abducted, elbow 135º flexed, forearm pronated
position of dynamometer	Lateral epicondyle of humerus
position of examiner	Standing next to subject
fixation	None

Additional remarks

For a good symmetry it is advisable to bring both arms in the position described. Bending to the contra lateral side must be avoided. This elongates the deltoid muscle and will influence the result.
In this position gravity has a marked influence. In patients with severe weakness in these muscles an alternative would be a supine position with otherwise the same standardisation.

Muscle group 4: Elbow flexors

position of subject	Supine, shoulder adducted, elbow 90º flexed, forearm supinated
position of dynamometer	Just proximal to wrist crease (flexor surface)
position of examiner	Standing next to subject
fixation	Subject grasps edge of examination couch with contralateral hand

Additional remarks

The subject must ly flat with at most one cushion, otherwise the standard position will be interfered with. There is a tendency to move the shoulder up and forward, elongating the biarticular biceps muscle. Especially the male elbow flexors can be very strong. Above 200N it is often necessary for the examiner to sit directly against the supinated forearm to give additional support to prevent pulling the subject form the examination couch. It is impossible to measure both elbow flexors from one side.

Muscle group 5: Elbow extensors

position of subject	Supine, shoulder adducted, elbow 90º flexed, forearm supinated
position of dynamometer	Just proximal to wrist crease (extensor surface)
position of examiner	Standing behind subject
fixation	Subject grasps edge of examination couch with contralateral hand

Additional remarks

The subject must ly flat with at most one cushion, otherwise the standard position will be interfered with. Many subject have a tendency to raise the elbow, but with proper instructions this can be prevented.

Muscle group 6: Wrist extensors

position of subject	Sitting, forearm supported and pronated, wrist in neutral position, fingers flexed
position of dynamometer	Just proximal to 3rd metacarpal head
position of examiner	Standing in front of the subject
fixation	None

Additional remarks

The examiner can measure this muscle group very comfortably by holding the dynamometer with both hands and by increasing the force by just leaning with his own weight. This must be done slowly and with caution app. 1-2 seconds. Especially in these muscles a brisk break test will give an enormous increase in strength, which must be avoided. The wrist joint is placed on the edge of a table. This edge must not be too sharp, because this will produce pain in situ. Prevention is easy by one or two folded tissues under the wrist joint. The same applies for the dynamometer, pressing on the metacarpalia.

In the measuring position described above, gravity plays a role, but this is of no practical importance. If the wrist extensors are so weak that gravity cannot be overcome (+/- 2-3N), there still would be no readable deflection on the dynamometer scale.

Muscle group 7: Three point grip

position of subject	Sitting, forearm pronated, wrist extended
position of dynamometer	Distal phalanx of thumb under applicator, distal two phalanges of dig 2 and 3 above, scale of dynamometer directed to examiner
position of examiner	Standing in front of the subject
fixation	none

Additional remarks

This is the only test in which the contraction is truly isometric. The examiner must prevent that the 4th and 5th finger are compressing the dynamometer too. Prevention is easily possible by bending these two fingers before the contraction.

Muscle group 8: Hip abductors

position of subject	Supine, hip 45º flexed, knee 90º flexed, contralateral knee supported by chest of examiner
position of dynamometer	Lateral epicondyle of knee
position of examiner	Standing on right side of the subject, chest of examiner against right knee
fixation	Subject grasps edge of examination couch with both hands

Additional remarks

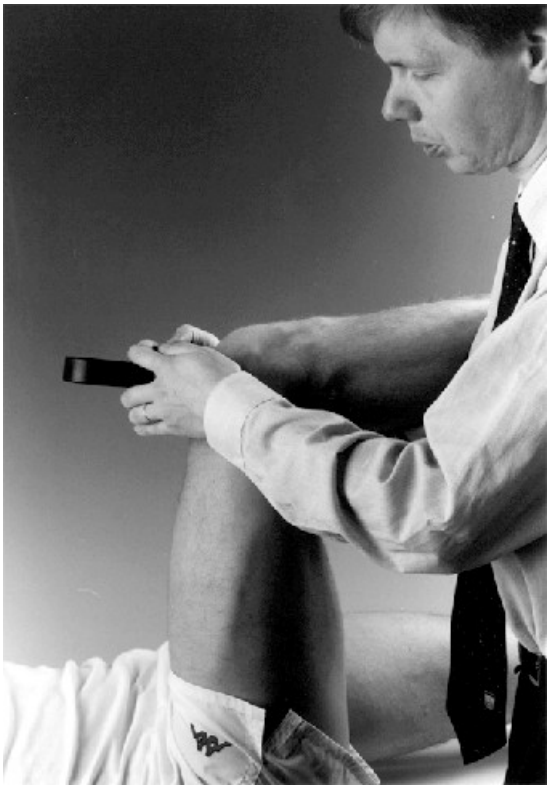
The right and left hip abductors are difficult to measure separately because for stabilisation of the pelvis the contra lateral abductors must contract too. Therefore both sides are tested at the same time and the weakest side will determine the result. This drawback is not very serious, because weakness of these muscles seldom occurs unilaterally, but nearly always bilaterally and symmetrically, as in proximal myopathies.

Muscle group 9: Hip flexors

position of subject	Supine, hip and knee 90º flexed, ankle supported by examiner
position of dynamometer	Anterior surface of distal thigh
position of examiner	Standing on right side of the subject, right arm supporting lower part of the leg
fixation	Subject grasps edge of examination couch with both hands

Additional remarks

Some synergistic hip flexor muscles are biarticular (rectus femoris, tensor fasciae latae and sartorius) and the subject will try to elongate these muscles by bending the knee. Supporting the lower part of the leg counteracts this unwanted movement effectively.



Muscle group 10: Knee extensors

position of subject	Prone, knee 90º flexed
position of dynamometer	Anterior surface of distal shant
position of examiner	Standing on right side of the subject
fixation	Subject grasps edge of examination couch with both hands

Additional remarks

The knee extensors in normal subjects are so strong they cannot be measured. Beyond ±160N it is difficult to maintain a proper position and to avoid gliding of the dynamometer of the shin. Normally knee extensors are far stronger than 160N and if this value is surpassed hardly there still must be the suspicion of a pathological condition.

Muscle group 11: Knee flexors

position of subject	Prone, knee 45º flexed
position of dynamometer	Heel
position of examiner	Standing on right side of the subject
fixation	Subject grasps edge of examination couch with both hands

Additional remarks

Because all hip flexors are biarticular there is a strong tendency to elongate these muscles by raising the buttocks. Even with clear instructions this is hardly to suppress and without doubt it will influence the result. A belt over the posterior pelvis could help, but this would be time consuming and the test-retest results in normals where not much worse compared with other muscle groups. A large part of the healthy subjects and patients develops cramp during the contraction. Formerly we measured with a knee flexed 90º and in that position cramp occurred even more often, hindering correct strength assessment. It is clear that cramp will negatively influence the strength level and the reliability of the results.

Muscle group 12: Foot dorsiflexors

position of subject	Supine, foot 90º dorsiflexed
position of dynamometer	Just proximal to metatarsophalangeal joints (dorsal surface)
position of examiner	Standing in front of the subject
fixation	Subject grasps edge of examination couch with both hands

Additional remarks

This muscle group is not easy to measure. In my experience it is difficult to determine on which moment the muscle gives away. Giving away of these muscles consists of a minor displacement of the foot, but with careful inspection this slight movement can be perceived.

Muscle group 13: Foot plantarflexors

position of subject	Supine, foot 90º dorsiflexed
position of dynamometer	Just proximal to metatarsophalangeal joints (plantar surface)
position of examiner	Standing on right side of the subject
fixation	Subject grasps edge of examination couch with both hands

Additional remarks

Normal foot plantar flexors are far too strong to test! Only in the case of rather severe weakness this muscle group comes within the measuring range.

The same difficulties are encountered as in the foot dorsi flexors: it is an arduous task to determine whether the muscles give away. Many patients with a severe paresis of the plantar flexors have some degree of contracture and the test cannot be carried out in the 90º dorsiflexion standard position. In these cases it is extra difficult to measure a real voluntary contraction and not the passive stretching of the muscle.

Appendix 1: Technical specifications

Measurement scale	0 - 500 Newton
Accuracy load cell	0,1% (maximum)
Accuracy display	0,1% (full scale)
Power	2 pieces 544 6.2 volt batteries
Operation	One button (on/reset)
Display	auto shut-off after 15 seconds
Dimensions	4-digit display with low battery-indication
Weight	Ca 150 x 85 x 85 mm
Delivered applicators	- finger applicator (little surfaces) - 'arm' applicator (larger surfaces) - flat applicator (flat surfaces)
Available applicators	- fist grip applicator - pinch grip applicator - pain pressure applicator

Appendix 2: reference values adults

Reference values		women		men	
#	Centile value	P5	P50	P5	P50
1	Neck extensors	118	>125	>125	>125
2	Neck flexors	49	75	107	>125
3	Shoulder abductors	75	105	111	160
4	Elbow flexors	146	190	216	>250
5	Elbow extensors	80	105	115	156
6	Wrist extensors	81	111	126	170
7	Three point grip	65	86	94	125
8	Hip abductors	174	238	223	>250
9	Hip flexors	124	167	190	>250
10	Knee extensors	>160	>160	>160	>160
11	Knee flexors	78	122	118	162
12	Foot dorsiflexors	164	235	232	>250
13	Foot plantarflexors	>250	>250	>250	>250

These reference values are based on measurements with 50 normal women and 50 normal men in the age of 20 – 60 years. For quick practical clinical purposes, the 5th and 50th centile values will suffice. For experienced examiners, results of repeated measurements will differ between 10% and max 20%.