# Development of innovative training solutions in the field of functional evaluation aimed at updating of the curricula of health sciences schools



## MODULE BIOMECHANICS OF SPINE

## Didactic Unit C: HOW DO I ASSESS SPINE?

## C.1. What methods may I apply to assess the function of the spine appropriately?

## Part II: Measuring function in the spine: most widespread devices & clinical scales

# Index

## 1. Objectives

- To learn the methodology for evaluating spine mobility with different instruments, emphasising the use of a classic goniometer and manual inclinometer.
- To learn the American Medical Association's impairment evaluation system based on loss of mobility for the segment evaluated.
- To learn about other instruments that may be used to measure motion, strength and muscular activity in the spine.

# 2. Measuring function in the spine: the most widespread devices

## 2.1. Measuring kinematic parameters

### Goniometry

Classic goniometers consist of two mobile arms articulated around a common fulcrum. The method to use them is accepted and widespread in measuring spine mobility, giving the angle for each arc of movement. The only exception is with dorsal mobility, and especially thoracic-lumbar rotation, for which it is not suitable to use the classic goniometer for measurements[1].

Measuring cervical mobility with a classic goniometer[2]

**Cervical flexion and extension**

The patient is instructed to make the desired motion, flexing or extending their cervical spine.

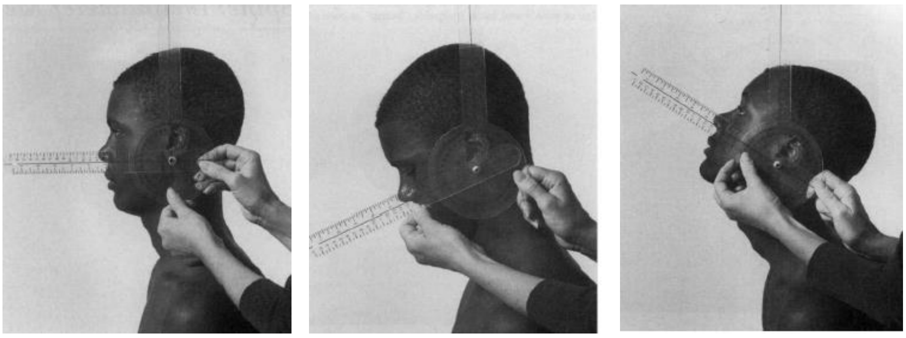

Figure 1. The goniometer is placed to measure the cervical flexion and extension. Its stationary arm points perpendicular to the floor, with its fulcrum at the patient's earlobe. The mobile arm remains parallel to the floor, following a line from the earlobe to the base of the nose.
Image from Berryman-Reese N. et al, 2002[2].

## Lateral cervical flexion

The patient is told to tilt their head laterally to the right and left without moving their trunk or shoulders, attempting to touch their shoulder with their ear.

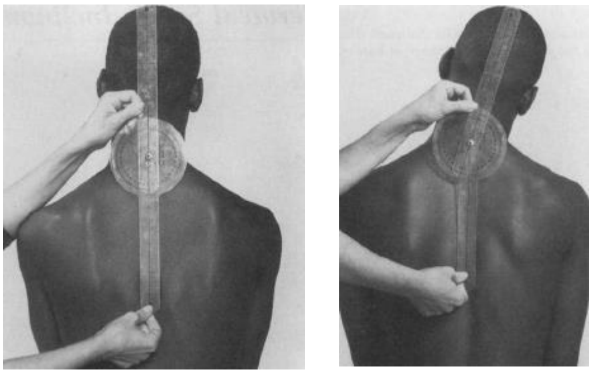

Figure 2. Goniometer placed to measure lateral cervical flexion. The stationary arm points perpendicular to the floor, in line with the spine, with its fulcrum at C7. The mobile arm starts perpendicular to the floor, in line with the cranium's posterior medial line.
Image from Berryman-Reese N. et al, 2002[2].

## Cervical rotation

The patient is told to make a cervical rotation to the right and left without moving their trunk or shoulders, attempting for their chin to come in line with their shoulder.

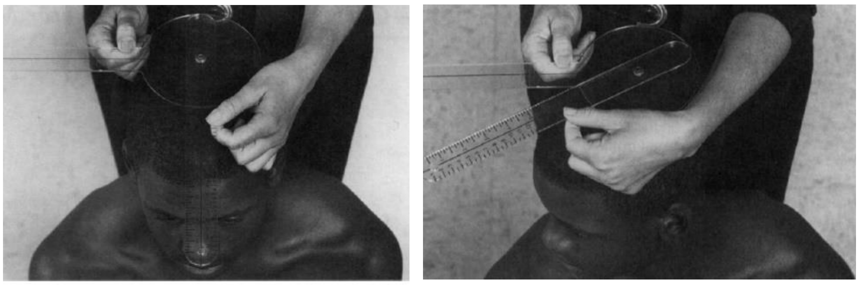

Figure 3. Goniometer placed to measure cervical rotation. The stationary arm is lined up with an imaginary line connecting the subject's two acromions, with the goniometer's fulcrum placed at the top of their head. The mobile arm is lined up with their nose. Image from Berryman-Reese N. et al, 2002[2].

Measuring lumbar mobility with a classic goniometer:

### Lumbar flexion

The patient is instructed to carry out the desired motion, flexing their spine as far as possible with their knees extended in order to reach the floor with their finger tips. Then the patient returns to the upright standing position[2].

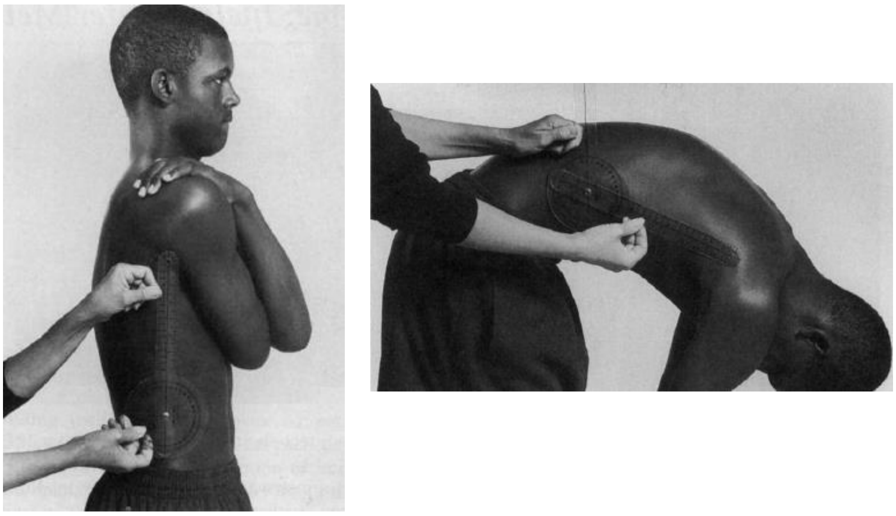

Figure 4: Lining up the goniometer when measuring lumbar flexion. Its stationary arm points perpendicular to the floor, with its fulcrum at the level of the patient's last rib. The mobile arm follows the patient's torso along the midaxiallary line. Image from Berryman-Reese N. et al, 2002[2].

### Lumbar extension

The patient is instructed to carry out the desired motion, in this case placing their hands on opposite shoulders and bending backwards while keeping knees their extended[2].

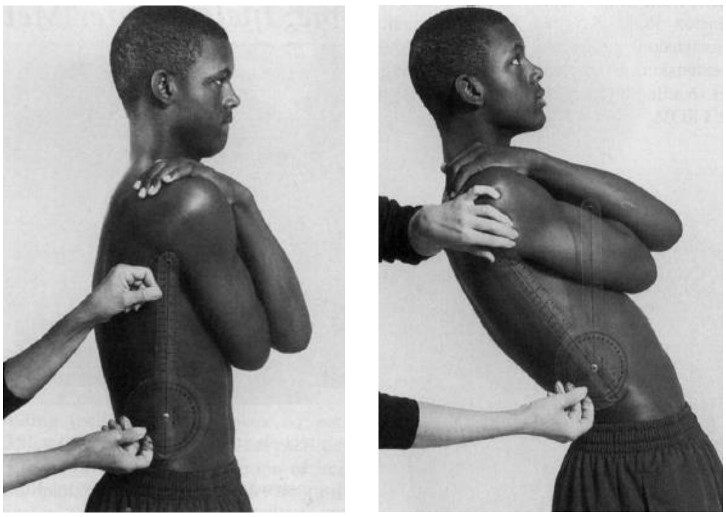

Figure 5: Lining up the goniometer when measuring the lumbar extension, equivalent to the one indicated for flexion of this segment. Image from Berryman-Reese N. et al, 2002[2].

**Lateral lumbar flexion**

The patient is instructed to follow the desired motion. Running their hand down the side of their leg, the patient laterally flexes their spine as far as possible. The patient keeps their knees extended and does not bend their trunk forwards or backwards while performing the movement[2].

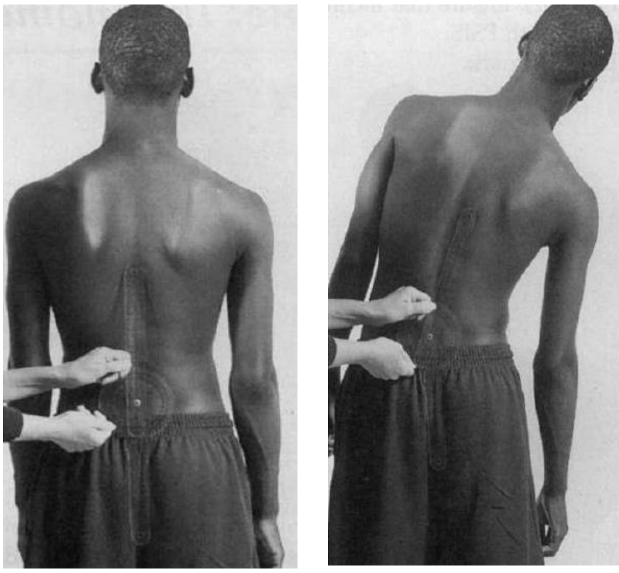

Figure 6: Lining up the goniometer when measuring lateral lumbar flexion. The stationary arm remains perpendicular to the floor in line with the intergluteal cleft. The mobile arm is lined up with the spine. Image from Berryman-Reese N. et al, 2002[2].

## Electrogoniometry

In addition to the aforementioned classic goniometers, electrogoniometers can be used to measure cervical motion ranges. However, this method also poses some limitations: it is necessary to consider a benchmark position that is repeatable. This is sometimes difficult because it depends on the person's anthropometric characteristics, which can give rise to mistakes of several degrees. This is why it is essential to have a very precise protocol for instruments.

## Inclinometry

<u>Measuring cervical motion with inclinometers</u>[2]:

**Cervical flexion and extension**

Although it is possible to take this measurement with only one inclinometer (which enables combined joint movements to be calculated and shown), it is more advisable to use two to measure this arc. To do so, one of the inclinometers must be placed over vertebra (spinous process) T1 and lined up with the saggital plane, holding the second inclinometer over the occiput. On beginning to take the measurement, the head must be in a neutral position[1].

From there, the subject is asked to flex their neck as far as possible. The two angles given by the two inclinometers are noted down, with the angle obtained at T1 being subtracted from the one from the other inclinometer. The procedure is the same for cervical extension, but asking the patient to extend their neck as far as possible instead of flexing it.

It is advisable to take three measurements for each range, calculating the final value as the mean of these three.

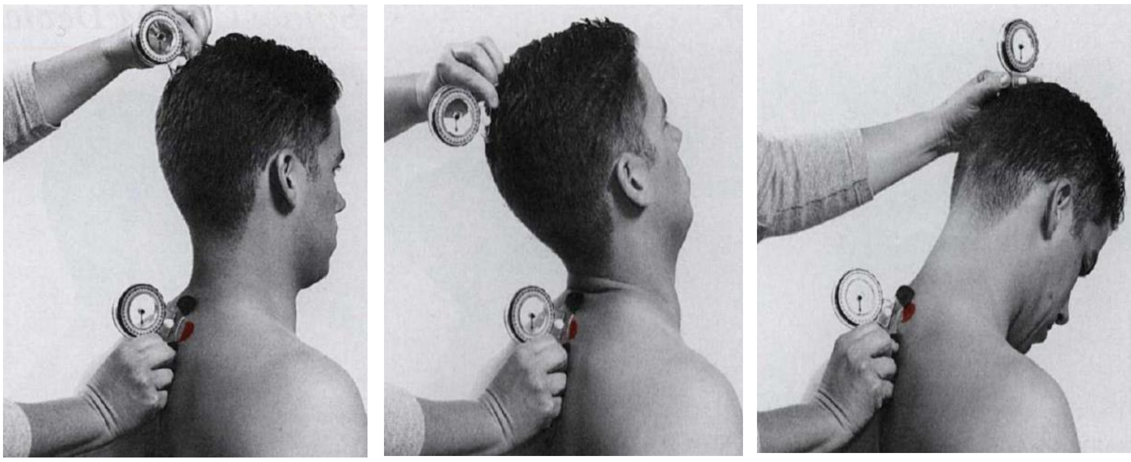

Figure 7: Placing the two inclinometers to measure cervical flexion and extension. Image from Berryman-Reese N. et al, 2002[2].

**Lateral cervical flexion**

As with flexion and extension, a single inclinometer could be used for lateral flexion, but it is more advisable to use two. If two are used, they are placed in the same way as for measuring flexion and extension of this segment[1], but they must be lined up with the frontal or coronal plane.

In this case, we ask the patient to tilt their head as far as possible to the left, and again we subtract the angle measured at T1 from the one taken at the occiput. Then we take the same measurement tilting to the right.

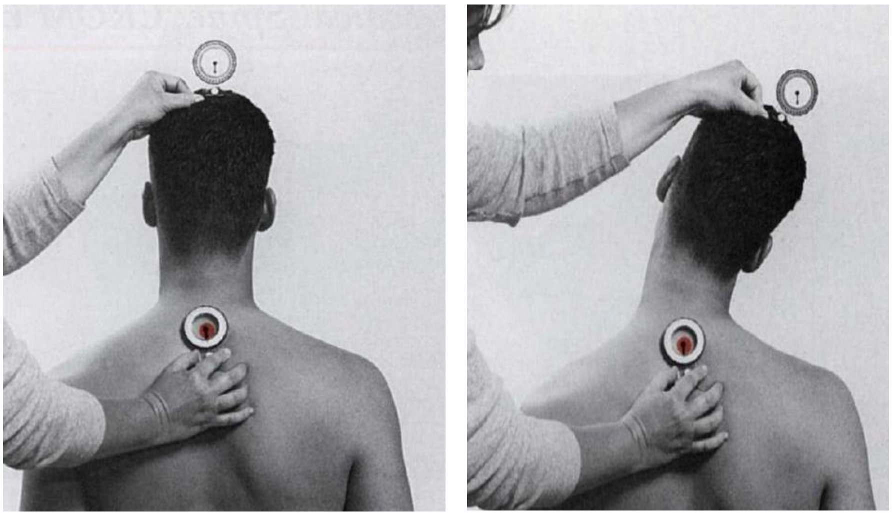

Figure 8: Placing the two inclinometers to measure cervical lateral flexion. Image from Berryman-Reese N. et al, 2002[2].

**Cervical rotation**

In this case, the evaluation technique involves stabilising the shoulders in decubitus supine, so only one inclinometer is needed[1].

To do so, the subject lays down in decubitus supine on an examination table with their shoulders bare in order to check they do not rotate. The inclinometer is placed on their forehead in the coronal plane.

The subject is asked to rotate to the right as far as possible, and the angle is noted. The same procedure is followed rotating to the left. In each case, it is recommended to take at least three measurements.

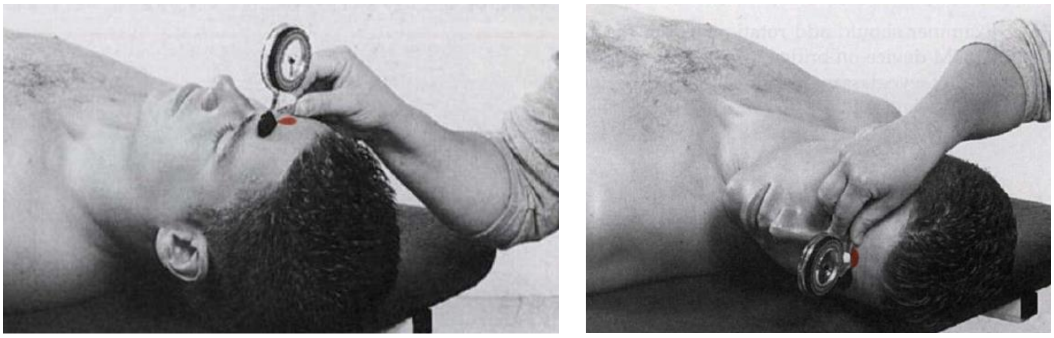

Figure 9: Placing the two inclinometers to measure cervical rotation. Image from Berryman-Reese N. et al, 2002[2].

Measuring dorsal and lumbar motion with inclinometers:

### Dorsal flexion and extension

Although it is possible to take this measurement with only one inclinometer (which enables combined joint motions to be calculated and shown), it is more advisable to use two to measure this arc. In this case, the inclinometers are placed over vertebrae (spinous processes) T1 and T12, with their bases lined up along the spine's axis[1].

From there, the subject is asked to flex and extend their dorsal back as far as possible. The two angles given by the two inclinometers are noted down, with the angle obtained at T12 being subtracted from the one at T1 (i.e. T1-T12)[2].

It is advisable to take three measurements for each range, calculating the final value as the mean of these three.

### Dorsal rotation

Although it is possible to take this measurement with only one inclinometer (which enables combined joint motions to be calculated and shown), it is more advisable to use two to measure this arc. In this case, the inclinometers are placed over vertebrae (spinous processes) T1 and T12, with their bases perpendicular to the axis of the spine[1].

The subject must start from a position flexing their trunk approximately parallel to the floor. From there, the subject is asked to rotate their dorsal zone as much as possible, with their arms crossed and attempting to point to the ceiling with their elbow on the side being assessed. The two angles given by the two inclinometers are noted down, with the angle obtained at T12 being subtracted from the one at T1 (T1-T12)[1].

It is advisable to take three measurements for each range, calculating the final value as the mean of these three.

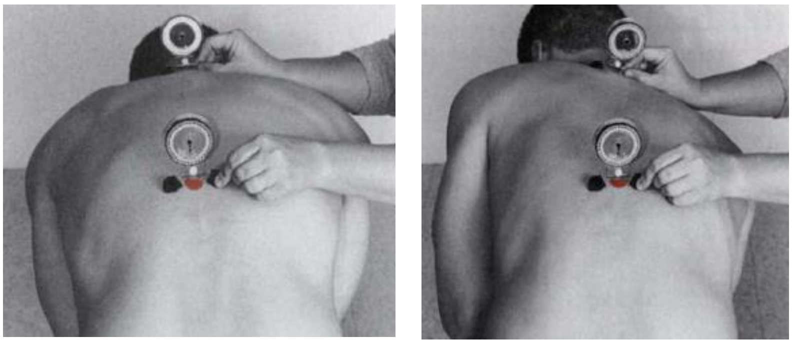

Figure 10: Placing the two inclinometers to measure cervical rotation. Image from Berryman-Reese N. et al, 2002[2].

## Lumbar flexion and extension

Although it is possible to take this measurement with only one inclinometer (which enables combined joint motions to be calculated and shown), it is more advisable to use two to measure this arc. To do so, one of the inclinometers must be placed over vertebra (spinous process) T12 in line with the saggital plane, with the second one over the sacrum (approximately at its medial point)[1].

From there, the subject is asked to flex and extend their lumbar zone as far as possible. The two angles given by the two inclinometers are noted down, with the angle obtained at T12 being subtracted from the one at T1 (T1-T12)[2].

It is advisable to take three measurements for each range, calculating the final value as the mean of these three.

Figure 11: Placing the two inclinometers to measure lumbar flexion and extension. Image from Berryman-Reese N. et al, 2002[2].

## Lateral lumbar flexion

The inclinometers are placed at the same place as for flexion and extension, but in this case they are in line with the coronal or frontal plane. From there, the subject is asked to tilt laterally to one side or another, noting down the two angles given by the inclinometers, and subtracting the angle at the sacrum from the one found at T12 (T12 - sacrum)[1].

It is advisable to take three measurements for each range, calculating the final value as the mean of these three.

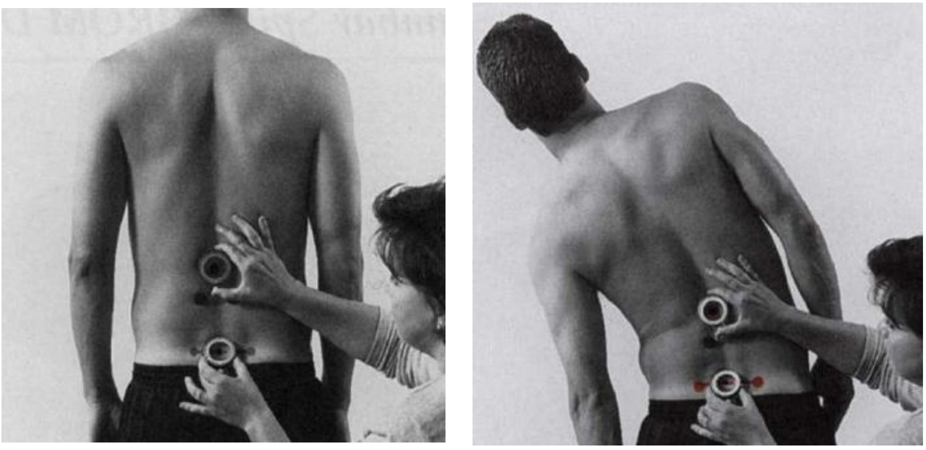

Figure 12: Placing the two inclinometers to measure lateral lumbar flexion. Image from Berryman-Reese N. et al, 2002[2].

In addition to classic inclinometers, electronic inclinometers can also be used, following the same procedures above but with simpler instruments and the possibility of using software to help streamline the recording of angles.

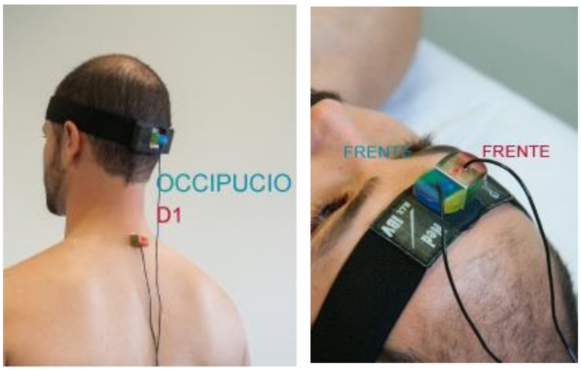


Figure 13: Placing the two electronic inclinometers to measure cervical flexion and extension and cervical lateral flexion (left) and cervical rotation (right). Sistema NedRangos/IBV (Source: Instituto de Biomecánica de Valencia).

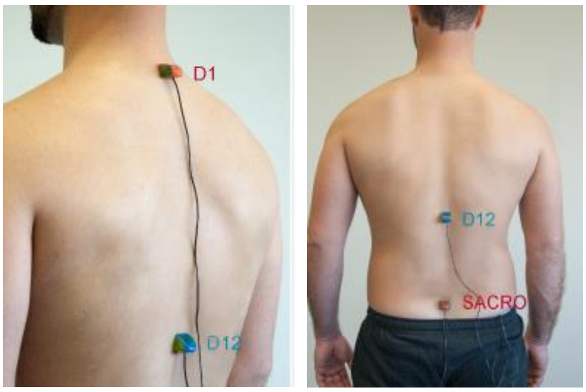


Figure 14. Placing the two electronic inclinometers to measure dorsal (left) and lumbar (right) motion. Sistema NedRangos/IBV (Source: Instituto de Biomecánica de Valencia).

## Other methods: photogrammetry

Photogrammetry techniques enable motion and its different properties to be analysed (speed, acceleration, angular range) thanks to a camera recording a set of markers placed on the patient, following a specific structure for the biomechanical model used. This is a very accurate technique, eliminating sources of error by the evaluator compared to other methods such as the classic goniometer. Its great versatility has made it a very widespread technique that is particularly suitable for carrying out global analyses or ones that involve the combined motions of numerous joints, as is the case of the spinal column. It has unquestionable potential for functional evaluation of motor disabilities. Figure 15 shows a graph with the acceleration and angular velocity components for the trunk obtained by photogrammetry on carrying out an activity such as lifting a weight.

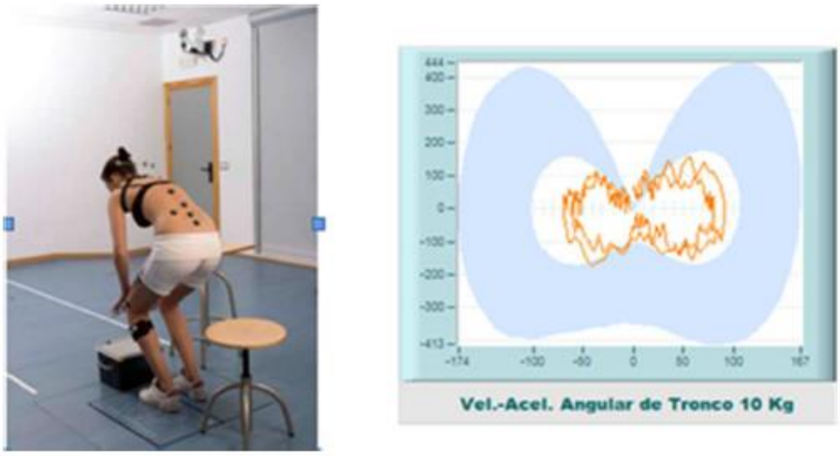


Figure 15: Measuring the gesture of lifting a box (left) and phasor graph (trunk velocity against acceleration) during the gesture (right). Sistema NedLumbar/IBV (Source: Instituto de Biomecánica de Valencia).

As well as this activity, we could measure the motion pattern of the lumbar spine in other activities such as sitting down and standing up from a chair, crouching or flexing as much as possible while standing.

Figure 16: Measuring the gesture of standing up from a chair. Sistema NedLumbar/IBV (Source: Instituto de Biomecánica de Valencia).

## Other methods: MCU system (MCU (Multi Cervical Unit)

The MCU has a computerized interface that records real-time cervical spine movement and isometric strength in all three planes of motion. This eliminates the subjectivity of manual testing. Plus, the dynamic strengthening protocol complements manual therapy, while it maintains objectivity for the progression of cervical spine rehabilitation.

Figure 17. MCU system. Information and image from https://www.btetechnologies.com/rehabilitation/mcu/[3]

***Note: For more information about devices and instrumentalised analysis used to measure forces, movement, pressures, physiological signs, anthropometric and morphometric parameters, please see the contents included in Educational Units D and E from the MODULE BIOMECHANICS: FOUNDATIONS OF BIOMECHANICS APPLIED TO THE LOCOMOTOR SYSTEM***

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Whereas in part I of this Educational Unit we saw how the guides for evaluating permanent impairments from the American Medical Association lay down levels of impairment according to the “Injury Model”, we shall now look at how the AMA also has a system for classifying the impairment according to the so-called “Range of Motion Model”. Hence:

**Table 1. Whole Body Impairment (WBI) according to the AMA's "Range of Motion Model" for the cervical spine[1]**

| Flexion | | Extension | | Lateral flexion | | Rotation | |
|---|---|---|---|---|---|---|---|
| Degrees (º) | % WBI | Degrees (º) | % WBI | Degrees (º) | % WBI | Degrees (º) | % WBI |
| 0 | 5 | 0 | 5 | 0 | 4 | 0 | 6 |
| 15 | 4 | 15 | 4 | 15 | 2 | 15 | 4 |
| 30 | 2 | 40 | 2 | 30 | 1 | 40 | 2 |
| 50 | 0 | 60 | 0 | 45 | 0 | 60 | 1 |
| | | | | | | 80 | 0 |

**Table 2. Whole Body Impairment (WBI) according to the AMA's "Range of Motion Model" for the dorsal spine[1]**

| Flexion | | Rotation | |
|---|---|---|---|
| Degrees (º) | % WBI | Degrees (º) | % WBI |
| 0 | 4 | 0 | 3 |
| 15 | 2 | 11 | 2 |
| 30 | 1 | 15 | 1 |
| 60 | 0 | 30 | 0 |

**Table 3. Whole Body Impairment (WBI) according to the AMA's "Range of Motion Model" for the cervical spine[1]**

| Flexion (with hip angle >45º) | | Extension | | Lateral flexion | |
|---|---|---|---|---|---|
| Degrees (º) | % WBI | Degrees (º) | % WBI | Degrees (º) | % WBI |
| 60 | 0 | 0 | 7 | 0 | 5 |
| 45 | 2 | 11 | 5 | 11 | 3 |
| 30 | 4 | 15 | 3 | 15 | 2 |
| 15 | 7 | 15 | 2 | 15 | 1 |
| 0 | 11 | 25 | 0 | 25 | 0 |

## 2.2. Measuring kinetic and physiological parameters

### Dynamometric platforms

By using dynamometric platforms to assess the spine, a three-dimensional analysis can be made of the lower limbs' reaction force against the ground on carrying out different activities involving the trunk or paravertebral musculature, as in the case of standing up from a seated position on a chair or lifting a weight with the upper limbs. It gives information about what the support is like and possible anomalies in the force exerted by a lower limb if there is pain (for example, due to unilateral sciatica).

This usually appears due to asymmetry in spreading the force between the two legs. It is an excellent tool to assess the strategy for movement in the context of different pathologies associated with pain or strength impairments.

### Dynamometry systems

Traditionally, it has been attempted to measure the strength of the spine under isometric isokinetic and isodynamic conditions. In these tests, maximum voluntary contractions are required against resistance in order to supposedly achieve maximum force.

Systems have been developed that are sometimes very sophisticated to measure the strength of the paravertebral musculature. The main techniques used in muscular evaluation are:

- Isometric: These include manual tests on muscles, using springs and strain gauges, as well as dynamometers. The advantages of isometric systems are their low cost (although there are very sophisticated ones), the simplicity of the tests and the ease of interpreting the data.


Figure 18. Simple manual isometric dynamometry system. Images from https://tienda.fisaude.com/dinamometro-evaluacion-musculo-esqueletica-microfet2-p-39680.html[4]

-Isotonic: These can be based on the use of free weights in a system of controlled movements, or on using systems that adapt to the resistance during movement. Most isotonic evaluations are concentric. The evaluation is carried out throughout the range of motion, though there are usually problems with reliability in the measurements and in the patient's familiarisation with the kind of exercise.

- Isokinetic evaluation: This requires the patient to move their body (trunk and limbs) at a speed controlled and preselected by the examiner. The systems are controlled via a dynamometer that acts passively, only allowing concentric exercises, or actively, allowing concentric and eccentric exercises. There are a great many commercial machines. The advantage of these kinds of isokinetic apparatus is that they assess the entire range of motion at different speeds.


Figure 19. Isokinetic evaluation machine (Source: Internal documents from the Valencia Biomechanics Institute (*Instituto de Biomecánica de Valencia*)).

- Isoinertial (or isodynamic): The resistance against motion is constant in isoinertial contraction. This can be evaluated using a triaxial dynamometric device that records the angular position, angular velocity, torque for the three primary axes of the lumbar region, work and power. The difference compared to isokinetic ones is that they analyse muscular performance in three axes at the same time, as well as the acceleration of the trunk.

## Surface electromyography

The trunk muscles' activity can be estimated indirectly using electromyography (EMG). This is why surface EMG is usually the technique used to evaluate the lumbar zone, specifically to analyse muscular behaviour during motion such as flexion and extension of the trunk (analysis of lumbar flexion-relaxation). It can also be used in any other segment of the spine, also known as cervical flexion-relaxation, although in this case the muscular response is less evident[5].

Flexion-relaxation (FR) refers to a pattern of muscle activity during trunk or cervical spine flexion, in which the muscles initially contract but ultimately relax at what appears to be a distinct point in the flexion range of motion (ROM)[6].

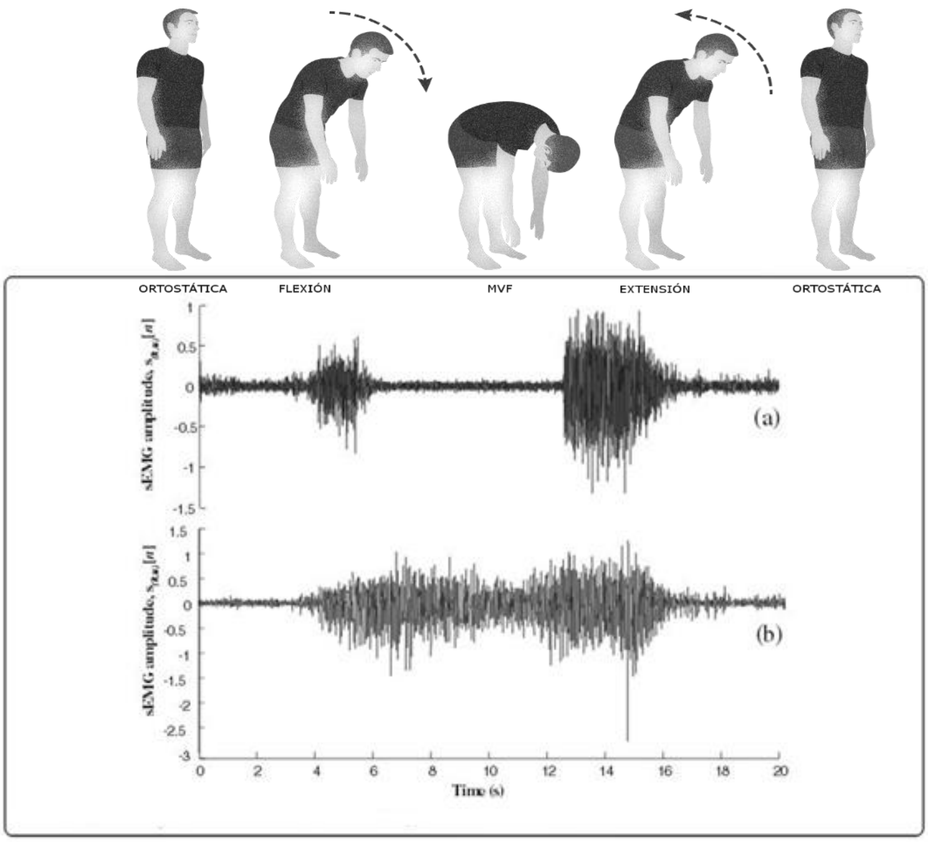


Figure 20. EMG signal from a healthy patient (top) and a patient with lumbalgia (bottom) while flexing and extending their trunk. From Nougarou et al. EURASIP *Journal on Advances in Signal Processing* 2012, 2012:151 http://asp.eurasipjournals.com/content/2012/1/151[7]

***Note: For more information about protocols and devices for performing a biomechanical analysis of the spine, as well as to learn how to interpret the results obtained in healthy and pathological subjects, see the contents included in Educational Unit D (1 to 6) of this very module.***

# 3. Measuring function in the spine: clinical scales

Clinical scales are a source of clinical information obtained through standardised questionnaires.

## 3.1. Cervical spine

The most widespread scales for evaluating the cervical spine are the Neck Disability Index (NDI)[8], the Neck Pain and Disability Scale (NPDA)[9] and the Northwick Park Neck Pain Questionnaire (NPQ)[10].

## 3.2. Lumbar spine

The most widespread scales for evaluating the lumbar spine are the Oswestry Disability Index (ODI)[11] and the Roland-Morris Questionnaire (RMQ)[12].

***Note: For further information about clinical scales used in evaluating the neck and lumbar spine, see the contents included in Educational Unit C.2. in this very module.***

## 4. Key ideas

- One of the fundamental aspects to evaluate function and impairment in the spine is the evaluation of motion. This can be done visually or by using specific tests that require only a measuring tape.
- However, these methods pose a series of limitations, so that other instruments with a greater or lesser level of accuracy and sophistication are often recommended: classic goniometers, manual inclinometers, electronic inclinometers or photogrammetry.
- To evaluate other aspects of the spine such as strength and muscular activity, there are other instruments available such as different kinds of dynamometers (isometric, isotonic, isokinetic) and surface electromyography.
- Another kind of useful tool to evaluate disability and impairment perceived by the patient in the context of spinal pathology is clinical scales

## 5. References

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