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 D: INSTRUMENTED ANALISYS OF THE SPINE

D.3. How is a normal biomechanical assessment of the cervical spine?

Index

1. Objectives

- To learn the purpose of biomechanical assessment in the clinical sphere.
- To recognise normal results in a biomechanical cervical assessment.
- To become familiar with interpreting the results from a cervical kinematic assessment among a normal population.
- To become familiar with interpreting the results from a cervical muscular strength assessment in a normal population.
- To apply the knowledge learnt to a clinical case.

2. Clinical and biomechanical evaluation

Biomechanics is the analysis of the functioning of the human body from a mechanical point of view. It is a science that studies the human body or one of its components from a mechanical point of view, in other words it studies the behaviour of bodies subjected to forces. To do so, biomechanics is based on knowledge from medicine, biology, physics and engineering, and one of its uses is in the clinical biomechanical evaluation of human functions.

Knowledge of biomechanics is used to objectively analyse the functional repercussions caused by a certain spinal injury or pathology on the spine's functions (mobility, support and protection). This evaluation is based on applying protocols for measuring that use techniques with instruments and which are carried out in a human motion analysis laboratory, in other words a biomechanics laboratory. Biomechanical tests to evaluate the spine allow its functioning to be assessed; in other words, the performance of the neuromusculoskelatal system as regards mobility, as opposed to most classic examinations where the individual is actually passive.

It is important to remember that the purpose of biomechanical evaluation is to objectively confirm and quantify the existence of a functional alteration in the cervical spine of the person being assessed, regardless of what may have caused it. Therefore, these tests or evaluations do not replace anamnesis or a physical examination of the patient, and an analysis of their results must stay within the clinical realm.

You can see details of the measuring protocols mentioned in this unit in Educational Unit D1, "What protocols for are there for cervical biomechanical evaluation with instruments?"

Remember the elements that make up a mechanical evaluation test:

- What **function** is being assessed.
- What **instrument** and **technique** it uses.
- What **assessment protocol** has been used**.**
- What **results it provides**, in what units and with what data analysis techniques they have been obtained.
- **Standardized criteria for interpretation**.

This topic concentrates on analysing the results from a cervical evaluation among a normal population with biomechanical analysis techniques. Students will acquire skills to interpret them, and at the end of this they will be able to recognise the results and ascertain how they compare with a normal pattern of cervical functionality.

3. Functional assessment of the cervical spine.

The cervical spine is located in the upper third of the spine and has a three-fold function of support, mobility and protection. It thus enables the head to be held up and moved, which, considering the sensory importance of this body segment, is in turn essential for most daily living activities or DLAs. It is therefore evident that functional assessment of the cervical spine, considering its overall functional importance, is of great interest, especially considering the high prevalence of some sort of functional impairment in cases of cervical injury or pain.

In this vein, it is well known that there are a large number of clinical conditions that may cause an impairment in cervical mobility, thus limiting patients' functionality and making it difficult to perform certain DLAs. For example, it is common for patients after whiplash syndrome with classifications of Quebec Grade IIA upwards to have a limitation to the active and sometimes passive range of motion (ROM). This fact is corroborated by various authors such as Baydal[1] in his doctoral thesis, which also explains that there is a significant correlation between ROM impairment and the subjective symptoms reported by the patients. Some authors also point to a correlation between ROM recovery and a positive evolution after a cervical traffic injury, and consider it to be a sensitive parameter in distinguishing healthy subjects from pathological ones. In fact, the same author in another work[2] in which a functional assessment was performed via a kinematic study of the cervical spine, found significant differences in the range of motion (ROM) between pathological (whiplash syndrome) and healthy subjects, with a lower ROM for the former.

Ou et al[3] highlight the concurrence of symptoms such as stiffness, weakness and limitation to mobility in the context of cervical pain. They use the measurement of this item (ROM) to assess the overall improvement of a group of patients after applying a given treatment (in this case essential oils), finding a significant difference in the values of mobility before and after, which was associated in turn with an improvement in other symptoms such as the pain. Many other authors[5-11] also use or propose the measurement of cervical mobility to functionally assess a group of patients with a certain pathology or to see the effect of a given treatment[12].

Even so, it is necessary to consider that the ROM will not always be affected, since it will depend on the type of cervical pathology and the degree of involvement. For example, in a study by Lluch et al[4] comparing two groups of patients with chronic cervical pain under different kinds of treatment, no significant differences were found for this parameter (ROM) after intervention in any of the groups, although there were in other items like pain. This indicates that sometimes other types of approaches focusing on other kinds of variables may also be indicated, such as the measurement of pain, muscle strength or activity.

For functional assessment of the cervical spine, the kinematic approach appears to be essential, since some of the most important variables that show impairment in patients with pain or other kinds of cervical pathologies are: the range of motion (ROM), which is fundamental for many activities of daily life, and motor control, which can be measured kinematically by different specific tests. Furthermore, measurement of cervical muscle strength or activity can be essential, too.

4. Assessment of cervical range of motion (ROM)

A normal cervical spine can perform movements in six degrees of freedom. The physiological patterns of motion for the spine are flexion-extension, lateral flexion and axial rotation. Flexion-extension is a motion contained within the saggital plane composed of rotations and translations. Similarly, Lateral flexion is a motion also combining rotation and translation but within the frontal plane. On the other hand, axial rotation is a pure rotation movement around the longitudinal axis of the vertebrae.

If there are no external loads, the spine's motion is due to the activity of the musculature. The agonist muscles initiate the motion, whereas the antagonists inhibit it. The range of vertebral motion varies from one place to another, mainly depending on the orientation of the articular facets. The spine's overall motion can be considered to be the combined action of a set of vertebral functional units, and it is this overall motion that is assessed by means of biomechanical tests.

However, to measure the range of cervical motion and get reliable results, it is necessary to consider a repeatable benchmark position. This means that a very accurate protocol is needed for taking measurements. The range of motion is affected by the variables of age and sex. For example, the cervical range of motion for a woman of 70 years of age is not the same as for a 20-year-old woman or a man of the same age. Even so, there are few results published that take this difference into account. Most bibliographical references establish differences between sexes in which women have greater cervical mobility than men, but the differences are not statistically significant[12]. Age affects cervical mobility, and for this reason in the 1960s Ferlic et al[13] carried out a study to determine the influence of age on the cervical range of motion. They concluded that in the age range between 15 and 74 years, the decrease in mobility was 21% for flexion-extension, 35% for lateral flexion and 20% for axial rotation. In 1992, Youdas[14] published more definitive information about the cervical spine's range of motion, measured using electrogoniometry and passive mobility tests. In his work, one can see the results (mean and standard deviation) segmented by sex and age. The author found that mobility decreases by about 4º per decade in both men and women. More recently in 2000, Castro's motion tables[15] were published. The results are shown in segments by age and gender, and the measuring technique used was an ultrasound system. There are also those by Ferrario from 2002[16], which are segmented by sex but not by age. These measurement were made using photogrammetry. For its part, the American Medical Association and the American Academy of Orthopaedic Surgeons[17] published normality patterns for cervical ranges of motion, but did not segment them by sex or age groups.

This variety of data in scientific publications leads to a necessary reflection on an analysis that can now be carried out to interpret the results more accurately: they must be compared with those that have been obtained with the same measuring technique and evaluation protocol.

To conclude, it should be stressed that there are three possibilities for interpreting the results of a cervical biomechanical evaluation on the range of motion. The results obtained can be compared to those from a group of subjects comparable to the characteristics of the person being evaluated, and measured with the same measuring technique and protocol (by comparing with databases). Alternatively, the results from the same subject can also be compared when they are obtained in different evaluation sessions within the same clinical process. Another option is for the results to be compared with benchmark values that have been accepted and validated by the scientific community. The latter possibility is used very much in clinical evaluations of joint motion, albeit with an awareness that the impairments that may be found may be explained by factors associated with differences in the subject's physical constitution or the measuring apparatus and protocol used. In such cases, one must be careful with the interpretation made and always take into account the patient's clinical data.

Below, one can see the type of results obtained following a range of motion evaluation with biomechanical techniques, and standardised criteria for interpreting them.

Evaluation with inclinometers

Inclinometry is a simple, portable technique that enables cervical mobility to be measured. The American Medical Association (AMA)[17] considers it to be a viable and potentially accurate technique to determine the spinal column's mobility, since it is easy to palpate the subcutaneous bony structures that show the ends of the three regions (cervical, dorsal and lumbar).

Figure 1. System with two electronic inclinometers, located over the corresponding bony protuberances (occipital, D1) to assess the maximum joint range for cervical spine flexion-extension motion.

The result obtained from this kind measuring device is:

- **Maximum range in degrees** of active motion for the spine segment evaluated.

Directly or indirectly from this result, one can obtain or calculate:

- **Loss or impairment of motion (IM)** as a percentage for the segment evaluated compared to benchmark values.

Within the maximum range or breadth of motion, the motion values can be presented in terms of total range, which gives a total value for the saggital, frontal and transverse planes, i.e. three results. They can also be presented via the main directions of movement: flexion and extension. Thus, in a complete evaluation of cervical spine motion there are six results: flexion, extension, right lateral flexion, left lateral flexion, right rotation and left rotation.

To carry out an interpretation of the results from this kind of test, one has to compare them with the results from a group of healthy subjects, comparable to the characteristics of the person evaluated and measured with the same measuring technique and protocol. Even so, it is most common to compare the results with cervical motion benchmark values that have been accepted and validated by the scientific community. Another completely valid possibility is to compare the results for the same subject when they are obtained in different evaluation sessions.

Below, one can see the results for the active cervical range of motion obtained following a cervical biomechanical evaluation of a person with no pathology or painful condition in their cervical spine. In order to make this measurement, a technique with two inclinometers has been used and the recommendations from the American Medical Association (AMA) for measuring the cervical spine have been applied for the position and for the number of repetitions of the measurement.

	Pos. Neutra (OCC/D1)	Pos. Flexión (OCC/D1)	Pos. Extensión (OCC/D1)	Flexión	Criterio AMA	Extensión	Criterio AMA
1ª	9.7º / 19.6º	64.4º / 51.3º	-37.8º / 1.3º	23.0º	OK	29.0º	OK
2ª	12.7º / 21.0º	66.8º / 51.6º	-36.8º / -0.7º	23.0º	OK	27.0º	OK
3ª	8.0º / 17.3º	67.9º / 51.9º	-43.9º / -6.4º	25.0º	OK	28.0º	OK

Figure 2. Results recorded by each inclinometer (technique with two inclinometers) placed over the occiput (OCC) and the first dorsal spinous process (D1) in order to evaluate the range of the cervical spine's flexion-extension. The criterion for repeatability of the measurements is met (AMA criterion).

With the results shown in Figure 2, the criteria for repeatability defined by the American Medical Association are met. Therefore, the results for flexion and extension of the cervical spine obtained in three consecutive tests are deemed valid. The final impairment in mobility taken into account is the one corresponding to the greatest angle measured in the three tests.

If we analyse the results in the example, the patient gives values of 54.7º, 54.1º and 59.9º for flexion with the inclinometer located at the occiput for the three repetitions. Flexion for the inclinometer at D1 is seen to be 31.7º, 39.6º and 34.6º. These values are the result of subtracting the value from each inclinometer at maximum flexion from the value given in the neutral position. For example, in the first repetition for the inclinometer over the occiput, the maximum flexion position (64.4º) is subtracted from the value obtained at the neutral position (9.7º), giving 54.7º as the result for real flexion with this inclinometer. For D1, the same procedure is applied, subtracting the maximum flexion position (51.3º) from the one found at the neutral position (19.6°), giving a real flexion result of 31.7° for that inclinometer. Then, the real flexion for the cervical spine found with two inclinometers on the first repetition is obtained by subtracting the real flexion found with the inclinometer at the occiput from the one found with the inclinometer at D1 (54.7° - 31.7°), giving a result of 23° for the maximum flexion. This calculation procedure is the one used in all tests, whatever the motion measured. If the inclinometers are used with software, this calculation is carried out automatically, thereby helping the evaluating doctor with the procedure.

Applying the same procedure for calculation, the second repetition gives 23º and the third 25º. The mean angle for cervical flexion is 23.7º, and the three results do not diverge by more than 5º from the mean. Therefore, the criteria have been met for the validity of the calculation, and it is used to interpret the results from the clinical point of view of the maximum flexion angle for the valid series, which in this case would be 23°. The following figures show the final result (having done all the calculations) for a cervical evaluation with a technique using two inclinometers on a person with no motion limitation.

	Amplitud máxima	PM frente referencia AMA
Flexión	80º	0%
Extensión	70º	0%
Flexión Lateral Izquierda	45º	0%
Flexión Lateral Derecha	42º	7%
Rotación Izquierda	80º	0%
Rotación Derecha	80º	0%

Figure 3. Results for maximum range of motion for the cervical spine and percentage of loss or impairment of mobility (IM) for each of the tests compared to the benchmark values of the American Medical Association (AMA). Two inclinometers have been used to obtain these results.

The following graph is another way of showing the results:

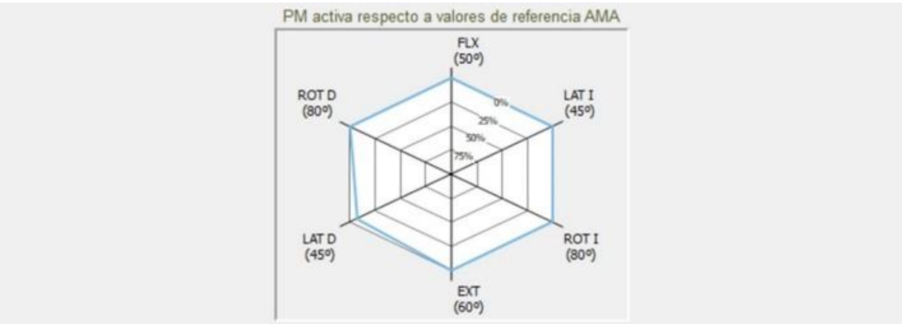

Figure 4. Graph comparing the percentage of impairment of active cervical mobility with the benchmark values of the American Medical Association (AMA) for each of the axes of motion evaluated. These benchmark values are in brackets and the percentage of motion impairment is shown by the blue line.

In order to **interpret this type of evaluation**, students are advised to follow the standardised criteria for interpretation, looking for the answer for themselves:

- What is the maximum range recorded for each of the motions?

- Is the motion recorded for each of the axes within normality?
- What values have been taken as benchmarks of normality?
- What is the most limited movement or the one with the greatest loss of mobility? And the least limited one?
- Is the loss of mobility recorded significant?
- Have significant asymmetries been found in the laterality of the motions?

Applying these interpretation criteria, you can give a reply to the results from the example that has been posed. For example, the interpretation to be made would be:

> As can be seen in Figure 3, a maximum value of 80° has been obtained for flexion; 70° for extension; 45° and 42° for left lateral and right lateral flexion respectively; and 80° for each of the rotations.
>
> In general, these values are considered normal for cervical spine motion, given that they are greater than the benchmark values being used in this evaluation (50° for flexion; 60° for extension; 45° for lateralisations and 80° for rotations), as seen in the graph in Figure 4.
>
> It could be said that the right lateral flexion is a little below its benchmark value (42° compared to 45°), but the difference is insignificant because the impairment in mobility (IM) is below 10%. Loss of mobility may begin to be considered significant when it is above 10%.
>
> There are no significant asymmetries recorded, since the only difference is in the lateral tilts and it only comes to 3°.

To sum up, in the case posed, the final interpretation for the data recorded with inclinometers is that the patient's cervical mobility is good, generally equal to or above the motion values that have been taken as a benchmark, and there are no significant asymmetries. Thus, the mobility is considered normal, with no cervical motion impairment in the cervical movements analysed.

5. Kinematic assessment of the cervical spine

Kinematic analysis of motion not only gives the range of motion (ROM) but also enables a more accurate definition of it, for example by recording coupled movements, calculating the velocity of movement and analysing its smoothness and repeatability.

Two of the techniques used to evaluate the aforementioned kinematic parameters are photogrammetry and inertial sensors. To get kinematic parameters of motion for the cervical spine, the patient must make a cyclic motion reaching their maximum range of motion at a speed that is comfortable for them. In a kinematic assessment of the cervical spine, you can compare the results obtained with a control group of people (group of healthy subjects). There is some benchmark data to determine the results properly. Remember that in these cases, in order to make a proper, valid comparison, the same measuring technique and the same evaluation protocol must have been used.

By using a kinematic analysis system, information about movement of the spine in other planes is also obtained. This finding is normal, since the motion carried out by the spinal column is a coupled movement. Coupled movements are rotations and translations that are associated with other simultaneous rotation or translation movements on another axis. These coupled movements, together with the primary movements, form part of the cervical motion, and people without symptoms are characteristic for having individual variations. One cause of controversy is whether age has an effect on the coupling. In a study with healthy men and women, Trott et al[18] observed that age had a minor effect. On the other hand, with a similar sample to that study, Malmstrom et al [19] observed that age had a considerable effect.

In order to **interpret the results** of a kinematic evaluation of cervical spine motion, the student is advised to add the following to the criteria commented in the previous section (evaluation with inclinometers):

- What was the velocity of motion in each of the axes? Was it a slow or fast motion?
- Was the pattern of motion repeatable?
- Was the motion smooth?

In order to apply these interpretation criteria while getting familiar with the results obtained in this kind of evaluation, a recording is shown below of the cyclic cervical flexion-extension motion for a person with no pain or pathology in their cervical spine. A system of photogrammetry has been used for measuring, which recorded several consecutive cycles of cervical spine flexion-extension for 30 s (red line) at a comfortable speed for the person being measured.

In this case, the main component of the motion took place in the saggital plane. The red line represents the total angle of flexion (represented with a negative sign) and extension (represented with a positive sign). Furthermore, one can see that there is a certain coupled movement component in the other two axes, with a minimal rotation (shown in blue) and lateral flexion (shown in green) associated with it. Subjects with cervical pathology and pain causing them to have a functional alteration are commonly observed to have a limitation to motion in this test.

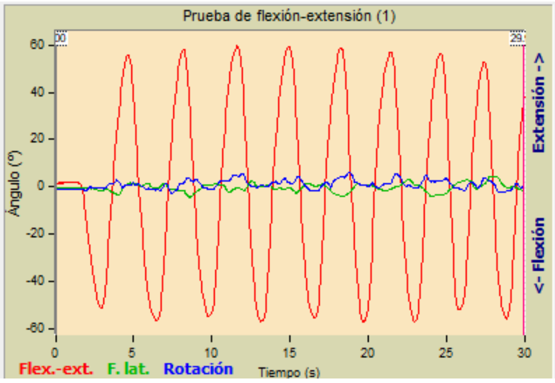

Figure 5. This shows the cervical flexion-extension motion (red line) over a period of time (30 s), together with the coupled motions (green and blue lines) obtained in a kinematic system of analysis (3D photogrammetry).

With the results of the above graph (Figure 5), it can be said that the measured person's cervical motion was fast, which is compatible with a normal pattern. One can see that it is fast because in 30 s there are 8-9 flexion-extension cycles at a comfortable speed. If the movement were slow, the number of cycles recorded in this interval of time would be much lower. We can also see this in previous topics, when talking about cervical evaluation in cervical spine pathology.

A graph with results of this type also gives the maximum cervical range reached. In order to obtain more precise data, it would be necessary to consult the numerical values of the maximums in each of the cycles and obtain their average as representative of the cervical motion. In this specific case, an approximate maximum of 60º is reached for cervical extension and for flexion, as can be seen by determining the values for the maximum peaks of the curves (motion cycles) in FigureFigure 5

Another way to represent the results is by referring only to the degrees of mobility (range of motion) and comparing them with a benchmark, whether it is the AMA values as seen above with the inclinometers or values from a healthy control sample performing a gesture by applying the same protocol and instrument-based measuring technique. To do so, in order to carry out a proper interpretation we must know what kind of values are being used as a benchmark.

In the example in the following graph, the benchmark values are obtained from a database made up of people with no cervical pain or pathology who have been measured with the same measuring technique and protocol as the person being evaluated. If this aspect is not indicated with the results or report shown, it is not possible to know it from simply seeing this graph (Figure 6).

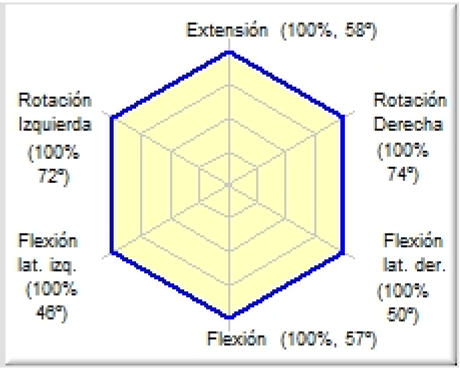

Figure 6. Visual hexagon of the range of motion observed together with its percentage of normality. It shows the range of motion in degrees and the percentage of normality corresponding to that range according to a comparison with a database of people with no cervical pathology as deduced by the measuring apparatus used (NedCervical/IBV).

Figure 6 shows the absolute values in degrees obtained for each of the axes of movement, and the situation for the average range of motion performed by the person evaluated (blue line) compare to a benchmark (database of normality from the NedCervical/IBV cervical spine evaluation system). In this evaluation system, this benchmark pattern is segmented by age and gender. The further the blue line sits outside this graph, the more normal or nearer to normal ranges of motion the results are for the person evaluated.

In the example, the ranges of motion are considered normal in all of the motions analysed. There is also objective proof of symmetry in degrees of rotation and lateral flexion, since there is little difference between the degrees performed to one side and the other. The value in brackets and the percentage indicate how near this specific motion is to what is considered normal in the evaluation system applied, with normality considered to be a value between 90% and 100%. The furthest from this would be 0%. This way of interpreting the result as a percentage of normality is only found in the NedCervical/IBV application. If you would like to know more about this matter, you can read the following article[20:]

> Baydal Bertomeu, J.M., Serra Añó, M.P., Garrido Jaén, J.D., López Pascual, J., Matey, F., Gimeno, C., Soler, C., Dejoz, R. "Development of a new method for evaluating cervical mobility based on photogrammetry techniques." ("*Desarrollo de una nueva metodología para la valoración de la movilidad cervical basada en técnicas de fotogrametría.") Rehabilitación, 2007; 41(2):53-60*

As we have seen in Figure 5, when the spine moves, it does so at a more or less fast speed. An analysis of this velocity also helps explain the characteristics of the movement performed and helps to differentiate between a normal or altered pattern of movement. Ohberg[21] identified angular velocity as the most discriminating variable between a healthy group and a pathological one. Other authors such as Grip[22] and Slöjander[23] also studied this parameter and although its discriminating ability was not so significant, they do coincide in establishing that the most common pattern is a decrease in velocity of movement in the cervical pathological group with pain compared to a control group of people with no cervical pathology or pain.

The following graphs show the cervical spine motion performed by a person for each of the axes of movement (flexion-extension, lateral flexions and rotations). Here, the angular velocity of the cervical spine motion (º/s) is shown against the angle of motion (º).

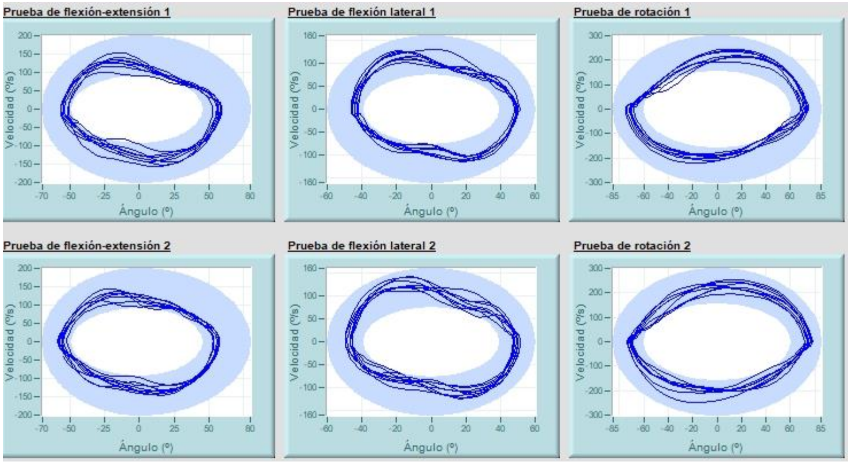

Figure 7. Graphs representing angular velocity with respect to the angle of cervical motion for the two recordings of each of the motions (flexion-extension, lateral flexions and rotations). The blue band represents the normal pattern considered in the measuring apparatus used, which is acting as a benchmark to learn what the evaluated person's motion is like (NedCervical/IBV).

If we are shown graphs of this kind, we must know what is being represented, and from there we can see the ranges obtained and the velocity of movement that has been used to reach them. In this case, the blue band indicates where the pattern is that acts as a benchmark to know if the movement performed is within a normal pattern or not. A normal pattern is considered to be one that has a good range (wide) and good velocity of movement (fast). If this is not the case, one can see if it is very far off.

Another piece of information we can find with a kinematic analysis of motion is the smoothness with which it is performed. This information is related to the lack of vacillations or stops when the neck is moving, which could be related to painful points during the joint's path of movement or voluntary control over the gesture due to fear of pain. As for the smoothness of the movement, there are studies that show that a neurological injury may affect control over the movement and thus notably diminish the smoothness in performing it[24,25]. Sjölander[23] found that people with cervical pain had less smoothness in their movement.

Repeatability is another parameter that is measured in this type of evaluation. This parameter gives information about the stability of the results obtained in the same single session. This information is related to the implication or effort made by the patient on performing a measurement to the utmost of their physical possibilities. A high repeatability in an evaluation of an apparently healthy person lends consistency to the results obtained. In the end, the repeatability measured, often via the coefficient of variation (coefficient obtained by dividing the standard deviation of repetitions by its mean and multiplying by 100), establishes a percentage to determine the consistency of the performance carried out by the person evaluated. According to Dvir et al[26], the coefficient of variation in cervical mobility within the same measuring session falls within 5%.

To sum up, a normal functionality pattern in cervical motion is considered to be met when the biomechanical analysis of the motion shows a wide, symmetrical, fast and repeatable motion. This is the overall benchmark pattern that must be sought for an evaluation of this type. Even so, an alteration in one of these characteristics does not in itself imply a cervical functional alteration. For example, a result from an evaluation with a good range of motion, high repeatability but low velocity, within the context of a clinical process in which the patient does not report pain or limitation, can be considered normal, even if a motion is performed slowly and in a controlled way as may occur due to a strategy to protect against pain or a reappearance of it.

6. Kinematic assessment in ADL

Sometimes kinematic analysis techniques are used to record and evaluate cervical spine motion while the person is performing an activity from daily life that requires them to turn, flex or extend their head. The information obtained from this type of test is based on the parameters that have been mentioned in the previous section, most notably the cervical range of motion necessary to perform these activities or the of speed performing them.

The following example shows the results from a kinematic motion analysis test in which the person is asked to turn their head to look at specific lights located on the ceiling to their right, left and above them. Hence, the person who is being assessed performs a gesture that includes the motions of rotation, flexion and extension with a level of demand on the range that is lower than for the maximum ranges.

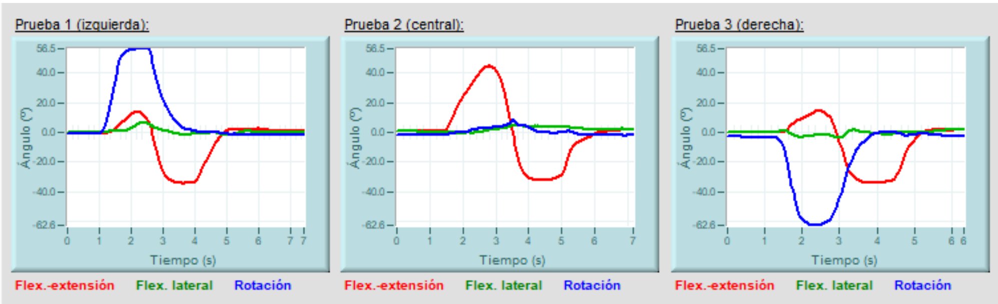

Figure 8. Graph of the mobility of the cervical spine when the patient stares at a light to their left, above them and to their right.

The following table shows the result obtained for range, velocity and maximum acceleration on performing the gestures requested. The values are expressed in percentages of normality, since the absolute values for each parameter have been compared to a database of subjects with no cervical spine pathology. If the result recorded in this table is above 90%, it is interpreted as a value within a normal pattern of motion.

	Rango		Velocidad máxima		Aceleración máxima		
	Flex.-ext.	Rotación	Flex.-ext	Rotación	Flex.-ext.	Rotación	Valoración
Prueba 1 (izq.)	100.0	100.0	100.0	100.0	90.8	100.0	98.5
Prueba 2 (central)	100.0	-	92.2	-	85.4	-	92.5
Prueba 3 (der.)	100.0	100.0	100.0	100.0	94.6	100.0	99.1

Figure 9. Results in percentages of normality from each of the functional tests. Values below 90% in the normality index are considered not normal or functionally altered.

Hence, with these results it can be concluded that the motions performed are normal and fall within the normal pattern of range of motion and rapidity of movement (angular velocity/acceleration).

7. Strength assessment of the cervical spine

The evaluation of cervical spine strength by using a technique with instruments is less widespread than for the evaluation of strength in the lumbar spine. Even so, below there is a description of the results from this kind of test that can be used to learn the state of the cervical musculature.

Assessment of muscular strength. Cervical isometrics

There are different systems to evaluate cervical muscular strength and one of the most widely used is isometric dynamometry. To carry out an assessment of isometric strength, manual dynamometers can be used or more sophisticated dynamometers such as the ones found in isokinetic machines.

A manual dynamometer for the cervical spine is a light, portable, easy-to-use device. With this kind of assessment, the patient must make a maximum muscular effort against the dynamometer, which is usually held statically by the evaluator. The test can be carried out by telling the subject to perform an activity requiring force, in other words to push against the device in the direction being studied. This type of assessment mainly concentrates on the flexor and extensor muscles of the cervical spine, and as in all kinds of measurement the protocol must be standardised and controlled. An isometric analysis can also be done with machines connected to a computer with the patient usually required to be seated. The patient's position is important, as in all biomechanical evaluation tests. The pelvis and trunk must also be properly held so they do not compensate for other movements.

The most common results obtained with this type of assessment of strength in the cervical spine are:

- Maximum cervical flexor strength, which is the maximum force from the flexor musculature in isometric conditions.
- Maximum cervical extensor strength, which is the maximum force from the extensor musculature.
- Mean flexor strength is the mean of the maximum forces performed in the repetitions considered in the protocol.
- Mean extensor strength is the mean of the maximum forces performed in the repetitions.
- The coefficient of variation is the percentage of variability in the force obtained from the repetitions performed.
- Maximum flexor/extensor strength ratio and/or mean flexor/extensor strength ratio.

It is difficult to establish normative data about cervical isometric strength because although there are studies showing the reliability and validity of this kind of assessment, the protocols and instruments used vary so much that it makes it impossible to establish.

You can see some of these values in the following publication[27]:

Garces, G. L., Medina, D., Milutinovic, L., Garavote, P., & Guerado, E., (2002). “Normative database of isometric cervical strength in a healthy population.” *Medicine and science in sports and exercise*, *34*(3), 464-470.

In general, the values obtained for maximum isometric force from the cervical spine extensors among women and among men vary rather a lot in the publications reviewed. However, they do seem to coincide on the force obtained among men being greater than among women, and within the muscle groups the extension force is greater than flexion by about 50-60%. This is because the extensor muscles have a fundamental role in posture, and the nape muscles must counteract the weight of the head at all times, which tends to fall forwards. The anterior location of the head’s centre of gravity explains the relative power of the posterior muscles in the nape compared to the neck’s flexors. In fact, the extensors fight against gravity, whereas the flexors help it. This also explains why the nape muscles always have a tone against the head falling forwards.

In order to **interpret the results** from the cervical spine isometric force assessment, one can follow the following criteria:

- What is the maximum force recorded for each of the muscle groups?
- Does it follow the normal agonist/antagonist relationship pattern?
- Have the recorded values been repeatable?

Below, one can see the results that can be obtained following a cervical isometric force evaluation of a person with no cervical pathology or pain.

	FLEXION (Kg)	EXTENSION (Kg)
Trial 1	8.2	14
Trial 2	8.9	13
Trial 3	9	15
Average	8.7	14
Maximum	9	15
CV	5.0	7.1

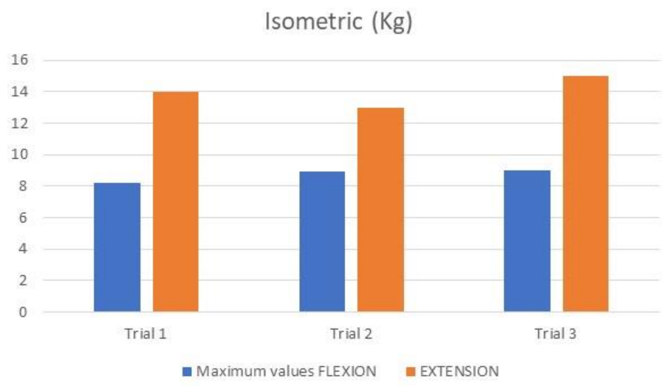

Figure 10. Graph with the maximum isometric force from the flexor and extensor cervical muscles in three repetitions.

The interpretation to be made with these results is that the person assessed reaches a maximum measured force of 8.7 kg for cervical flexion and 14 kg for cervical extension. This means a difference of 41% between the two isometric tests. The coefficient of variation was 5% for flexion and 7.1% for extension, so the results obtained are quite repeatable. Values above 15% may indicate little effort.

Assessment of muscular activity. Surface EMG

The trunk muscles' activity can be estimated indirectly using electromyography. It is important for students to distinguish between two types of electromyography: clinical or diagnostic EMG, which studies the characteristics of the motor unit's potential; and surface EMG, which studies muscular function and activity. By using EMGs, one can find a muscle's level of activity at any moment of the motion or in a sustained posture, and learn the muscles' coordination between each other. This is why surface EMG is usually the technique used to evaluate the cervical zone, specifically to analyse muscular behaviour when a motion is being performed that involves the cervical muscles.

Oberg[28] argues that surface EMG enables muscular contraction to be detected in the cervical zone with a high level of reliability. There are studies showing a direct relationship between cervical pain and a reduction in cervical muscular force, too. It also seems clear that the most discriminatory parameters to differentiate between healthy and pathological are those pertaining to a lack of ability to relax the muscles. This is seen in controlled contraction tests[29] where the base level of force can be measured, as in tests associated with carrying out a task and measuring the background level difference in a state of relaxation before and after exercise. In healthy subjects, after exercise the level of activity in the cervical muscles returns to the initial situation, whereas in those with pain it stays at a residual level of activity[30].

That is the purpose of EMGs applied to an analysis of the level of activity in the cervical muscles. The EMGs are intended to detect anormal muscular activity at times when the muscle should not be active. For example, at rest the activity should be minimal, and when there is movement the activity increases. What EMGs cannot do is diagnose neuromuscular alterations. A study by the American Academy of Neurology[31] questions the interest in surface in the EMG to determine neuromuscular alterations, evaluate pain in the cervical spine, and as a diagnostic tool for alterations in the musculoskeletal system. After analysing over 2,500 studies, the report rejects EMGs as a replacement for needle EMGs in neuromuscular diagnosis. It also rejects it as a diagnostic technique for assessing mainly pain because the articles published do not show an ability in the technique to discriminate, and above all because it is not a technique that has been proven to be reliable and repeatable.

Even so, this type of test is being used today above all in assessing the lumbar spine via standardised tests such as the flexion-relaxation test. Furthermore, in recent times this test has begun to be used in assessing the cervical spine. By way of example, the following graph shows the result of what a cervical myoelectric silence would be, although it is advisable to read the following articles[32,33], which may help students understand this type of test.

> Meyer, J. J., Berk, R. J., & Anderson, A. V. (1993). "Recruitment patterns in the cervical paraspinal muscles during cervical forward flexion: evidence of cervical flexion-relaxation." *Electromyography and clinical neurophysiology*, *33*(4), 217-223.
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> Burnett, A., O'Sullivan, P., Caneiro, J. P., Krug, R., Bochmann, F., & Helgestad, G. W. (2009). "An examination of the flexion-relaxation phenomenon in the cervical spine in lumbo-pelvic sitting." *Journal of Electromyography and Kinesiology*, *19*(4), e229-e236.

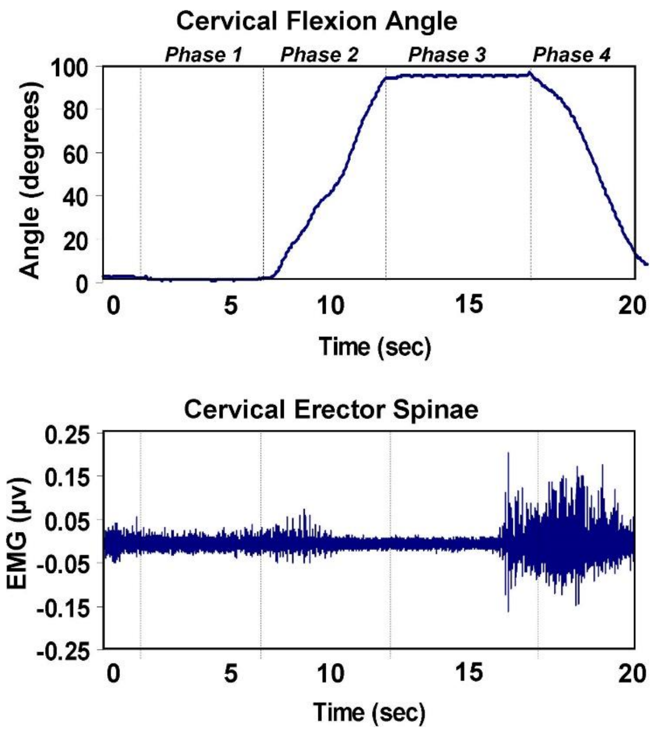

Figure 11. Raw surface EMG trace for the cervical erector spinae (bottom) from a subject displaying the flexion-relaxation phenomenon with activation prior to re-extension, during the experimental protocol. The cervical flexion angle is also shown (top). Data is presented for the different phases of the protocol: upright (Phase 1), forward flexion (Phase 2), full flexion (Phase 3), re-extension (Phase 4). Image and footnote from Burnett, A., O'Sullivan, P., Caneiro, J. P., Krug, R., Bochmann, F., & Helgestad, G. W. (2009). "An examination of the flexion-relaxation phenomenon in the cervical spine in lumbo-pelvic sitting." *Journal of Electromyography and Kinesiology,* 19(4), e229-e236.

8. Key ideas

- The purpose of biomechanical clinical evaluation is to objectively confirm and quantify the existence of a functional alteration in the cervical spine of the person being assessed.
- In the clinical sphere, biomechanical evaluation tests are mainly used to evaluate the cervical spine's range of motion and characteristics of movement.
- The cervical spine's strength is also evaluated mainly in isometric conditions.
- Surface EMG enables the muscular activity in a movement or sustained posture to be learned, and the flexion-relaxation phenomenon is beginning to be studied in this zone of the spine.
- When interpreting results, on comparing benchmark values one must ensure that they come from an evaluation that uses the same measuring protocol and the same instrumental assessment technique.
- If this is not the case, it must be done taking into account at all times the clinical process that is being assessed, to give more or less importance to the impairments that may be found.
- When interpreting data compared to benchmark values, the source containing the data used as a benchmark must be mentioned.
- The results from a report on a biomechanical assessment of the spine must be accompanied by its units of measurement.

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