Module 1: ROM Monitoring Test

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Range of motion (ROM), in the field of medicine and rehabilitation, refers to the amount of movement a joint can achieve while preserving the integrity of the anatomical structures involved. Abnormal joint movement has helped diagnose and monitor pathological musculoskeletal injuries and track responses to treatments.
There are two types of range of motion:

- **Active**: This refers to the degree of mobility a joint can achieve by using its surrounding muscles without any external assistance.
- **Passive**: This refers to the degree of mobility a joint can achieve when an external force is applied.

Several factors influence ROM.

- Anatomical and biomechanical factors: Joint type and structure, elasticity, and muscle strength.
- Biochemical factors: Muscle metabolism.
- Neurophysiological factors: Muscle tone and the muscles' ability to relax.
- Other factors: Psychological condition, age, gender, and genetic predisposition.

ROM tests objectively assess both an athlete's progress and the effectiveness of injury prevention, training, or recovery programs, while also identifying potential injury risk factors.

Several factors can affect the reliability of ROM measurements:

- **The examiner**: the person's experience can influence the precision and reliability of the ROM measurement. Therefore, training is essential to achieve consistent measurements.
- **Measurement procedure**: clearly outlining the technique used to measure ROM is crucial. A standardized, protocol-driven, and well-documented procedure ensures accurate measurements.
- **Measuring instruments**: ROM can be measured using various devices like goniometers or inclinometers. The device's condition and proper calibration directly affect the accuracy of the measurements.
- **Reproducibility**: it refers to the ability to repeat measurements and obtain similar results. To achieve high reproducibility, the same measurement must be repeated several times, obtaining consistent results.
- **Subject positioning**: the subject must be in a relaxed, comfortable position to avoid muscle tension, allowing for optimal positioning to measure ROM.

The following procedures outline how ROM measurements are obtained through six tests that evaluate different body regions:

- Ankle test
- Hip internal/external rotation
- Active Knee Extension (AKE)
- Passive Straight Leg Raise (PSLR)
- Dynamic Hamstring test

- Modified Thomas test

Proper execution of these tests, by strictly following the standardized protocol, will yield accurate, valid, and reliable results, crucial for assessing athletes.
Knowing the validity and reliability of clinical tests is essential for correctly interpreting results, making informed decisions, and ensuring the quality of scientific research. Therefore, for the presented tests, scientifically-based information on reference values, validity, reliability, execution procedures, result analysis parameters, and recommendations for interpreting and visualizing the results will be provided.

Unit 1. Ankle Test

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Ankle range of motion (ROM) measurements are crucial for assessing physiotherapy in specialized groups like athletes (1). These measurements can help identify potential connections to foot pain, ankle injuries (2), and other lower limb disorders.

Based on a study of dorsiflexion ROM reliability (3), weight-bearing measurements are more reliable (ICC 0.93-0.96) than non-weight-bearing measurements (ICC = 0.32-0.72).

Various tools can be used to take these measurements, such as tape measures, goniometers, inclinometers, or the portable Leg Motion® device.

The Leg Motion® provides both visual and tactile feedback, ensuring proper execution of the dorsiflexion measurement and preventing variations in foot position. One study included the references used this tool to evaluate university students (4). The study reported high

inter-rater reliability using this device, with ICC values of 0.98 for the right side and 0.96 for the left side.

These findings suggest that this tool is a valid, portable, and user-friendly alternative for assessing weight-bearing ankle dorsiflexion ROM. It is also important to note that these studies demonstrate that even a single examiner with basic experience can achieve highly reliable results.

Procedure

Before performing the test, either a video or live demonstration should be shown to the athlete. To ensure familiarity with the test, and account for learning effects, it is recommended to perform repetition for practice before the actual test. After two minutes of rest, the test begins.

For the test, the subject stands on both feet with their hands on their waist. The foot being tested is barefoot and placed on the platform. The second toe and the heel should align with the longitudinal line, just behind the horizontal/transverse line. The non-tested foot should be positioned to maintain balance during the test. The examiner stands beside the leg being tested. The vertical reference extends to the lower edge of the subject's patella, 10 cm from the tested foot, as the starting reference. During the test, the examiner places a hand on the heel of the tested leg to detect any lifting off the ground.

The subject must flex the knee until it touches the reference in front, without lifting the heel off the ground. The reference is adjusted to a position where the subject can maintain heel-knee contact for 3 seconds. Pronation and supination of the foot is be restricted. Two maximum measurements are recorded for each foot.

Attempts are considered invalid and should be repeated if: (a) the heel lifts off the ground, (b) the non-tested foot passes the tested foot's position, or (c) the subject loses balance during the test.

Starting position

Final position

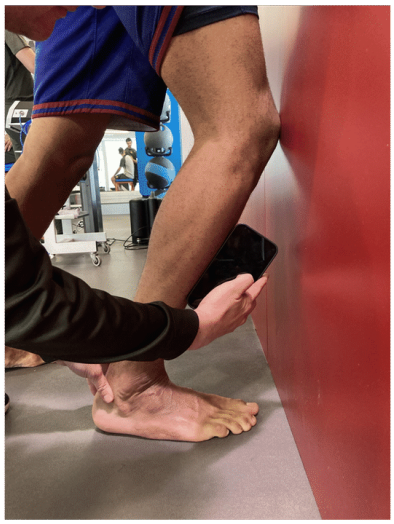
Instrument

For the test, a commercial device like LegMotion® (checkyourmotion.com) is used to facilitate the Ankle Test.

If such a device is unavailable, simpler alternatives include using a manual goniometer (Photo 1), a tape measure on the ground (Photo

2), or a standard inclinometer app on a smartphone (Photo 3). (5)





HeadingAnalysis, interpretation, and visualization of results

To analyze the results, the distance reached (in cm) for each attempt is recorded.

It's been observed that measurements below 10 cm or a dorsiflexion difference greater than 1.5 cm between both ankles (6) could increase the risk of injury. Considering lower limb kinematics, limited dorsiflexion in the ankle due to muscular issues is associated with dynamic knee valgus.

For this reason, measuring ankle dorsiflexion ROM is important in lower limb pathologies, regardless of whether the problem originates in the ankle or elsewhere. A reduction in ankle ROM increases the

demand on the knee and hip, potentially raising the risk of injury and/or decreasing athletic performance.

Given that the subjects are athletes, the reference values obtained from FC Barcelona in the 2022-23 season for this test are as follows (expressed in cm):

Men's football: 9,6 ± 2,7

Basketball: 12,4 ± 4

Futsal: 11 ± 3.5

Women's football: 10.7 ± 2.7

Handball: 11 ± 3

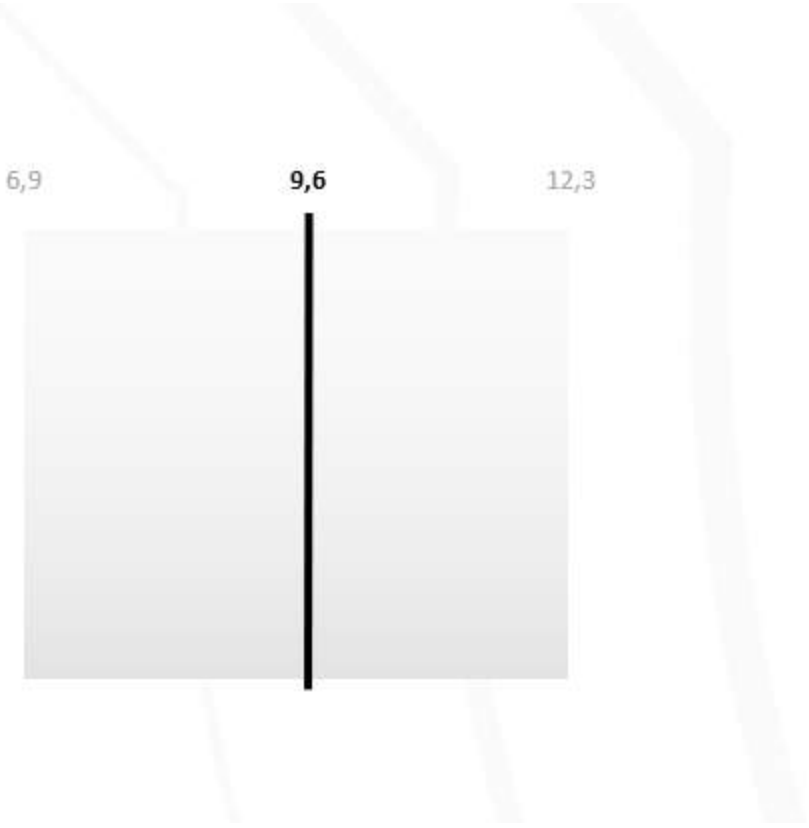
Rink hockey: 12.2 ± 2.8

This indicates variability in the results depending on the type of sport practiced.

Below is a potential visual interpretation of an athlete's progression in the Ankle Test after experiencing ankle pathology (fans).

The results can be displayed using bar graphs. The example shows the gradual increase in ankle dorsiflexion ROM over time in the Ankle Test. All values are measured in centimeters, including the difference between one foot and the other.

Showing the difference between both feet in a visual format can be more meaningful because, when the values are small, the asymmetries are large, which can lead to misinterpretation.



Graph 1. A visual representation of the Ankle Test range and the left-right difference in centimeters for an FCB athlete. The injured ankle is marked with an (*).

The difference between the two measurements, shown in the orange box, indicates progress. In this case, the difference between both sides has decreased. This information helps to objectively track the progress of treatment aimed at restoring symmetry between both feet.

It is also valuable to see where these results stand compared to the team/larger population. The black line shows the average, and the gray box indicates the area covered by one standard deviation from the team/population, helping contextualize the athlete's performance within the group.

Ankle Test

Instrument: LegMotion®.

Subject's position: double-leg stance, barefoot, with their hands on their waist.

Execution: the subject flexes the knee without lifting the heel off the ground until it touches the reference point placed in front.

Measurements: two measurements with each foot.

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Unit 2. Hip Internal/External Rotation

Unit 2. Hip Internal/External Rotation

Hip range of motion is a key clinical parameter for assessing joint function. It is commonly measured in various conditions, such as lower limb overload injuries, hip osteoarthritis, femoroacetabular impingement, lower back pain, and pubalgia, as well as to tailor individualized programs aimed at reducing injury risk. (1.2)

Despite advancements in technology to measure biomechanical variables in research, they have not yet been widely implemented in clinical practice. One example is measuring ROM, where the goniometer remains the standard tool used by physiotherapists. This is likely due to its ease of use, affordability, and portability. However, a limitation of the goniometer is its low inter-rater reliability, with intraclass correlation coefficients (ICC) <0,50. Inter-rater reliability is adequate (ICC > 0.80). (3-6)

As an alternative to the goniometer, a digital inclinometer is used at FC Barcelona to measure ROM. The inclinometer is similar to the goniometer in that it is lightweight and portable. Several studies have

shown that the inclinometer has good to excellent reliability (ICC > 0.88) and concurrent validity with the universal goniometer (ICC > 0.85) for both hip and shoulder assessments. (6-8)

Additionally, the inclinometer has two clear advantages for measuring hip ROM: it can be operated with one hand, freeing the other hand to stabilize the trunk as needed, and it has shown good inter-rater reliability (ICC > 0.80). (8)

Procedure

For this test, the subject lies in a prone position (if the table allows, face down) with their legs together. The examiner stands at the foot of the leg being assessed.

Before performing the test, axial traction is applied to align the lower limbs. The knee is then flexed to 90º, ensuring the hip remains in a neutral position. The inclinometer is placed two fingers above the tibial malleolus, finding the end feel (limit) without causing pelvic compensation.

Two non-consecutive measurements are taken for each limb, and a third should be taken if the first two differ by more than 10 %. The average of the two measurements is calculated, or the median is used if a third measurement is taken.

Internal rotation

External rotation

Instrument

A digital inclinometer is used as the primary tool to measure hip rotations (1). Several models with proven reliability and validity are available, including the ACUMAR™ digital inclinometer (model ACU 360) from Lafayette Instrument Company in Lafayette, IN, USA; the Digital Protractor Pro 3600 from Mitutoyo America in Aurora, IL, USA; and the Digital Angle-Sensor IP54, Bevel-Box, and Level-Box from Vogel Germany GmbH & Co. KG in Kevelaer, Germany. The latter is the device used at the club.

If these devices are unavailable, other alternatives described in the literature include using a manual universal goniometer (1) or inclinometer apps for smartphones. (9)

Analysis, interpretation, and visualization of results

For analysis, the range reached (in degrees) is recorded for each measurement.

According to the French orthopedic surgeon A.I. Kapandji, an internal rotation (IR) assessed in the prone position, as the one we are using for the measurement, should range between 30-40° of motion, while an external rotation (ER) should be greater than 60°. Consequently, it has been observed that a reduction in the total range of motion of the same joint complex (10), below 85°, or a reduced IR (11), predisposes athletes to injury due to the limitations it creates.

For this reason, it is important to consider hip ROM measurement in lower limb and lumbopelvic pathologies, regardless of whether the issue lies in the hip joint itself or another region. A reduction in the ROM of the hip-knee-ankle/foot joint chain can increase the demand on adjacent joints, raising the risk of injury and/or reducing performance in athletes.

Given that the subjects are athletes, the reference values obtained from FC Barcelona in the 2022-23 season for this test are as follows (expressed in degrees):

Futsal: RI 39,1 ± 18,4 / RE 40,4 ± 15,6 (Σ: 66,1 ± 16,35)

Women's football: RI 37,5 ± 9,4 / RE 43,3 ± 13 (Σ: 79,7 ± 8,3)

Handball: RI 27,7 ± 7,2 / RE 38 ± 8 (Σ: 53,5 ± 13,9)

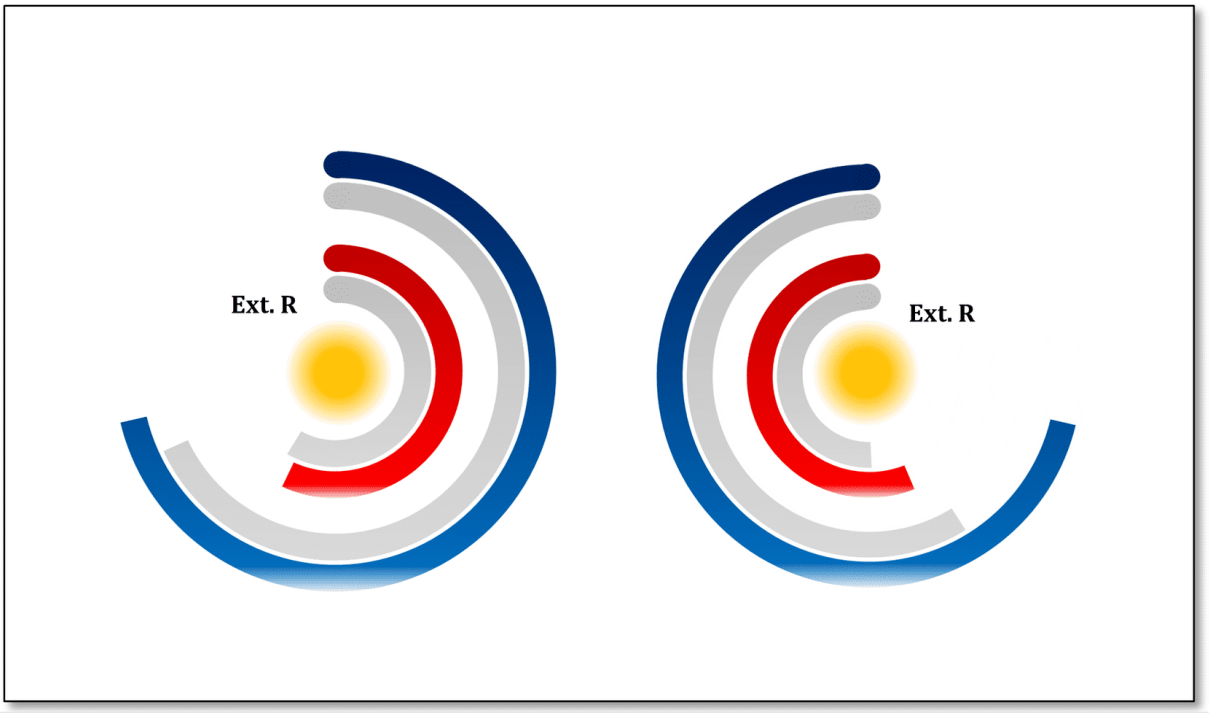
Rink hockey: RI 28,6 ± 8,3 / RE 39,2 ± 10,8 (Σ: 70,1 ± 9,9)

Basketball: RI 39,1 ± 9,8 / RE 51,2 ± 10,6 (Σ: 90,3 ± 17,1)

Men's football: RI 30,9 ± 6,8 / RE 42,9 ± 7,7 (Σ: 73,8 ± 8,9)

This indicates the variability in results depending on the type of sport practiced.

Regarding the visualization of the results in hip rotation tests, there are many possibilities. Below is a possible graphical interpretation of the internal and external hip rotation measurements for an FC Barcelona athlete during screenings (Graph 1).



Graph 1. Visual representation of the internal and external rotation of both legs, with the total sum of degrees for each, in an FCB athlete.

The example in the graph shows the results of internal and external rotation measurements in both legs on a specific date.

The gray line accompanying each rotation can also be observed, which allows us to contextualize the measurement with the team/population average. This allows us to determine where our athlete stands in relation to the group.

The center of the graph shows the total of internal and external rotation for that leg, relating it to injury predisposition due to reduced

ROM (10, 11).

Internal/external hip rotation

Instrument: digital inclinometer.

Subject's position: prone position, with their legs together.

Execution: an axial traction is performed to align the lower limbs, and the knee is flexed at 90° to ensure the hip is in a neutral position.

Measurements: two non-consecutive measurements of each limb, plus a third one in case the first two differ by more than 10%. The average of the two measurements is calculated, or a median is used if a third measurement is taken.

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Unit 3. Active Knee Extension (AKE)

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Hip joint mobility limitations due to muscular issues are commonly seen in patients with lower limb injuries and lumbar pathology. Numerous variables have been studied in the etiology of movement dysfunctions, with muscle extensibility limitation being a key factor. This can interfere with joint biomechanics and muscle function, thereby affecting athletic performance and predisposing athletes to injury. (1, 2)

Monitoring the tolerance to tension in the posterior chain (hamstrings, triceps surae, and other tissues that may restrict movement) allows for individualized treatments for injured athletes and intervention in reducing injury risk. Additionally, muscle length is an outcome that is analyzed in asymptomatic individuals who participate in exercise and sports. Therefore, to ensure accurate testing and appropriate interventions, it is essential to have reliable measurement methods. (3)

The Active Knee Extension Test (AKE Test) is used, with intra-rater reliability ranging from 0.78 to 0.94 and inter-rater reliability reaching 0.98-0.99. (4, 5)

The inter-rater and intra-rater reliability is highest for the AKE Test when a distal inclinometer is used at the tibial tuberosity for an objective measurement. The tested limb is maintained at 90° of hip flexion, supported by the subject's upper limb. A vertical side bar is placed adjacent to the table to provide the subject with a visual reference and ensure vertical alignment of the femur. (5)

Procedure

The subject lies in a supine position with their head resting on the table throughout the procedure. The hip of the leg to be assessed should be flexed to 90° (aligned using a visual reference of the vertical bar with the greater trochanter, while the participant holds their leg proximal to the popliteal pit). The shoulders and foot remain relaxed.

The examiner stands on the homolateral side of the tested leg, holding the inclinometer on the distal part of the anterior tibial tuberosity.

For the test, the non-assessed lower limb is secured with a strap around the distal third of the thigh, ensuring constant visual

supervision of the subject's position during the measurement, maintaining the hip at 90°, the head in contact with the table, and the shoulders and foot relaxed.

During execution, the subject extends the knee as much as possible and holds the position (without jerking) until the examiner records the measurement.

Two consecutive measurements are taken for each leg. The average value of the two measurements is calculated. The degree of knee flexion achieved is recorded, with 0° indicating full extension.

Instrument

For AKE Test assessment, the literature describes different devices for measurement: pendulum goniometer (6), arm goniometer (7), as well as various types of inclinometers (2, 5). However, to streamline the measurement process, and in line with the literature, we will continue

using the Digital Angle-Sensor, IP54, Bevel-Box, and Level-Box (Vogel Germany GmbH & Co. KG, Kevelaer, Germany) as the reference measurement devices.

That said, if this type of device is unavailable, the alternatives mentioned (various goniometers) may be used, as well as a reference inclinometer app for smartphones.

Analysis, interpretation, and visualization of results

To analyze the results, record the range achieved (in degrees) for each measurement taken.

A range less than 20º up to full extension is considered within normal values. A range exceeding 20º, restricted by excessive tension in the posterior chain—particularly in the hamstrings—is considered reduced (2, 7). This limitation can increase the risk of lower limb injuries, especially in the hamstrings (4) and the lumbopelvic region.

Therefore, when evaluating lower limb pathology, particularly muscle issues in the posterior chain, it is crucial to assess the active ROM in knee extension.

Given that the subjects are athletes, the reference values obtained from FC Barcelona in the 2022-23 season for this test are as follows (expressed in degrees):

Men's football: 30.4 ± 11.9

Basketball: 38.4 ± 19.3

Handball: 29.4 ± 8.4

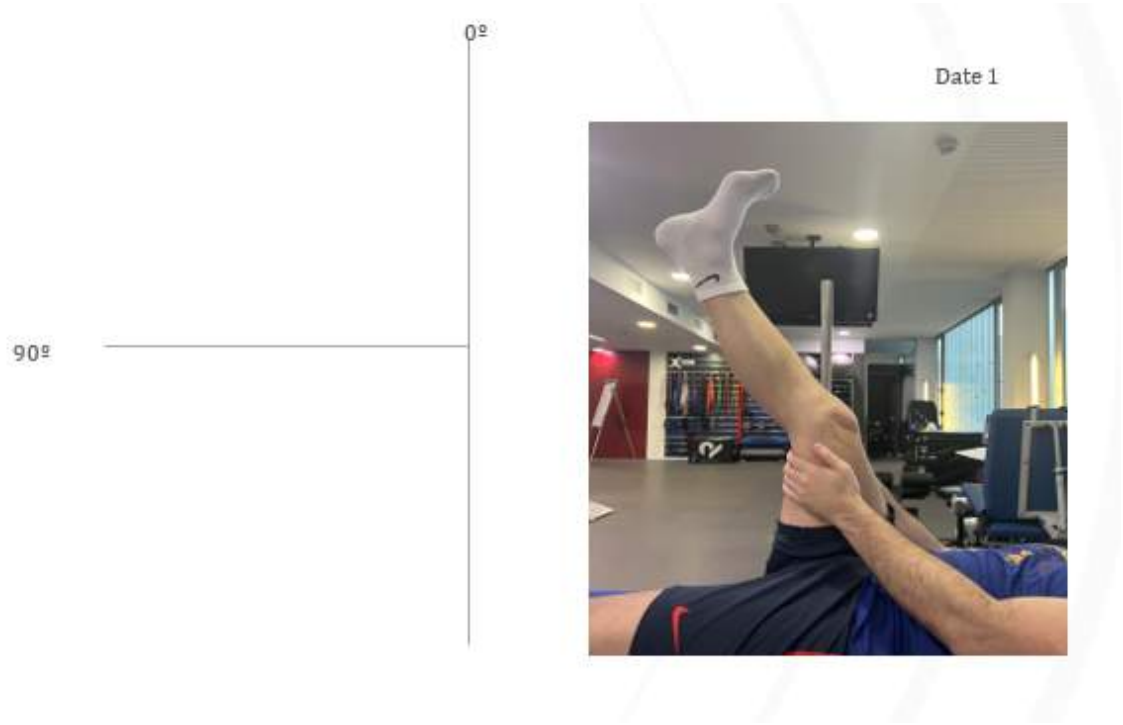
Futsal: 36.1 ± 7.8

Rink hockey: 24.2 ± 9.4

Women's football: 26.3 ± 8.2

This indicates variability in the results depending on the type of sport practiced.

Below is a graphic interpretation of the results from an AKE Test performed on an FC Barcelona athlete during a screening (Graph 1).



Graph 1. Visual representation of the degrees achieved by an FCB athlete in the AKE test. The values shown represent the degrees remaining to reach 0º (full knee extension). The image illustrates the test.

The graph displays the AKE test measurements alongside an image to remind us of the position in which the measurements were taken. This helps clarify the graph's orientation and prevents any confusion.

The starting point is 90º of knee flexion, and the goal is to get as close to 0º as possible (maximum extension).

The gray line between the two measurements indicates the team/population average, providing context for the athlete's position relative to the group.

This test is associated with the risk of injuries in the posterior chain (4).

Active Knee Extension (AKE)

Instrument: Digital inclinometer.

Subject's position: supine position with the head resting on the examination table at all times. A 90º hip flexion is performed on the leg being assessed.

Execution: the subject fully extends the knee and holds the position while the evaluator records the measurement.

Measurements: two consecutive measurements for each limb. The average value of the two measurements will be calculated.

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Unit 4. Passive Straight Leg Raise (PSLR)

Unit 4. Passive Straight Leg Raise (PSLR)

Flexibility is a key physical attribute, often associated with athletic performance and commonly linked to muscle injuries.

Therefore, it is essential to accurately and reliably evaluate an athlete's muscle extensibility, whether for monitoring progress in a training program or measuring the effectiveness of strategies in a rehabilitation setting. (1)

The PSLR test is one of the most widely used methods to assess muscle extensibility. It involves a passive hip flexion movement, with the knee fully extended, performed by the examiner. Some authors argue that the passive nature of the test offers an advantage over the AKE by eliminating quadriceps and hip flexor activity, thus providing a more accurate measure of hamstring extensibility. (2-4)

For the PSLR, an average ICC of 0.96 was obtained for the SLR, indicating high reliability. (4)

However, some studies have concluded that the subject's position during the AKE prevents pelvic rotation and eliminates potential neurological interference that may occur during the PSLR maneuver. (4)

Procedure

The subject lies supine on the examination table, with arms by their sides and legs extended. The examiner stands beside the leg being assessed.

To perform the test, the examiner places their cranial hand on the front of the knee to prevent hip flexion and rotation while holding the inclinometer on the distal part of the anterior tibial tuberosity. The non-assessed leg is secured with a non-elastic strap at the distal third of the thigh.

To execute the test, the examiner places their caudal hand on the subject's heel and carefully lifts the leg, flexing the hip with the knee extended, while ensuring the hip does not rotate externally. The movement continues until the limit of stretching is reached, which marks the end of the test.

Two consecutive measurements are taken for each leg. The average value of the two measurements is calculated.

Starting position

Final position

Instrument

For the PSLR test, the literature describes various tools for measurement (5,6), including the inclinometer and goniometer. As with previous tests, to make the measurement process more efficient, whenever supported by literature, the inclinometer Digital Angle-Sensor, IP54, Bevel-Box and Level-Box (Vogel Germany GmbH & Co. KG, Kevelaer, Germany) will be used as the reference measurement device.

However, if this device is unavailable, the test can also be conducted with an arm goniometer or a reference inclinometer app for smartphones.

Analysis, interpretation, and visualization of results

For analysis, the range reached (in degrees) is recorded for each measurement.

Normal hip flexion is generally considered to be 68º or higher, with good values around 70-71º, and excellent values at 88º or above (6). A hip flexion range of less than 68º, caused by excessive tension in the posterior chain (primarily the hamstrings and peripheral nervous system, including the sciatic nerve and its branches), is considered limited. This restriction can raise the risk of injury to the lower limbs, especially in the posterior chain muscles and the lumbopelvic region.

This makes it crucial to measure passive hip flexion ROM when evaluating both lower limb and lumbopelvic pathologies.

Given that the subjects are athletes, the reference values obtained from FC Barcelona in the 2022-23 season for this test are as follows (expressed in degrees):

Men's football: 68.1 ± 8.6

The following graph offers a possible visual interpretation of the progression of the PSLR test in an FCB athlete with a hamstring injury (Graph 1).

Graph 1. This graph shows the progression over time in the PSLR results for an FCB athlete. The injured leg is marked with an asterisk (*). The graph also displays the left/right asymmetry for each measurement.

From the graph, we can see the time-based improvement in the athlete's ROM during the PSLR test, leading to eventual symmetry.

Additionally, the asymmetry between the two legs, as highlighted in the orange box, shows a decreasing trend over time. This provides an objective representation of the treatment's progress.

The black line shows the average, and the gray box indicates the area covered by one standard deviation from the team/population, helping contextualize the athlete's performance within the group.

Passive Straight Leg Raise (PSLR)

Instrument: digital inclinometer.

Subject’s position: supine position, with arms resting along the body and legs fully extended.

Execution: the examiner places their caudal hand on the subject’s heel and carefully lifts the leg,

flexing the hip with the knee extended, while ensuring the hip does not rotate externally.

Measurements: two consecutive measurements for each limb. The average value of the two measurements will be calculated.

References

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Unit 5. Dynamic Hamstring Test

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Hamstring injuries are among the most frequent in professional football, and significant resources are currently being allocated to reduce their occurrence. Askling et al. (1) identified two main mechanisms of hamstring injury in elite football players:

- Stretch injuries, which occur during eccentric movements like high kicks.
- Spiral injuries, which happen during high-speed running or sprinting.

New technologies have enabled the development of innovative methods for analyzing physiological, kinematic, and spatial positioning variables in sports. These have allowed for the creation of new training and rehabilitation methodologies aimed at preventing muscle injuries and improving athletic performance.

One of the most frequently used tests for hamstring injuries is the Active Straight Leg Raise (ASLR), also known as the Askling Test. During this test, the subject lies supine on a table or the floor and voluntarily lifts the leg with the knee extended, causing an eccentric contraction of the posterior thigh muscles and a concentric contraction of the hip flexors (2). A sensor, called a gyroscope, is used to measure the angular velocity during this movement, assessing the performance of both the agonist and antagonist muscles. One of the most widely used sensors for this purpose is the WIMU PRO™.

A study (3) showed excellent validity for this test (ICC=1.00; r=1.00) and strong inter-device reliability (Bias = .41º/s; CV = .21%), concluding that the WIMU PRO™ is a valid and reliable tool for measuring angular velocity in the ASLR or Askling Test.

Procedure

For preparation, the subject lies supine, with arms along the body and legs extended. The examiner stands on the side of the contralateral leg.

For the test, the WIMU PRO™ device should be secured with an elastic band on the anterior side of the distal third of the tibia. The examiner stabilizes the contralateral leg, preventing flexion of the knee or hip, and any movement of the pelvis.

For execution, the subject raises the leg as fast as possible through the full range of motion, while maintaining knee extension.

The subject performs three repetitions with each leg, with a one-second rest between repetitions. Measurements to be recorded for each leg: maximum angle (degrees), maximum speed (degrees/second), and the angle at maximum speed (degrees). The repetition with the highest measurement in angle at maximum speed will is selected for each leg.

Starting position

Final position

Instrument

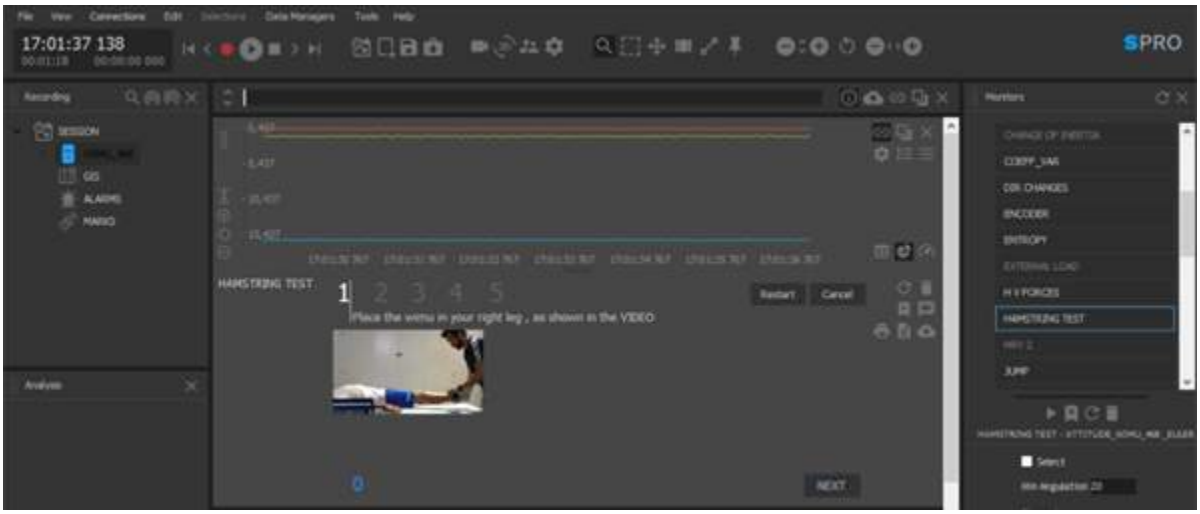
Stability is measured using the WIMU PRO™ inertial device (RealTrack Systems, Almería, Spain). The WIMU PRO™ unit contains three triaxial gyroscopes that can detect angular velocity with a full-scale range of 2000 degrees per second. The device weighs 70 grams and measures

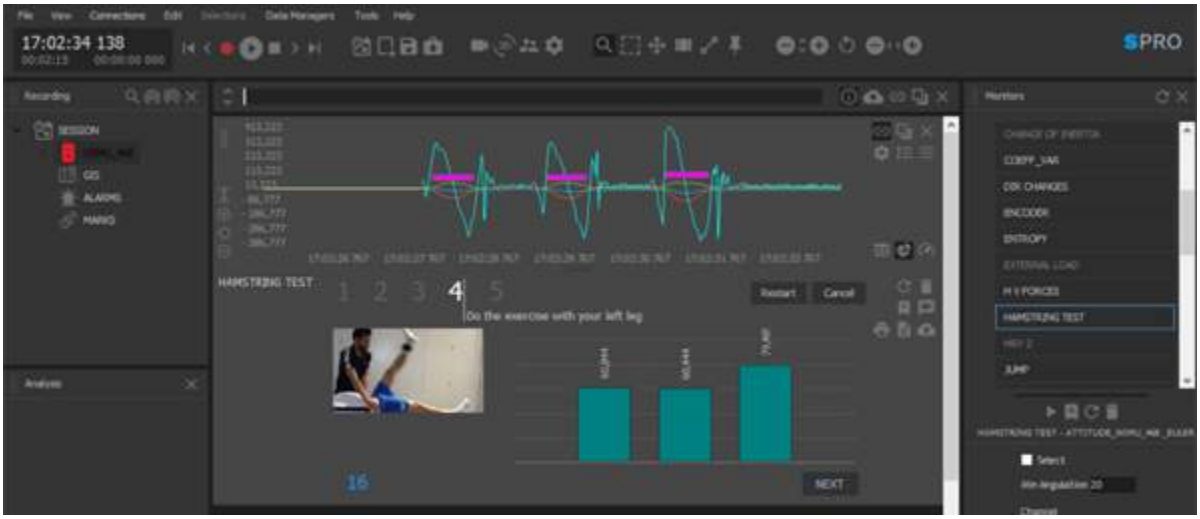
81×45×16 mm. To auto-start the unit and prevent accelerometer errors, leave the device still for 30 seconds on a flat, magnet-free surface. The unit should be secured with an elastic strap around the ankle, above the malleoli, with the device positioned on the anterior side of the leg.

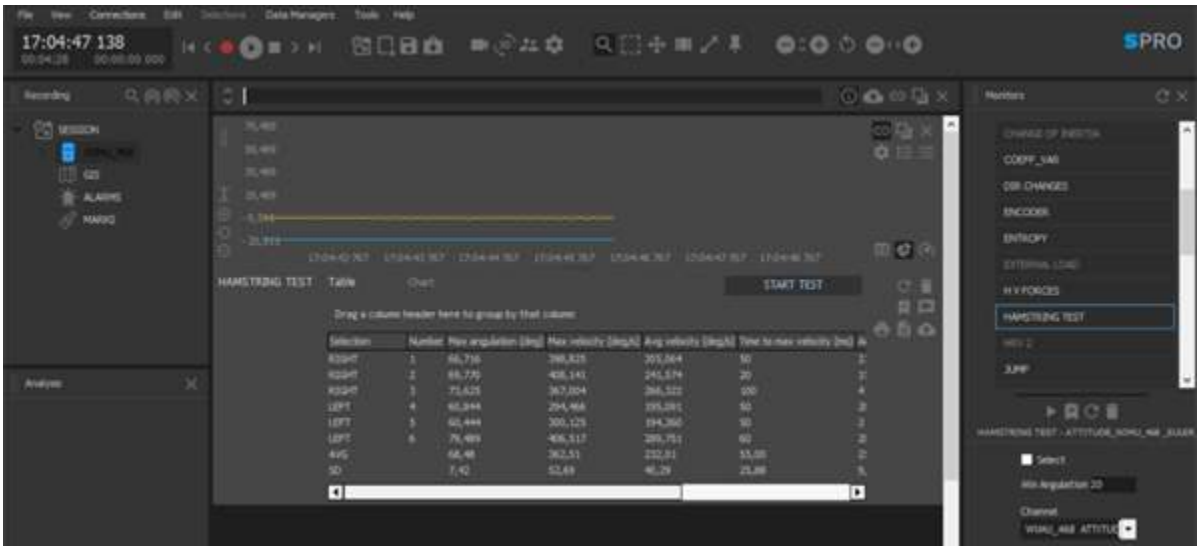
Analysis, interpretation, and visualization of results

The data recorded by the WIMU PRO™ device will be processed using S PRO™ software (RealTrack Systems, Almería, Spain). If the device is connected to Wi-Fi during the test, data can be extracted immediately. Otherwise, the data will need to be analyzed later, with each test manually selected for review.

The steps for conducting the test in real time are outlined below, followed by a table of results that specifies the criteria for selecting the values for analysis.


17:01:37 138
SPRO
HAMSTRING TEST
1 2 3 4 5
Restart
Cancel
Place the wrmu in your right leg , as shown in the VIDEO
NEXT


17:02:34 138
SPRO
HAMSTRING TEST
1 2 3 4 5
Restart
Cancel
Do the exercise with your left leg
NEXT



The table that appears after analyzing the results (Table 1) shows the values for each of the three repetitions for both legs. Select the repetition with the highest angle at maximum speed for each leg. This value is essential for determining the other results for that repetition, even if the remaining two variables show higher values in other repetitions.

Selection	Number	Max angulation (deg)	Max velocity (deg/s)	Avg velocity (deg/s)	Time to max velocity (ms)	Angle at max velocity (deg)	Difference with previous (deg/s)
RIGHT	1	92,672	328,484	250,040	193	60,538	
RIGHT	2	94,587	334,122	279,672	45	19,103	5,638
RIGHT	3	96,008	365,311	275,405	68	28,368	31,189
LEFT	4	89,932	374,840	273,341	168	56,166	9,529
LEFT	5	89,755	426,941	317,083	63	29,651	52,101
LEFT	6	94,085	399,185	282,433	93	39,562	27,756
AVG		92,84	371,48	279,66	105,00	38,90	14,14
SD		2,56	37,78	21,65	60,98	16,46	29,92

Table 1. Visual representation of the results from the Dynamic Hamstring Test performed on an FCB athlete. The arrows indicate the values that determines the selected repetitions.

Given that the subjects are athletes, the reference values obtained from FC Barcelona during the 2022-23 season for the angle at maximum speed (which determines the selected repetition) are as follows:

Futsal: 45º ± 11.3º

Women's football: 49.5º ± 13.7º

Handball: 51.6º ± 9.3º

Basketball: 56.3º ± 11.5º

For the remaining values, the average obtained from the entire population was:

- Maximum angle: 86.46º
- Maximum speed: 370.96º/s

This indicates variability in the results depending on the type of sport practiced.

Below is a potential graphical interpretation of a Dynamic Hamstring Test result for an FC Barcelona athlete during screenings (Graph 1).

By examining the example in the graph, you can observe the results displayed by the device after analyzing the data extracted from the test.

The first bar represents the maximum angle reached by the athlete when lifting the straight leg, while the bar just below shows the degrees at which maximum speed was achieved (indicated by the green bar and displayed in the orange box).

The aim is to visualize the degrees at which maximum speed is achieved and whether they are close to the maximum angle reached, as well as to determine if the speed reached is consistent across both legs.

This test induces muscle stretching in extreme joint positions, focusing on the eccentric work of the hamstring muscles, as literature has demonstrated that eccentric work is effective in preventing injuries in this muscle group (4, 5).

Dynamic Hamstring Test

Instrument: WIMU PRO™ device.

Subject's position: the subject lies supine, with arms at the sides and legs extended.

Execution: the subject performs a leg raise at the highest possible speed and full range of motion while keeping the knee extended.

Measurements: three repetitions are conducted for each leg.

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Unit 6. Modified Thomas Test

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ROM is a crucial element of clinical assessment, allowing for the creation of an accurate clinical picture for diagnosis and the identification of injury risk factors. Several studies indicate that hip flexor extensibility is crucial for preventing postural dysfunction, which can lead to lower back, hip, and knee pain, as well as affecting overall human performance. (1-3)

In this context, the Modified Thomas Test has become a widely used tool in clinical practice for assessing hip flexor extensibility. It evaluates the extensibility of three key muscles: the iliacus, the psoas major (forming the iliopsoas group), the rectus femoris, and the tensor fasciae latae. (4, 5)

The study results revealed high inter-rater reliability for the inclinometer, with intraclass correlation coefficient (ICC) values ranging from 0.89 to 0.92. Regarding intra-rater reliability, high values

were observed for both instruments and among different examiners. The ICC ranged from 0.91 to 0.93. (6-8)

Procedure

For preparation, the subject should stand while being supported at the edge of the table, just above the gluteal fold. The examiner is positioned to the side of the tested leg.

To perform the test, the subject holds the knee of the non-tested leg by the proximal third of the tibia, keeping both the knee and hip flexed while relaxing the arms.

During execution, with the examiner's assistance, the subject will lean back, allowing the leg to be assessed to hang off the table. The inclinometer will be placed two transverse fingers above the superior pole of the patella.

Two non-consecutive measurements are taken for each limb, and a third should be taken if the first two differ by more than 10 %. After the first measurement for both legs, the subject will stand up and rest against the table again to 'reset' their position. The average of the two measurements is calculated, or the median is used if a third measurement is taken.

Starting

Final position

Instrument

For assessing the Modified Thomas Test version, the literature once again describes the arm goniometer (1, 9, 10) and the inclinometer (1, 9) as devices to consider for measurement. As with previous tests, to make the measurement process more efficient, whenever supported by literature, the inclinometer Digital Angle-Sensor, IP54, Bevel-Box and Level-Box (Vogel Germany GmbH & Co. KG, Kevelaer, Germany) will be used as the reference measurement device.

If such devices are unavailable, the test can also be conducted using an arm goniometer, an inclinometer app for smartphones, or through the trigonometric process described in the literature (10).

Analysis, interpretation, and visualization of results

For analysis, the range reached (in degrees) is recorded for each measurement. A negative value is assigned when the thigh falls below the horizontal position, indicating true extension, while a positive value is assigned when the thigh remains above horizontal, signifying an extension deficit.

Normal values are defined as any angle of -30º or more when measured relative to the horizontal. As a result, a reduced range caused by excessive tension in the anterior chain—primarily affecting the hip flexor muscles—is classified as an extension limitation when values fall below the required -30º.

A reduced range of hip extension is associated with increased lumbar curvature, which can lead to potential back pain, altered biomechanics in walking and running, knee dysfunctions, and the hip angle achieved during kicking in certain sports (9). This makes it a crucial factor to consider.

Given that the subjects are athletes, the reference values obtained from FC Barcelona in the 2022-23 season for this test are as follows (expressed in degrees):

Men's football: -28.9 ± 9.8

Basketball: -26 ± 8.8

Futsal: -29.1 ± 8.6

Women's football: -31.2 ± 9

Handball: -30.3 ± 8.6

Rink hockey: -30.6 ± 6.7

This indicates variability in the results depending on the type of sport practiced.

Below is a graphical representation of the Modified Thomas test for an FCB athlete with a quadriceps injury (Figure 1).

Graph 1. The visual representation shows the increase in ROM in the Modified Thomas test throughout the treatment progression of an FCB athlete. We can observe asymmetry between the legs in each measurement. The injured limb is marked with an asterisk (*).

The graph illustrates the changes in ROM over time during the Modified Thomas test. In this case, a negative value indicates an

increase in range of motion (ROM), meaning greater mobility corresponds to a larger negative number.

The result is negative because the leg is positioned below the horizontal line. A result close to zero would suggest significant retraction in the anterior chain.

The graph also highlights the asymmetry between the two legs, indicated by the orange box. This asymmetry tends to decrease over time, corresponding with the increase in measurement values for each leg. This indicates progress in the treatment of the injury concerning hip mobility.

The black line represents the average, while the gray box indicates the area that covers the standard deviation of the team/population, allowing us to contextualize the athlete's condition relative to the group.

Modified Thomas Test

Instrument: digital inclinometer.

Subject’s position: double-leg stance, supported on the edge of the table above the gluteal fold.

Execution: the subject leans back, allowing the leg being assessed to hang off the table.

Measurements: two non-consecutive measurements of each limb, plus a third one in case the first two differ by more than 10%. The average of the two measurements is calculated, or a median is used if a third measurement is taken.

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