Module 2: Strength Monitoring Test

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Clearly understanding the concept of strength (in all its forms) is essential when planning treatment or training for athletes.

Mechanical force is a vector quantity used to describe how one object influences another, leading to changes in motion or shape. This concept is fundamental in physics and is applied across various fields of engineering and applied sciences. Force is typically represented by the letter F, and in the International System of Units (SI), its unit of measurement is the newton (N). (1)

From a physiological perspective, strength refers to the muscles' ability to generate tension and perform work, which involves muscle contraction. This process is complex and involves a series of biological and biochemical mechanisms that allow muscle fibers to produce force. (2)

When measuring and assessing strength, the key metrics to track are the peak force generated and the time it takes to reach that peak—this is the force value being analyzed and the relationship between that force and the time required to achieve it. The relationship between force and time forms what is known as the force-time curve (F-t curve). When force is measured during dynamic action, the F-t curve has an equivalent, known as the force-velocity curve (F-v curve). (3)(4)

There are various ways to classify strength. One classification, proposed by J. Badillo and J. Ribas in their book *Strength Training Programming*, is as follows:

- **Maximum isometric/static strength (MIS)** refers to the strength generated by a muscle when it contracts without changing length. In simpler terms, during an isometric contraction, the muscle produces tension without movement. This type of contraction occurs when holding a fixed position against resistance. With the proper instruments, measuring this type of strength will yield an isometric or static F-t curve. This force is measured in newtons (N).
- **Maximum dynamic strength**: if the resistance used to measure force is overcome, but it can only be done once, the force measured is the maximum dynamic strength (MDS). This is often regarded as the value of a one-repetition maximum (1RM).
- **Relative maximum dynamic strength**: when measuring force using resistances lower than those for MDS (1RM), we obtain a series of values, each representing a relative maximum dynamic strength (RMDS), with the highest value being MDS. Therefore, an individual will have a single MDS value for a specific movement and conditions, but multiple RMDS values depending on the different resistances used for measurement. This force is always expressed in newtons (N).
- **Useful strength** refers to the ability to apply muscle strength effectively and efficiently in specific activities or daily practical situations. Unlike pure or maximum strength, useful strength focuses on how strength is applied functionally in sports, manual work, or everyday tasks.
- **Explosive strength** is the result of the relationship between the force produced, either manifested or applied, and the time needed to produce it. Therefore, explosive strength (ES) represents the production of force over a unit of time, expressed in N·s-1.

Below are the procedures used to obtain strength measurements for different muscle groups:

- Isokinetic Test at 60 and 240º per second.
- Hamstring gauge, unilateral isometric strength::
  - 90º hip flexion – 90º knee flexion (supine position).
  - 90º hip flexion – 20º knee flexion (single-leg stance).
- Quadriceps gauge, unilateral isometric strength:
  - 90º knee flexion (seated position).
- Abductor and adductor gauge, bilateral isometric strength:
  - 45º hip flexion – feet flat on the table (supine position).

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 5. Isometric unilateral quadriceps gauge: 90° knee flexion (seated position)

Unit 6. Abductor and adductor gauge, bilateral isometric strength: 45° hip flexion...

Unit 1. Instrument

Unit 1. Instrument

Currently, there are many instruments available to measure strength, including gauges and isokinetic devices.

Force gauges are devices commonly used in sports and performance research to measure forces, times, and other variables related to exercise and physical activity. Various devices are available on the market today, offering a range of prices and features. One notable example is the Chronojump Boscosystem® (www.chronojump.org). With a maximum capacity of 500 kg and weighing just 638 g, it offers excellent portability and ease of use, making it ideal for both sports and scientific applications.

These devices are characterized by:

- Precision and reliability: providing accurate measurements of the force applied during various exercises.

- Ease of use: with integrated hardware and software, the system is easy to set up and operate, even for non-specialists.

- Flexibility and adaptability: it can be used across a wide range of sports and research settings.

The basic operation of a muscle force gauge involves converting the applied force into an electrical signal, which is then measured and analyzed through the following steps:

1. **Application of force**. The user applies force to the dynamometer. This may involve compression, tension, or any other specific muscle action that the device is designed to measure.

2. **Sensor deformation**. Inside the dynamometer, piezoelectric sensors deform when force is applied.

3. **Change in electrical resistance**. The sensor's deformation causes a change in its electrical resistance. In strain gauges, this change is directly proportional to the applied force.

4. **Signal conversion**. The change in resistance is converted into an electrical signal. Since this signal is

very small, it is typically amplified by a signal conditioning circuit.

5 **Measurement and recording**. The amplified signal is sent to a measurement system, such as a microprocessor, computer, or recording device. This system interprets the signal and converts it into a force reading that can be viewed and analyzed.

Isokinetic devices are instruments that enable muscle exercises to be performed at a constant speed throughout the full range of joint movement. The machine's resistance is "accommodating," meaning it adjusts to match the force exerted by the patient, allowing the muscles involved to always develop maximum tension and fiber activation.

This feature makes isokinetic devices highly versatile and beneficial for functional evaluations, rehabilitation, and training.

The main type of movement that can be analyzed using this device is:

- Isokinetic movement: in this type of movement, the speed remains constant, while the machine's resistance adjusts based on the force exerted by the patient ("accommodating" resistance).

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Unit 2. Isokinetic Test 60° and 240°/second

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The isokinetic test is an advanced, specialized assessment used to measure muscle strength and performance. Isokinetic tests are widely used in sports, rehabilitation, and clinical research for several reasons. They allow for the evaluation of maximum strength and muscle endurance in different muscle groups, which is crucial for identifying imbalances between agonist and antagonist muscles and preventing injuries. These tests are also essential for tracking patients' progress during rehabilitation, especially after surgeries like anterior cruciate ligament reconstruction (ACLR). The data provided helps make informed decisions regarding the safe return to sports activities (1,2).

However, isokinetic dynamometers have some limitations, such as their high cost, the need for space, and the requirement for specialized personnel, which restrict their use to well-equipped centers. Additionally, there are variations in test protocols across different studies and centers, which may affect the comparability of results. The availability of specific normative values for various populations is still limited, which can complicate the interpretation of results in certain cases (2,3).

In conclusion, the isokinetic test is a valuable and precise tool for assessing muscle strength and performance, identifying imbalances, and guiding rehabilitation and return-to-sport programs. Proper application requires specialized equipment and standardized protocols to ensure reliable and comparable results. Reference values are essential for interpreting results and setting recovery goals in different sports and clinical populations (1-3).

Procedure

Before conducting the test, it's essential to record the athlete's personal data, including their weight, which is important for normalizing the results. The athlete should sit in the chair provided by the isokinetic device, with the backrest positioned at 85º for a comfortable posture. There should be a two-finger gap between the edge of the chair seat and the popliteal area. The axis of the arm that measures limb strength must align with the center of the external femoral condyle.

The examiner should secure the athlete in the chair using all provided straps (waist, shoulders, quadriceps, and ankle). The tibia support should be placed three fingers above the external malleolus. The limb that is not being assessed should also be secured with a support under the chair. After the setup, the athlete should be instructed to perform maximum flexion and extension. This will help ensure they can complete the movement to be tested without any restrictions.

Starting position

Final position

Tests conducted at 60° and 240º/second involve 5 repetitions at each speed, with a rest period of one to one and a half minutes between sets.

Below is a table (Image 1) showing the results obtained from an isokinetic test.

TEST:RODILLA - ISOCINÉTICO			
Número Ejercicio.	97	94	Diff. %
Fecha/Tiempo	14/05/2024 - 11:06	14/05/2024 - 11:01	
Tipo	CONCÉNTRICO	CONCÉNTRICO	
Series	TEST_60.240_CON	TEST_60.240_CON	
"	C_D - 2	C_E - 2	
Lado	DERECHO	IZQUIERDO	
Velocidad Ext/Flex	60/60	60/60	
# Rep. Ajuste/Ejerc.	5/5	5/5	
Ajuste límite ROM Ext/Flx	*/*	*/*	
Max ROM Ext/Flx	0/90	0/90	*/0
Media Torsión de Pico [Nm] Ext/Flx	211/174	231/170	-9/2
Torsión de Pico [Nm] Ext/Flx	219/179	246/177	-11/1
Torsión de Pico [Nm] Ext/Flx / Peso	3,17/2,59	3,57/2,57	-11/1
Ángulo @PT Ext/Flx	50/25	51/32	
Potencia Max Ext/Flx	260/235	291/232	-11/1
Ángulo Potencia @Max Ext/Flx	69/8	74/18	
Tot. trabajo Ext/Flx	957/785	1100/801	-13/-2
% Indice resisten. Ext/Flx	*/*	*/*	
% Rango Flex/Ext % :	81	71	14

Image 1. Table displaying the results from an isokinetic test performed at 60º/second on an FCB athlete.

TEST: KNEE - ISOKINETIC			
Exercise Number	**97**	**94**	**Diff. %**
Date/Time	5/14/2024 – 11:06 AM	5/14/2024 – 11:01 AM	
Type	CONCENTRIC	CONCENTRIC	
Sets	TEST_60_240_CON	TEST_60_240_CON	

Side	RIGHT	LEFT	
Ext/Flex Speed:	60/ 60	60/ 60	
# Rep Adjust/Exercise	5/ 5	5/ 5	
ROM Limit Adjustment Ext/Flx	"/"	"/"	
Max ROM Ext/Flx	"/"	"/0"	
Mean Peak Torque [Nm] Ext/Flx	211/ 174	231/ 170	-9/ 2
Peak Torque [Nm] Ext/Flx	219/ 179	246/ 177	-11/ -1
Peak Torque [Nm] Ext/Flx/ Weight	3,172/ 5.9	3,572/ 5.7	-11/ 1
Angle @PT Ext/Flx	50/ 25	51/ 23	
Max Power Ext/Flx	260/ 235	291/ 232	
Power Angle @Max Ext/Flex	69/ 8	74/ 18	
Total Work Ext/Flex	957/ 785	1100/ 801	-13/ -2
% Resistance Index Ext/Flx:	"/"	"/"	
% Flx/Ext Range %	81	71	14

While all data are important for evaluating the athlete, some metrics are more indicative of their condition. These include:

- *Peak Torque [Nm] Ext/Flx*: indicates the force values achieved by the quadriceps (Ext) and hamstrings (Flx) of each leg.
- *Peak Torque [Nm] Ext/Flx / Weight*: normalizes the exerted force according to the individual's weight, which is important for comparing different subjects.
- *Diff. %*: shows the asymmetry between the two legs, both in quadriceps (Ext) and hamstrings (Flx).
- *% Flex/Ext Range %*: provides the H/Q ratio for each leg.

Analysis, interpretation, and visualization of results

Injury prevention requires identifying and understanding the factors that contribute to injury, enabling the development of strategies to reduce risk. Despite the wide range of potential causes described in the literature, only a few factors have been scientifically linked to injuries, with intrinsic factors like strength imbalances being the most reliable predictors. (4)

Evaluating these muscle imbalances, specifically in the quadriceps and hamstrings, is also crucial for tracking rehabilitation progress and making decisions regarding Return to Sport (RTS), particularly after medium- or long-term recovery, such as anterior cruciate ligament (ACL) reconstruction. Moreover, athletes who pass these strength tests as part of an RTS assessment are at a lower risk of experiencing a second ACL injury, underscoring their importance. (2)

It has been established that evaluating these muscle imbalances through isokinetic ratios has gained acceptance based on both theoretical and empirical evidence (5). Mr. Croisier later categorized these knee joint strength ratios into two trends. The first is the Bilateral Strength Ratio, which refers to the imbalance between the strength of one body segment and its opposing counterpart, also known as bilateral imbalance. The second is the Unilateral Strength Index, which measures the imbalance between the strength of agonist and antagonist muscles during joint movement, also referred to as unilateral imbalance. These isokinetic strength ratios provide valuable insight into knee joint function, the risk of anterior cruciate ligament (ACL) injury, the main thigh muscles (quadriceps/hamstrings), and the dynamic stability of the knee. (6)

The Bilateral Strength ratio has traditionally been used to compare the maximum strength of the injured leg with the non-injured leg or the dominant leg with the non-dominant one. However, there is still no clear consensus on the most appropriate reference ratio. The

Unilateral Strength refers to the ratio between the maximum strength of the knee's extensor and flexor muscles. This is calculated by dividing the peak isokinetic strength of the flexor muscles (H) by that of the extensor muscles (Q) during concentric contractions (7). This ratio is commonly known as the conventional H/Q ratio. Over time, the conventional ratio has been replaced by the functional ratio, which compares the eccentric peak torque of the hamstrings to the concentric peak torque of the quadriceps. This change was made because opposing muscle groups don't contract concentrically at the same time (8).

One key scientific article that established the foundation for isokinetic methodology regarding quadriceps and hamstring strength work was published in 2008 by Croisier and collaborators (4). From 2000 to 2005, a total of 462 professional football players from Belgium, Brazil, and France, aged 26 ± 6 years, were assessed using a test protocol that has since been widely referenced in numerous other studies, thus setting the foundation for future isokinetic work. This protocol included concentric efforts for the hamstrings and quadriceps at angular velocities of 60º/second and 240º/second, along with eccentric efforts for the hamstrings at velocities of 30º/second and 120º/second. Recently, Van Melick and colleagues published a scoping review, a newer approach to synthesizing scientific evidence. The review provides reference values for the maximum concentric and eccentric strength of the quadriceps and hamstrings at speeds of

60º/second, 180º/second, and 300º/second in athletes from soccer, basketball, and handball (2).

Given that this research is focused on professional athletes, and that FC Barcelona currently lacks specific reference values, those from this publication are provided:

<u>Men's football:</u>

Adolescents: 17.1 ± 0.8 years (n=58)

60º/s Quadriceps: Peak Torque, 182 ± 28 Nm

ECC Peak Torque, -

Hamstrings: Peak Torque, 97 ± 18 Nm

ECC Peak Torque, 151 ± 29 Nm

Ratio: HQR: - / DCR: 84 %

180º/s Quadriceps: Peak Torque, 145 ± 13 Nm.

ECC Peak Torque, 244 ± 42 Nm

Hamstrings: Peak Torque, 87 ± 15 Nm

ECC Peak Torque, 138 ± 21 Nm

Ratio: HQR: 61 % ± 9 % / DCR: 96 % ± 20 %

300º/s Quadriceps: Peak Torque, 122 ± 14 Nm.

ECC Peak Torque, 249 ± 41 Nm

Hamstrings: Peak Torque, 72 ± 9 Nm

ECC Peak Torque, 141 ± 23 Nm

Ratio: HQR: 61 % ± 7 % / DCR: 117 % ± 23 %

Adults: 24.9 ± 1.2 years (n=1499)

60º/s Quadriceps: Peak Torque, 239 ± 16 Nm

ECC Peak Torque, 244 ± 42 Nm

Hamstrings: Peak Torque, 138 ± 4 Nm

ECC Peak Torque, 187 ± 19 Nm

Ratio: HQR: 60 % ± 3 % / DCR: 75 % ± 3 %

180°/s Quadriceps: Peak Torque, 168 ± 14 Nm.

ECC Peak Torque, 249 ± 40 Nm

Hamstrings: Peak Torque, 106 ± 7 Nm

ECC Peak Torque, 154 ± 1 Nm

Ratio: HQR: 62 % ± 6 % / DCR: 101% ± 3%

300°/s Quadriceps: Peak Torque, 134 ± 6 Nm.

ECC Peak Torque, 256 ± 15 Nm

Hamstrings: Peak Torque, 93 ± 7 Nm

ECC Peak Torque, 162 ± 4 Nm

Ratio: HQR: 68% ± 6% / DCR: 126% ± 5%

Women's football:

Adults: 21.3 ± 0.6 years (n=213)

60°/s Quadriceps: Peak Torque, 149 ± 3 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 87 ± 1 Nm

ECC Peak Torque: -

Ratio: HQR: 59 % ± 1 % / DCR: -

180º/s -

300º/s Quadriceps: Peak Torque, 83 ± 12 Nm.

ECC Peak Torque: -

Hamstrings: Peak Torque, 60 ± 9 Nm

ECC Peak Torque: -

Ratio: HQR: 72 % ± 11 % / DCR: -

<u>Men's basketball:</u>

Adults: 22.7 ± 0.6 years (n=73)

60º/s Quadriceps: Peak Torque, 299 ± 3 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 157 ± 8 Nm

ECC Peak Torque: -

Ratio: HQR: 55% ± 3% / DCR: -

180º/s Quadriceps: Peak Torque, 190 ± 12 Nm.

ECC Peak Torque: -

Hamstrings: Peak Torque, 107 ± 7 Nm

ECC Peak Torque: -

Ratio: HQR: 58 % ± 9 % / DCR: -

300º/s Quadriceps: Peak Torque, 147 ± 27 Nm.

ECC Peak Torque: -

Hamstrings: Peak Torque, 82 ± 19 Nm

ECC Peak Torque: -

Ratio: HQR: 65 % ± 10 % / DCR: -

<u>Women's basketball:</u>

Adults: 24.4 ± 2.6 years (n=14)

60º/s Quadriceps: Peak Torque, 185 ± 15 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 100 ± 10 Nm

ECC Peak Torque: -

Ratio: HQR: 57 % ± 9 % / DCR: -

180º/s Quadriceps: Peak Torque, 120 ± 10 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 55 ± 5 Nm

ECC Peak Torque: -

Ratio: HQR: 55 % ± 10 % / DCR: -

300º/s Quadriceps: Peak Torque, 75 ± 10 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 30 ± 4 Nm

ECC Peak Torque: -

Ratio: HQR: 51 % ± 10 % / DCR: -

<u>Men's handball:</u>

Adults: 25.9 ± 4.1 years (n=17)

60º/s Quadriceps: Peak Torque, 266 ± 51 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 163 ± 18 Nm

ECC Peak Torque: -

Ratio: HQR: 63 % ± 12 % / DCR: -

180º/s -

300º/s Quadriceps: Peak Torque, 181 ± 36 Nm.

ECC Peak Torque: -

Hamstrings: Peak Torque, 113 ± 22 Nm

ECC Peak Torque: -

Ratio: HQR: 63 % ± 9 % / DCR: -

<u>Women's handball:</u>

Adults: 21.1 ± 0.9 years (n=293)

60º/s Quadriceps: Peak Torque, 169 ± 5 Nm

ECC Peak Torque: -

Hamstrings: Peak Torque, 95 ± 2 Nm

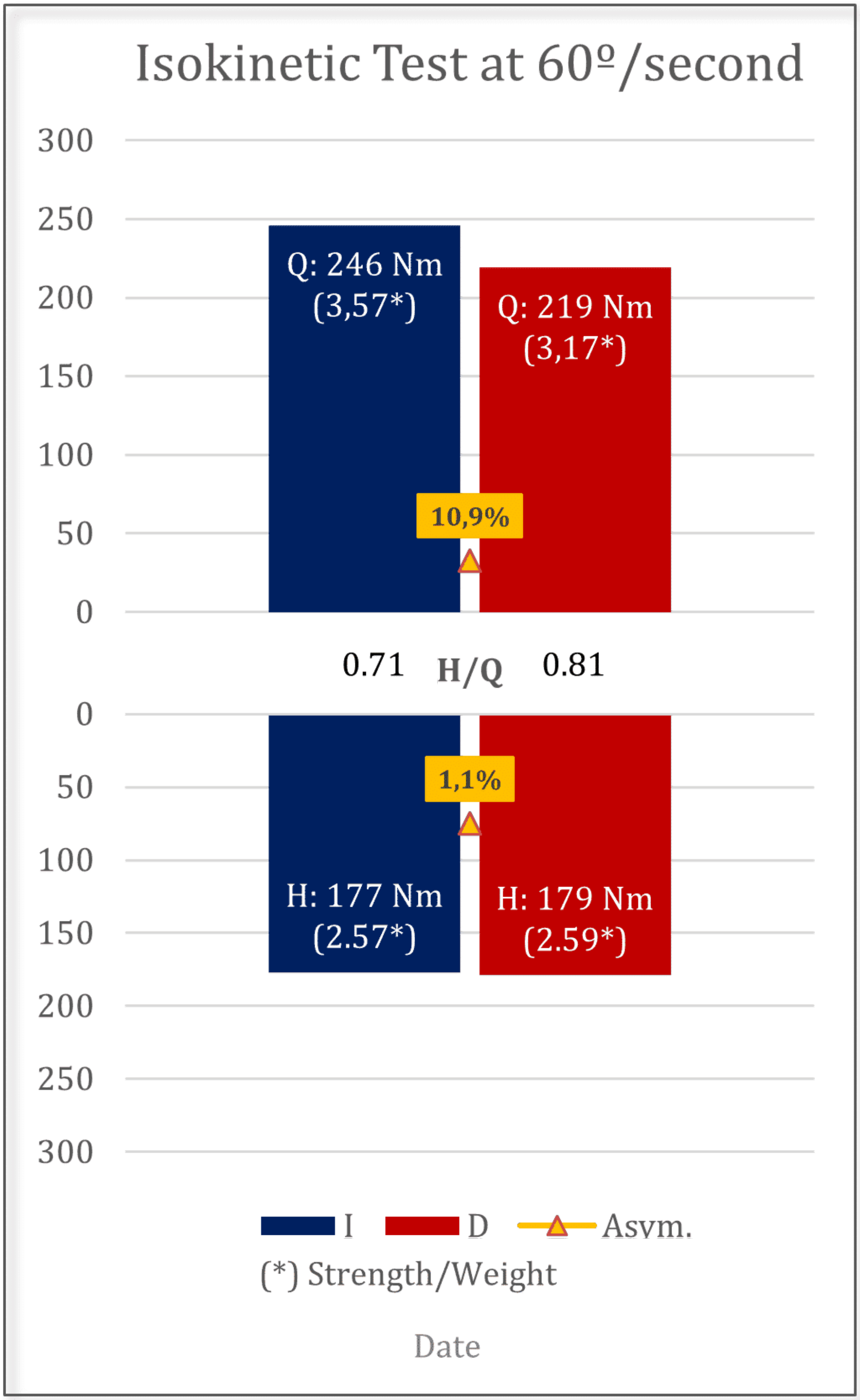
ECC Peak Torque: -

Ratio: HQR: 57 % ± 1 % / DCR: -

*HQR: Hamstrings-Quadriceps Ratio (conventional ratio) / DCR: Dynamic Control Ratio (functional ratio)

This indicates the variability in results depending on gender, age, and the type of sport practiced.

This graph (Graph 1) shows the peak torque generated by each muscle group (Q: quadriceps, H: hamstrings), the asymmetry between both legs within the same muscle group (highlighted in the orange box), the strength normalized by the individual's weight (*), and the H/Q ratio for each limb.



Graph 1. Visual representation of a isokinetic test results of an FCB athlete.

The aim is to provide all necessary information for interpreting the test results, allowing the examiner to easily assess the individual's condition based on these data.

ISOKINETIC TEST at 60 and 240 º/second

Instruments: isokinetic device.

Subject's position: seated position with proper posture and restraints to facilitate the movement being assessed.

Execution: the subject performs knee flexion and extension through its full range of motion with maximum force.

Measurements: five repetitions at each speed, with results extracted from the program.

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Unit 3. Hamstring Gauge, unilateral isometric strength: 90º hip flexion – 90º knee flexion…

Unit 3. Hamstring Gauge, unilateral isometric strength: 90º hip flexion – 90º knee flexion (supine position)

The isometric strength test for the hamstring muscles at 90 degrees of knee flexion is a tool used to assess the strength of the hamstrings in a specific position involving 90 degrees of hip and knee flexion. This test is crucial for identifying injury risks and assessing post-injury functional recovery (1).

Inter-rater reliability for this test has proven to be high, regardless of the examiner's physical abilities, which is essential in clinical settings. The position of the subject's body and foot can significantly influence the results of knee flexion torque. Greater torque is generated during knee flexion when the subject is seated with the foot in dorsiflexion, compared to supine positions or when the foot is in plantar flexion. Although manual dynamometry exhibits a strong correlation with isokinetic dynamometers, the values obtained from these two methods are not directly interchangeable. While isokinetic devices are more reliable and valid, they are also more expensive and less practical in some clinical settings (1,2).

The isometric test at 90 degrees of knee flexion is a valuable tool for assessing muscle strength. However, it is essential to standardize the participant's position and use appropriate fixation methods to obtain reliable results. Variability among methods and the impact of positioning must be taken into account to enhance measurement accuracy (1,2).

Procedure

For the test execution, the subject should lie supine on the floor,, with their arms along their body. The leg being assessed should be positioned with the hip and knee flexed at 90 degrees, with the foot suspended in the Foot Strap. The non-assessed leg should remain extended on the floor.

The examiner should stand laterally to the subject, stabilizing the hip by placing their hands at the level of the anterior superior iliac spines to prevent the hip from lifting off the ground during the test.

During the test, the subject should push downward with the heel of the assessed leg as forcefully as possible while keeping their arms and head flat against the ground. The subject should gradually increase force to achieve maximum contraction, maintaining this contraction for 3 to 5 seconds. The examiner will provide verbal prompts, such as a countdown of "3, 2, 1, Go," before the contraction begins.

Two contractions are performed for each leg, allowing for a minimum rest of 30 seconds between contractions. The reference will be the maximum contraction value obtained for each leg.

Assessment position

CONTINUE

Unit 4. Hamstring gauge, unilateral isometric strength: 90º hip flexion – 20º knee flexion...

Unit 4. Hamstring gauge, unilateral isometric strength: 90º hip flexion – 20º knee flexion (single-leg stance)

The isometric strength test for the hamstring muscles at 90/20 (90º hip flexion and 20º knee flexion) is a tool for assessing hamstring strength in a position that allows for greater knee extension. ts primary goal is to measure the isometric peak force (IPF) in a position reflecting increased knee and hip extension at 90º of flexion, which is relevant for assessing hamstring strength during high muscle activation scenarios (3).

The 90/20 test has shown moderate to high reliability, with coefficients of variation (CV) ranging from 7.3% to 11.0%. The positioning of the hands during the test affects reliability; the CV is lower when the hands are placed on the wall compared to resting on the chest for the dominant leg (7.3% vs. 11.0%). However, for the non-dominant leg, the CV is higher in the wall position than in the chest position (9.7% vs. 7.3%) (3).

In practical applications, isometric tests like the 90/20 are useful for monitoring hamstring strength in both sports and clinical settings. The 90/20 position may be particularly sensitive to detecting changes in muscle strength following intense activities, which is crucial for adjusting training and recovery programs. Additionally, implementing the 90/20 test can help identify strength deficits and muscle asymmetries, significant risk factors for hamstring injuries (3).

Research indicates that deficits in eccentric hamstring strength are associated with an increased risk of recurrent hamstring injuries in football. In particular, the Nordic hamstring test is widely used to detect muscle weaknesses and asymmetries between limbs. However, results from a recent study reveal no significant relationship between the Nordic test results and those of isometric tests, such as the 90/20 and knee flexion at 15º. This suggests that each test measures different aspects of muscle strength and are not interchangeable (4).

Specifically, the Nordic test detected asymmetries greater than 15% in 30% of players, while the knee flexion test at 15º identified asymmetries in 25%, and the 90/20 test found them in only 5% of players. This finding is significant because hamstring strength asymmetries are considered a critical factor in predicting the recurrence of injuries (4).

In conclusion, the 90/20 test is a useful and reliable tool for assessing hamstring strength. Regular use can provide valuable insights into athletes' physical conditions, assist in optimizing training and recovery programs, and contribute to injury prevention and performance enhancement. Furthermore, isometric tests may be more suitable during the initial phases of hamstring injury recovery, while eccentric tests, like the Nordic, may be more beneficial in the later stages of recovery to detect muscle weaknesses and asymmetries (3,4).

Procedure

For execution, the subject should stand on both feet, with their back against the wall and arms crossed at chest level. The leg to be assessed should be at 90º hip flexion and 20º knee flexion, with the foot suspended in the Foot Strap. The non-assessed leg should remain extended with the heel close to the wall.

During execution, the subject should push with the heel of the leg being assessed downward as forcefully as possible, without separating their arms or lifting their head off the wall. Bending the knee should be restricted. The subject should gradually increase force to achieve maximum contraction, maintaining this contraction for 3 to 5 seconds. The examiner will provide verbal prompts, such as a countdown of "3, 2, 1, Go," before the contraction begins.

Two contractions are performed for each leg, allowing for a minimum rest of 30 seconds between contractions. The reference will be the maximum contraction value obtained for each leg.

Assessment position

Analysis, interpretation, and visualization of results

Hamstring strains are the most common injury suffered by elite professional football players and represent the highest injury burden. A survey conducted among high-level professional football teams worldwide in the field of sports medicine and science identified 'fatigue' and 'muscle imbalance' as the two perceived modifiable risk factors considered most important for non-contact injuries in professional footballers (5).

Research suggests that fatigue may be a risk factor for hamstring strain injuries in professional football, with studies indicating that injuries are more common towards the end of football matches, as well as studies reporting a decrease in hamstring muscle strength production towards the end of games. Routine tests that analyze players' hamstring strength after matches and during the post-match period can provide a valuable method for tracking the extent of strength reduction and recovery in these high-risk muscles. Muscular imbalance, which can refer to differences between limbs or between agonist and antagonist muscles of the same limb, remains a topic of debate in the scientific community. Although the validity of muscular imbalance as a risk factor has not been fully confirmed or disproven, this information is essential for professionals. Consequently, any sufficiently sensitive test that can detect a player's muscular imbalance serves as a useful marker for professionals to make informed decisions regarding the extent of strength reductions and recovery in their players' dominant and non-dominant hamstrings (5).

Traditionally, hamstring strength assessments, like quadriceps evaluations, have been conducted using isokinetic dynamometry (6, 7). However, these tests have limited utility as monitoring tools for players who subsequently experience hamstring injuries (8), making them impractical for assessing a large number of athletes due to time inefficiency and the need for costly laboratory equipment. An alternative approach is to assess hamstring strength using isometric protocols that cause minimal structural muscle damage (9), which allows for regular use during the season or recovery phases. Additionally, the rate of force production can be quantified more easily (10), which is particularly relevant for athletes with limited time for force production.

At FC Barcelona, two different positions are used for the isometric test of the hamstring musculature: one in a supine position with the hip and knee flexed at 90º, and the other in a standing position with the hip at 90º and the knee flexed at 20º. Significant differences between these positions include variations in hamstring muscle recruitment (11, 12). Specifically, when the knee is flexed at 20°, there is greater activation of both the biceps femoris and the posterior chain, which includes the medial hamstrings and gluteus maximus (11).

The deficiencies measured in both isometric tests can be used for (11):

- Identifying injury risk factors for both the hamstrings and knee ligaments,
- Monitoring recovery processes involving the hamstring musculature, whether directly or indirectly affected,
- Informing decisions regarding athletes' return to practice and competition,
- Tracking the effectiveness of specific strength and conditioning programs.

Once the results of the isometric test are obtained, a quantitative comparison can be made between:

- The same player at various points during pre-season, in-season, pre/post-injury, and/or different recovery phases (13),
    - Keeping in mind that a hamstring strength symmetry of less than 80% resembles that of injured players. It is recommended that athletes

demonstrate a hamstring index (HI) of at least 80% before being cleared to run.

The hamstring index (HI) is calculated using the formula: (result of the affected limb/result of the unaffected limb) × 100%.

- Due to the risk of re-injury when returning to sports after recovery, such as post-ACL injury, the hamstring index (HI) must be at least 90% before athletes are allowed to return to play.

- Athletes in the same sport modality.
- Athletes playing in the same position or with similar characteristics from the same team.

Given that the subjects are athletes, the reference values obtained from FC Barcelona during the 2022-23 season for this test (results expressed in newtons) are presented according to the specific sport modality.

Unilateral Isometric Strength, DS 90/90º:

Women's football: 243.4 ± 43.4

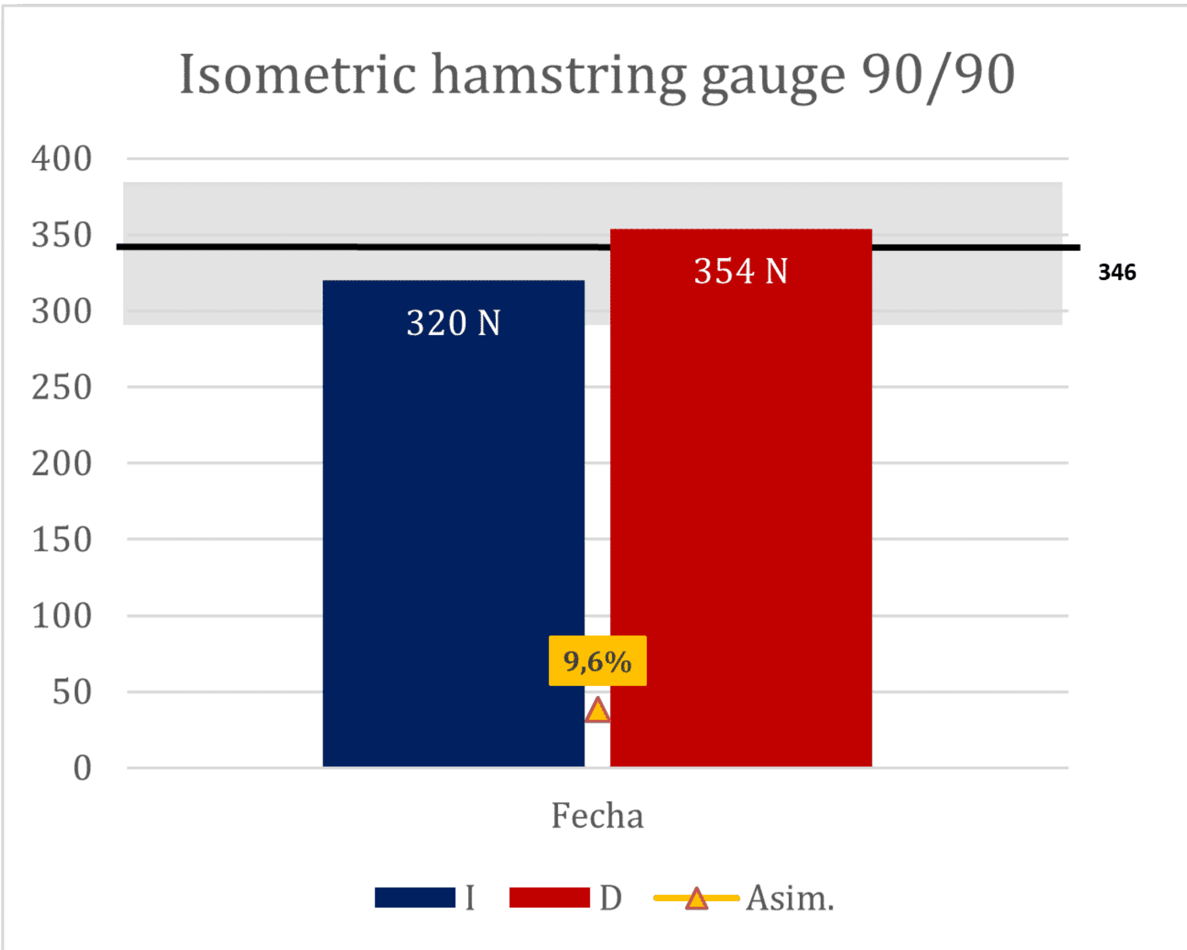
Unilateral Isometric Strength, BP 90/20º:

Futsal: 379.9 ± 122.7

Women's football: 349.6 ± 254.4

The proposed graphs for unilateral isometric strength in the hamstrings for the 90/90 test (Graph 2) and the 90/20 test (Graph 3) uses a column chart. Each bar displays the results obtained from the test for each leg, while a central orange box highlights the asymmetry between the two legs.

The black line marks the group/team average, and the gray rectangle indicates the area that covers one standard deviation.



Graph 2. Visual representation of the results of an isometric unilateral test conducted at 90º hip flexion and 90º knee flexion in a supine position for an FCB athlete.

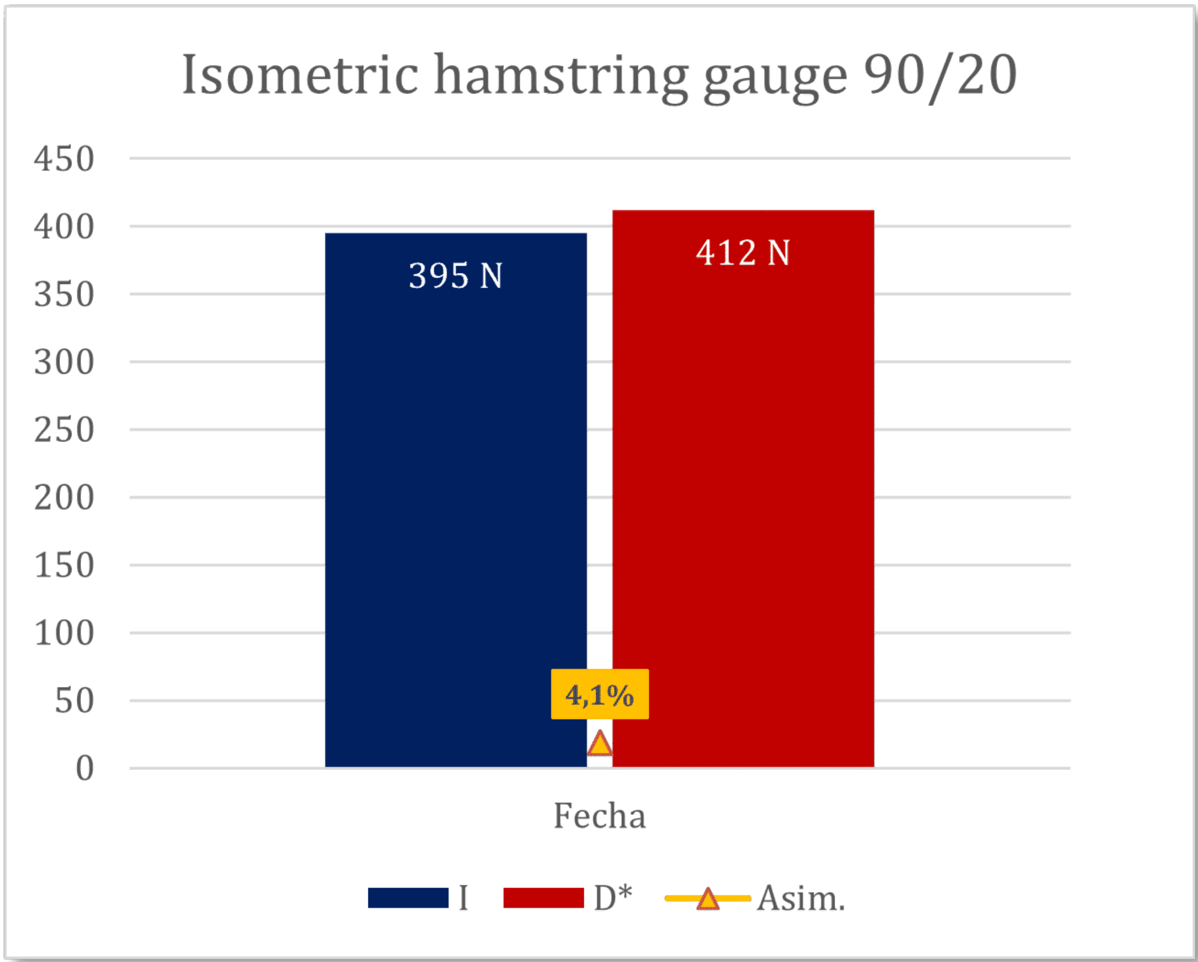
HAMSTRING GAUGE 90/90

Instruments: force gauge and a PC with the specific software.

Subject's position: the subject lies supine on the floor, arms alongside the body, with the assessed leg at 90º hip and knee flexion.

Execution: the subject pushes down with the heel of the assessed leg as hard as possible, progressively increasing force while maintaining the push for 3 to 5 seconds.

Measurements: two contractions are performed for each leg. The reference will be the maximum contraction value obtained for each leg.



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Graph 3. Visual representation of the results of an isometric unilateral test at 90º hip flexion and 20º knee flexion in a standing position for an FCB athlete.

HAMSTRING GAUGE 90/20

Material: force gauge and a PC with the specific software.

Subject's position: double-leg stance, with back against the wall, arms crossed at chest height. The leg to be assessed should be at 90º hip flexion and 20º knee flexion, with the foot suspended in the Foot Strap.

Execution: the subject pushes down with the heel of the assessed leg as hard as possible, progressively increasing force while maintaining the push for 3 to 5 seconds.

Measurements: two contractions are performed for each leg. The reference will be the maximum contraction value obtained for each leg.

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Unit 5. Isometric unilateral quadriceps gauge: 90º knee flexion (seated position)

Unit 5. Isometric unilateral quadriceps gauge: 90º knee flexion (seated position)

The isometric strength test for the quadriceps at 90 degrees of knee flexion is crucial in rehabilitation following anterior cruciate ligament reconstruction (ACLR). This test assesses the strength and symmetry of the quadriceps, which are essential for evaluating rehabilitation progress and effectiveness. Measuring isometric strength, which does not involve changes in muscle length or joint angle, is a safe and useful practice during the early stages of postoperative recovery (1).

The patient sits with their knee flexed at 90 degrees, aligning the lateral condyle of the femur with the dynamometer's axis of rotation. Maximum voluntary isometric contraction (MVIC) is measured in newtons per meter (Nm) and is normalized according to the patient's body weight. Additionally, the symmetry index of the limbs is calculated to assess the strength of both the surgical and non-surgical limbs (2).

This test provides valuable information about quadriceps strength, enabling adjustments to rehabilitation strategies. According to the OPTIKNEE consensus, assessing the muscle strength of knee extensors is critical for preventing post-traumatic osteoarthritis and optimizing musculoskeletal health following an ACL and/or meniscus injury. Isometric strength tests are recommended due to their reliability and validity in post-ACLR assessments. Consistent use of these tests with standardized protocols ensures accurate and useful outcomes in clinical practice (1,2).

Procedure

For the assessment, the subject should be seated at the end of the table with knees and hips flexed at 90 degrees, keeping their back straight and arms crossed at chest level.

The subject is secured to the table with a strap around the hip area during the execution of the test. The subject should attempt to perform a knee extension with the assessed leg as forcefully as possible, keeping their arms in place and maintaining an upright back. The subject should gradually increase force to achieve maximum contraction, maintaining this contraction for 3 to 5 seconds. The examiner will provide verbal prompts, such as a countdown of "3, 2, 1, Go," before the contraction begins.

Two contractions are performed for each leg, allowing for a minimum rest of 30 seconds between contractions. The reference will be the maximum contraction value obtained for each leg.

Assessment position

Analysis, interpretation, and visualization of results

As demonstrated by scientific literature, adequate muscle strength not only acts as a protective factor against injury but also having optimal strength values is crucial for athletic performance (3). Research indicates that isometric strength is beneficial in various sports, including football, wrestling, track cycling, and athletics (4, 5, 6), among others. McGuigan and colleagues (7) further observed that isometric contraction of the quadriceps is directly related to the performance of specific demands, such as vertical jump and one-repetition maximum (1RM) (8).

Supported by these findings, assessing maximum isometric strength is used to determine the effects of training (9, 10) and to monitor rehabilitation progress while designing exercise interventions based on identified needs and weaknesses.

Quadriceps strength asymmetries are common in cases of (13):

- Injuries to the quadriceps muscle,
- Patellofemoral pain (PFP),
- Knee injuries or surgeries (ACL injuries),

- Athletes with any conditions or deterioration of the knee joint, such as osteoarthritis.

These asymmetries, regardless of the associated medical diagnosis, can negatively impact a player's walking and running technique, their return to sports practice, their return to competition, and their performance in those settings.

Regarding the measuring devices used, while there are several available options available in the market to assess muscle strength, isokinetic dynamometry is considered the gold standard for assessing the flexor and/or extensor musculature of the knee (3, 13). It can detect subtle yet significant strength deficits between limbs and track the evolution of strength over time. However, this device is typically used only in research environments (14) due to its limited utility, as it requires a large space and is often too expensive for most settings. Consequently, an alternative method is necessary to quantify quadriceps strength asymmetries. Thus, supported by literature demonstrating the feasibility of assessing this through maximum isometric muscle strength with load gauges (11, 12), both devices—isokinetic dynamometry (previously described) and load gauges—are used at FC Barcelona.

Once the results of the isometric test are obtained, a quantitative comparison can be made between:

- The same player at different times during the preseason/season, pre/post-injury, and/or different phases of recovery, while considering the following:

  - A quadriceps strength symmetry of less than 80% is similar to that of injured players, which is why many authors recommend that individuals demonstrate a quadriceps index (QI) of at least 80% before being allowed to run. (15)

  The calculation of the quadriceps index (QI) = (result of the affected limb/unaffected limb result) × 100%.

  - Due to the risk of re-injury when returning to sports after a recovery process, primarily from the ACL, it is necessary for the quadriceps index (QI) to be at least 90% before they are authorized to return to the sport (13).

- Athletes in the same sport modality.

- Athletes playing in the same position or with similar characteristics from the same team.

Given that the subjects are athletes, the reference values obtained from FC Barcelona in 2022-23 season for this test (expressed in newtons) shows the variability depending on the type of sport practiced.

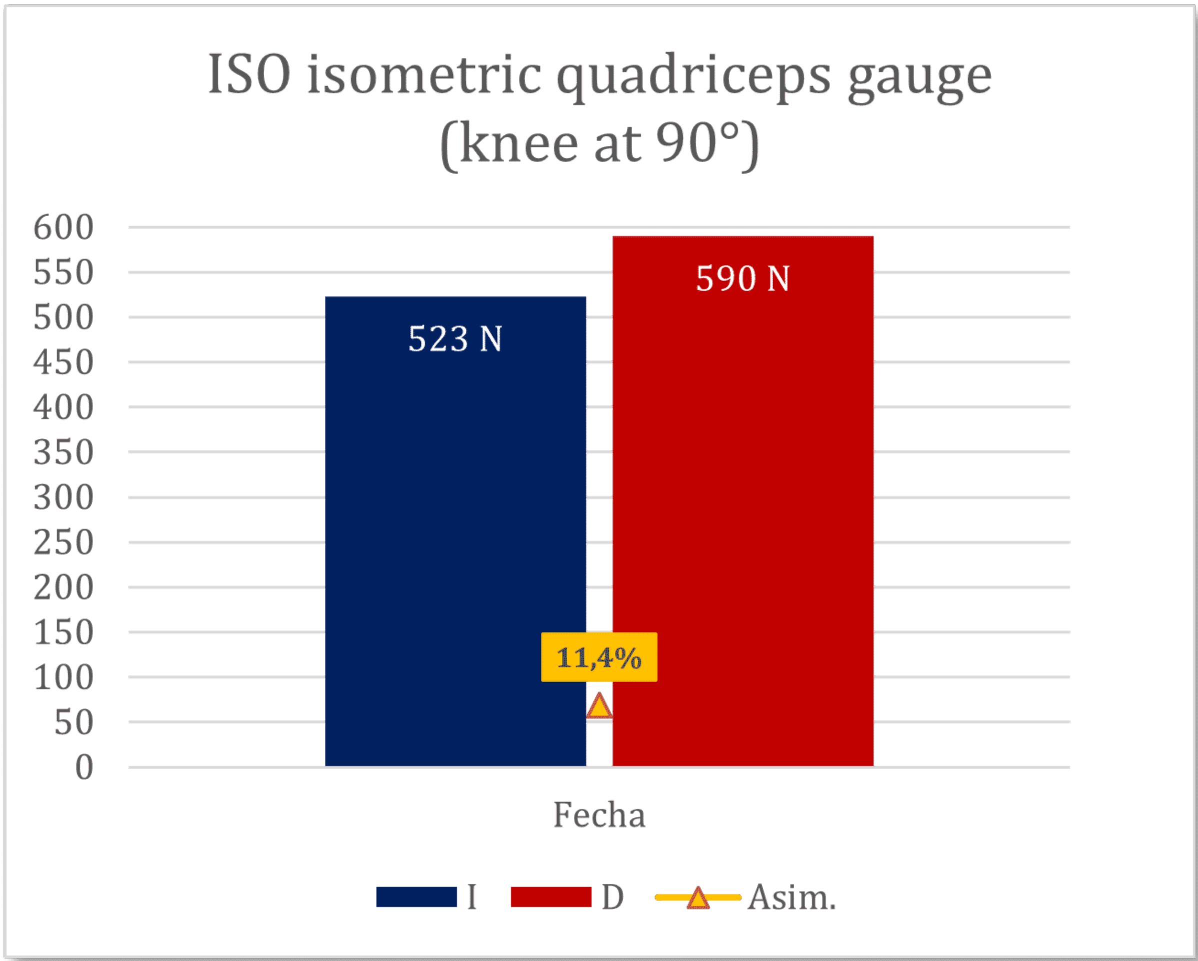
Women's football: 451.3 ± 55.1

Basketball: 405.8 ± 106.5

Futsal: 619.4 ± 150.7

The proposed graph for unilateral isometric quadriceps strength at 90° (Graph 4) uses a column chart to show the test results for each leg. A central orange box highlights the difference between the two legs.

The black line marks the group/team average, and the gray rectangle indicates the area that covers one standard deviation.



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Graph 4. Visual representation of the results from a unilateral isometric test at 90° knee flexion while seated, in an FCB athlete.

ISOMETRIC QUADRICEPS GAUGE 90

Material: force gauge and a PC with the specific software.

Subject's position: seated position with knees and hips at 90° flexion, back straight, and arms crossed at chest level.

Execution: the subject extends the knee of the assessed leg as forcefully as possible while keeping the arms crossed and maintaining an upright posture.

Measurements: two contractions are performed for each leg. The reference will be the maximum contraction value obtained for each leg.

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Unit 6. Abductor and adductor gauge, bilateral isometric strength: 45° hip flexion...

Unit 6. Abductor and adductor gauge, bilateral isometric strength: 45° hip flexion – flat feet in contact with the table (supine position)

The isometric strength test for hip adductor and abductor muscles is crucial for evaluating and monitoring the health and performance of athletes, especially in sports that involve intense hip movements like football, futsal, or hockey. This test quantifies the maximum isometric strength of the hip adductor and abductor muscles, providing important data to prevent injuries, design rehabilitation programs, and enhance athletic performance (1,2).

The data derived from this test offers information on strength symmetry between limbs, the balance of strength between adductor and abductor muscles, and the variability in strength throughout a sports season. Research indicates that weaknesses in the adductor muscles and imbalances in the adductor/abductor strength ratio are linked to a higher risk of groin injuries. For example, a study of hockey players revealed that those with an adductor to abductor strength ratio below 80% were significantly more prone to groin injuries. Likewise, research involving football players demonstrated that while abductor muscle strength typically increases throughout the season, adductor muscle strength remains stable. This leads to a deficit in the adductor/abductor strength ratio by mid to late season (1,2).

The isometric strength test for the hip serves a dual purpose: it is essential for the initial assessment of muscle strength and for ongoing monitoring throughout the sports season. This testing enables coaches and health professionals to pinpoint weaknesses and muscle imbalances that may increase the risk of injury in athletes. Targeted interventions, such as adductor strengthening programs, can then be introduced to address these imbalances and enhance hip stability. Implementing this test as part of a regular assessment program can help reduce the incidence of groin injuries, optimize athletic performance, and facilitate a safe return to sport after an injury. Numerous studies indicate that strength training and monitoring programs can effectively prevent declines in muscle strength throughout the season while maintaining an appropriate balance between the strength of adductor and abductor muscles (3-5).

In conclusion, the isometric strength test for hip adductor and abductor muscles is a valuable tool in sports medicine and physiotherapy. It provides data to inform injury prevention and rehabilitation programs, as well as for optimizing athletic performance. Early detection of muscle weaknesses and strength imbalances facilitates the implementation of effective intervention strategies, ultimately promoting the health and success of athletes (1).

Procedure

For preparation, the subject should lie supine, with arms along the body and the head resting on the table.

The hip should be at 45° flexion and the feet should be flat on the table.

Both legs are strapped at the distal 1/3 of the thigh with the adductor/abductor adapter.

For execution, the subject performs the action of separating (ABD) or bringing together (ADD) the knees, maintaining the initial position (without lifting the feet, arms, glutes, or head off the bench). The subject should gradually increase force to achieve maximum contraction, maintaining this contraction for 3 to 5 seconds. The examiner will provide verbal prompts, such as a countdown of "3, 2, 1, Go," before the contraction begins.

Two consecutive contractions are performed for each movement, with a minimum rest of 30 seconds between each. The reference will be the maximum contraction value obtained for each movement.

Assessment position

Analysis, interpretation, and visualization of results

The scientific literature indicates that a significant deficit in hip muscle performance—particularly a reduction in the strength of the abductor and/or adductor muscles—is linked to several common lower limb conditions in athletes. (6, 7)

Among the most frequently cited conditions are:

- Patellofemoral pain (PFP).
- Iliotibial band syndrome (ITBS).
- Anterior cruciate ligament injuries.
- Lumbopelvic pathologies, particularly groin pain (7, 8).
- Hip osteoarthritis.
- Thigh muscle injuries (8).
- Alterations in the biomechanics of the lower limbs in the frontal plane, increasing joint stress during prolonged dynamic movements like running (8, 9, 10).

Despite the availability of numerous tests to assess muscle strength in both healthy and injured individuals, only a limited number have been developed to objectively measure the strength and endurance of the hip abductors and adductors. Among these, the isometric test offers a standardized and user-friendly assessment method (1). This test primarily measures the maximum strength of the adductor and abductor muscles and calculates the agonist-antagonist strength ratio, known as the ADD/ABD Ratio, with results expressed in newtons (N).

In assessing muscular strength, particularly isometric strength, it is crucial to measure and quantify any existing imbalances and asymmetries in force between limbs. These factors serve as important predictors for the risk of ligamentous and muscular injuries. Once the results are obtained, a quantitative comparison can be made for the same player across various contexts:

- At different points during pre-season or the regular season, before and after injury, and during different recovery phases.

  Considering that a reduction of 15% in the strength of the adductor musculature is a recognized risk factor for injury (4). Additionally, an adduction to abduction (ADD/ABD) ratio of 0.9 or higher is considered a threshold that differentiates healthy athletes from those exhibiting deficits (11).

- Athletes in the same sport modality.

- Athletes in the same position or with similar characteristics on the same team.

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 newtons)

Men's football:

-

Basketball:

ABD 429 ± 77.4 / ADD 359.9 ± 102.1

Futsal:

ABD 441.2 ± 61.7 / ADD 398.9 ± 83.5

Women's football:

ABD 362.1 ± 63.4 / ADD 348.4 ± 58.3

Handball:

ABD 516.3 ± 65.1 / ADD 450.6 ± 83.6

Rink hockey:

ABD 440.8 ± 78.5 / ADD 416.6 ± 99.4

Although the average results of the different six sections are in a close range, some variability can be observed depending on the type of sport practiced.

The visual representation (Graph 5) illustrates the results of the isometric test conducted with a bilateral gauge, where the hips are flexed at 45º. It displays the values obtained for both adduction (ADD) and abduction (ABD), highlighting the previously mentioned ADD/ABD ratio within the orange box.

The black line indicates the average value of the team in each of the muscle groups.

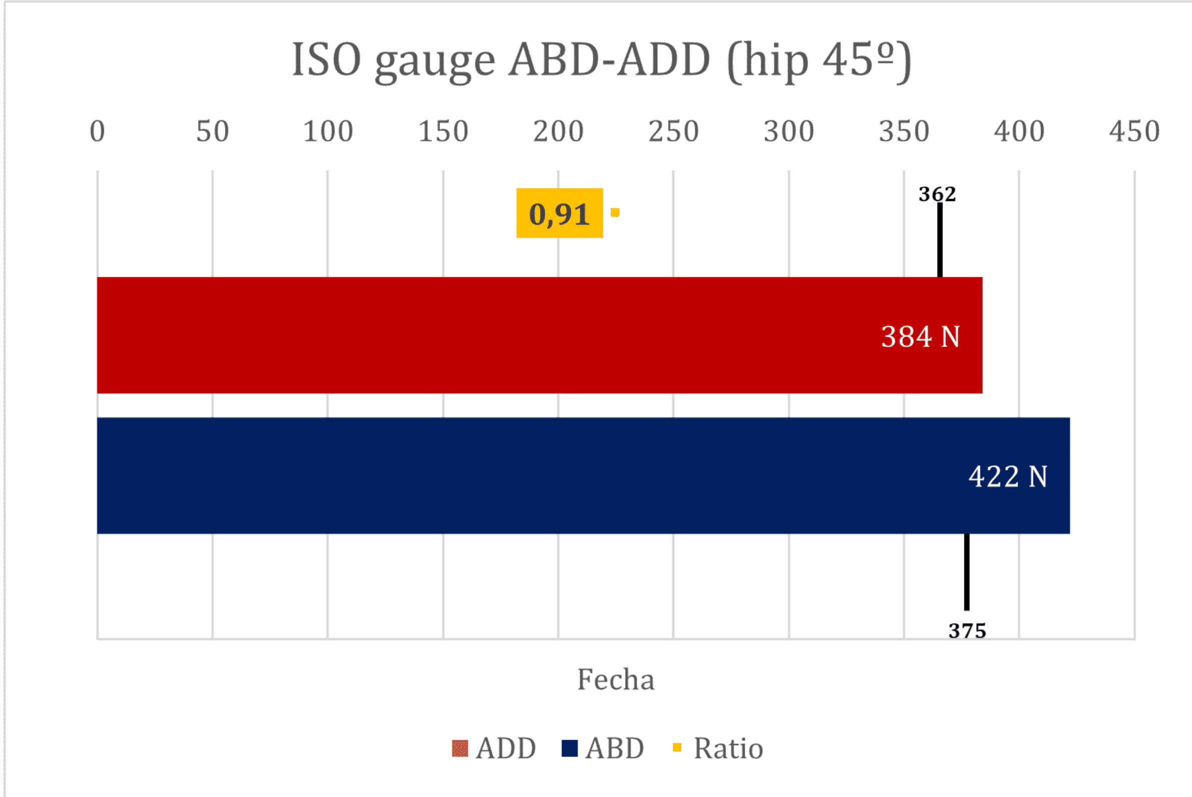

Figure 5. Visual repesentation of the results of a bilateral isometric test at 45º hip flexion in a supine position with flat feet on the table, in an FCB athlete.

Fecha = date

GAUGE ABDUCTORS/ADDUCTORS 45

Instruments: force gauge with adapter and a PC with the specific software.

Subject's position: the subject lies supine, with arms along the body and the head resting on the table. The hip at 45º of flexion and feet flat on the table.

Execution: the subject should perform the action of separating (ABD) or bringing together (ADD) the knees, maintaining the initial position (without lifting the feet, arms, glutes, or head from the bench).

Measurements: perform two contractions for each movement. The reference will be the maximum contraction value obtained in each case.

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