Module 4: Joint Stability and Core Monitoring Test

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Joint stability refers to the interaction between the functions of both passive and active structures. Passive structures include non-contractile components like fasciae, ligaments, tendons, and osteoarticular elements, which provide protection through tension or their geometric configuration. Active structures, on the other hand, consist of muscles that contribute to stability and protection either passively (through muscle tone) or actively (through muscle action and neuromuscular control) across various ranges of motion.

The tests will objectively assess both the progress and effectiveness of preventive, training, or recovery programs after an athlete sustains an injury, as well as help identify athletes with injury risk factors.

For a quantitative evaluation of body region functionality or the overall functionality of our athletes, these tests not only measure strength or range of motion but also provide combined information on motor control, proprioceptive ability, balance, coordination, and, most importantly, joint stability.

It's important to note that some tests require static postural control, where the subject must create a stable support base to maintain position and minimize body movements during the assessment. Other tests assess dynamic postural control,

where a certain degree of movement is allowed around the support base. While these don't replicate sports activity, they are closer to the demands of physical activities.

The following section outlines four tests that assess multiple qualities, which, when interacting, may help determine the degree of joint stability in different body regions:

- Star Excursion Balance Test (SEBT)
- Upper Quarter Y Balance Test (YBT-UQ)
- Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)
- Lumbopelvic stability assessment using an inertial device.

Knowing the validity and reliability of clinical tests is essential for correctly interpreting results, making informed decisions, and ensuring the quality of scientific research. Additionally, it is crucial to strictly adhere to the standardized protocol and correct test execution to ensure the reliability values reported.

For each of the tests presented, scientific evidence will be provided regarding their usefulness, validity and reliability, execution procedures, required instruments, result analysis parameters, and recommendations for interpreting and visualizing the results, including reference values, MDC (Minimal Detectable Change), SEM (Standard Error of Measurement), and cut-off points.

Unit 1. Star Excursion Balance Test (SEBT)

Unit 2. Upper Quarter Y Balance Test (YBT-UQ)

Unit 3. Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)

Unit 4. Assessment of lumbopelvic stability using an inertial device

Unit 1. Star Excursion Balance Test (SEBT)

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The SEBT is a lower limb assessment test that provides combined information about strength, balance, mobility, and joint stability.

Balance deficits have been extensively studied as risk factors for lower limb injuries. Dynamic stability assessment is widely used to track rehabilitation progress and to inform decisions about returning to sports. Given its significance, reliable assessment tools are essential.

To evaluate proprioceptive and neuromuscular deficits after lower limb injuries, postural control has commonly been assessed using variations of the Romberg test. Force platforms have been used to measure postural control during different standing variations. However, these static assessments have been criticized for being less sensitive in detecting motor control deficits related to functional capacity or sports performance.

The SEBT is a dynamic test designed to measure how far one can reach with a lower limb in three prescribed directions while maintaining balance on the opposite limb.

The first scientific study on SEBT reliability was published in 1998. Initially, the test involved measurements in eight movement directions. After several studies revealed strong correlations between certain directions, the test was simplified to focus on just three directions (anterior, posteromedial, and posterolateral). This simplified version, often referred to as the modified Star Excursion Balance Test (mSEBT), is now widely used. (1-4)

According to a systematic review, the SEBT has excellent intra-rater reliability, with an average ICC of 0.88 (0.84-0.93) for the anterior direction, 0.88 (0.85-0.94) for the posteromedial direction, and 0.90 (0.68-0.94) for the posterolateral direction. It also shows excellent inter-rater reliability, with an average of 0.88 (0.83-0.96) for the anterior direction, 0.87 (0.80-1.00) for the posteromedial direction, and 0.88 (0.73-1.00) for the posterolateral direction. The SEBT has proven effective in distinguishing individuals with lower limb injuries, such as chronic ankle instability, patellofemoral pain, and ACL reconstructions. For this reason, it is considered highly valuable in clinical practice. (5-8)

Procedure

To perform the test, a video or demonstration will be shown to the athlete. To ensure familiarization, and because of the learning effects observed with the test, it is recommended to perform between four and six repetitions with each limb in each direction, without causing fatigue. After a two-minute rest period, the test should start.

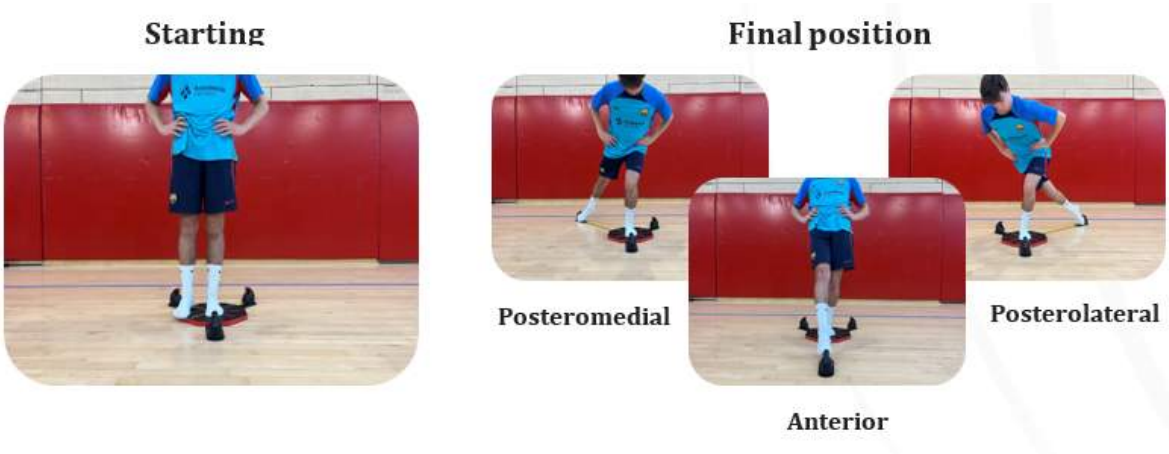
The starting position involves single-leg stance, with the barefoot foot aligned forward at the center of the three movement directions, and the most distal part of the big toe positioned at the starting point of the anterior direction.

The free limb will move over the tape measure in the anterior, posteromedial, and posterolateral directions relative to the supporting foot, lightly touching the tape at its maximum reach, with hands placed on the hips. The posteromedial and posterolateral directions form a 135° angle to the anterior direction and a 90° angle between them.

Three attempts will be performed with each limb in every direction. There is no set order for which limb or direction to evaluate first.

Attempts are considered invalid and should be repeated if: (a) failing to maintain single-leg balance, (b) lifting or moving the supporting foot, (c) not touching the tape measure with the free foot, (d) using the free foot for support (widening the base), (e) removing hands

from the waist during the test, or (f) failing to return to the starting position with control after movement. (2, 4, 9)



Instrument

The SEBT, measured by reaching along a tape measure, is a widely accepted, low-cost method for assessing dynamic stability. There are commercial devices available, such as the Y-Balance Test Kit™ (Functional Movement Systems®, Chatham, USA), which is limited to the mSEBT, and the Octobalance® (checkyourmotion.com), designed to facilitate the development of the SEBT.

When conducting the test with these tools, which include a marker that the participant moves with their free limb, the following attempts will be considered invalid and must be repeated: (a) if the subject does not maintain contact between their free foot and the marker throughout the movement, (b) if they strike the marker to move it, or (c) if they use the marker for support.

While the movements for both SEBT and Y-Balance test (YBT) are similar, significant statistical differences have been found in anterior reach distance (SEBT > YBT), though no significant differences exist for posteromedial and posterolateral reaches. Thus, the two tests should not be considered directly comparable. (9, 10)

Additionally, the Octobalance® uses the edges of its octagonal base as the starting point (0 cm) for measurements on the supporting foot.

Analysis, interpretation, and visualization of results

The distance reached (cm) in each attempt for all directions is recorded.

To allow better comparison across subjects, the normalized reach distance is calculated for each direction and expressed as a percentage of leg length. This percentage is determined by dividing the maximum reach distance by the subject's lower limb length and multiplying by 100.

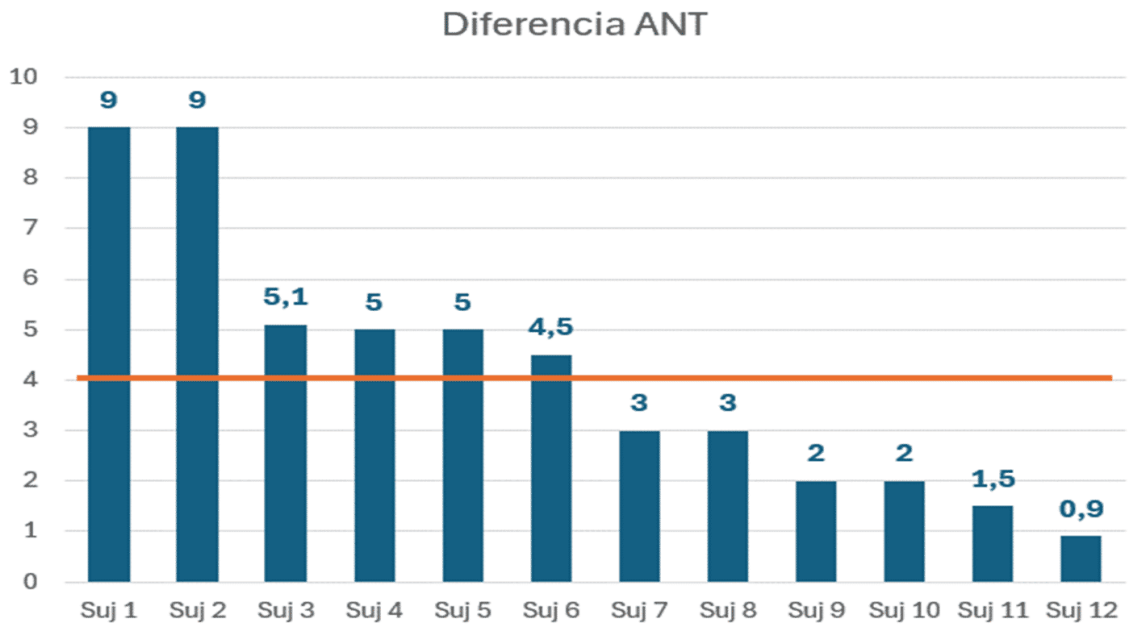
Limb length is measured in a supine position, recording the distance from the anterior superior iliac spine to the most distal part of each medial malleolus in centimeters.

For a comprehensive performance analysis for each limb, the composite reach distance is calculated, averaging the three

normalized measures to express a composite percentage of lower limb length.

In healthy individuals, clinically significant changes (MDC) can be considered if there is an increase or decrease beyond these thresholds: 5.87% for anterior reach, 7.84% for posteromedial reach, and 7.55% for posterolateral reach. In absolute values, these thresholds are 6.37 cm, 7.12 cm, and 8.76 cm, respectively. (8)

In the anterior direction, a right/left reach difference of 4.2 cm has been used to identify individuals with chronic ankle instability. Additionally, athletes with a reach difference of more than 4 cm were found to be 2.5 times more likely to suffer a lower limb injury during a season. Similarly, athletes with a composite score below 94% were 6.5 times more likely to sustain an injury. (5, 9). A graph showing the anterior reach differences in a group of subjects could be helpful in highlighting the cut-off point. (Graph 1).

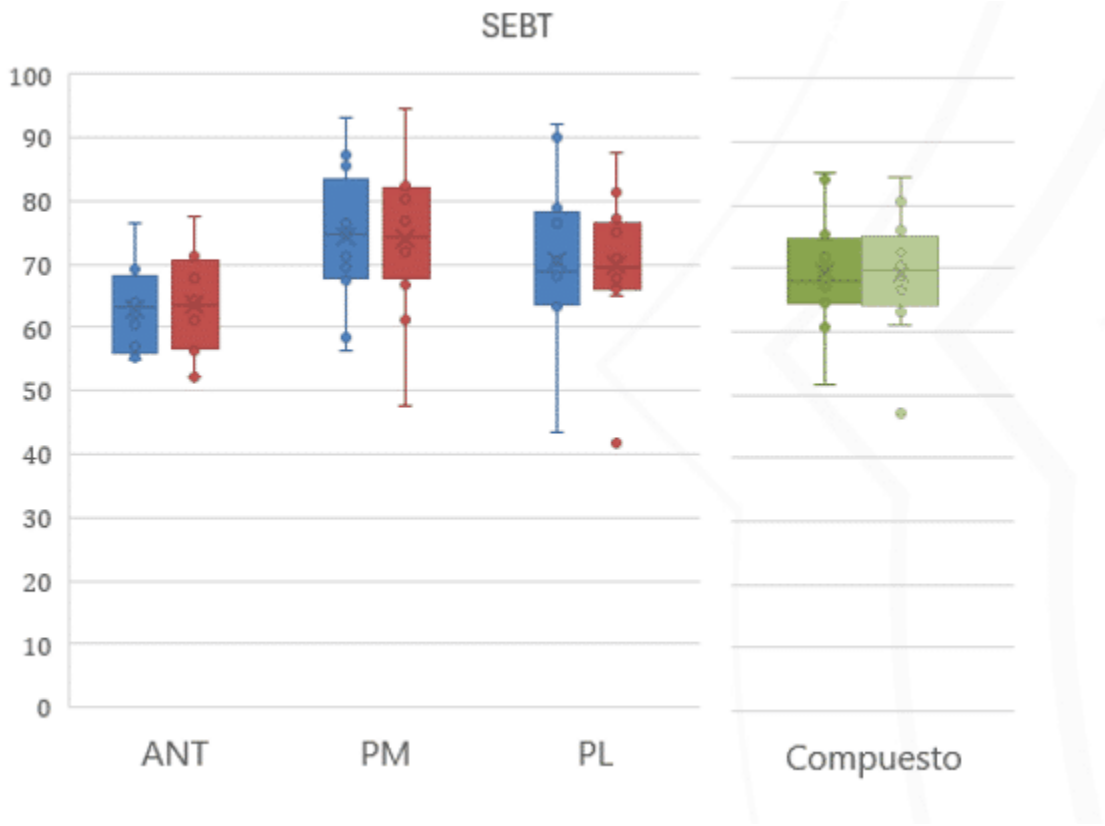


Diferencia ANT = ANT Difference | Suj 1 = Subj 1 (y así el resto)
Graph 1. Visual representation of the anterior reach difference (right/ left) among a group of FCB athletes. Cut-off point: 4 cm.

Since the Octobalance® starts measurements at the edges of the base (0 cm), the absolute values obtained are lower compared to those measured with a tape measure or the Y-Balance test kitTM. This results in a lower composite score, which is dependent on leg length. Therefore, the 94% threshold cannot be used to define the at-risk population, and it becomes harder to compare subjects.

The visual representation uses a boxplot to show the normalized results of both limbs in a group of subjects across all three movement

directions, along with global performance via the composite. (Graph 2).



Compuesto = Composite
Graph 2. Visual representation of normalized values and composite (green) scores for a group of FCB athletes.

The SEBT is a dynamic functional test that demands a high level of strength, motor control, mobility, and joint stability from the lower limbs. It is a valuable tool in clinical practice for assessing intervention outcomes, identifying deficits after injuries, and determining athletes at a higher risk of injury.

Star Excursion Balance Test (SEBT)

Instrument: Octobalance®.

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

Procedure: the subject reaches as far as possible with the free foot in the anterior, posteromedial, and posterolateral directions relative to the supporting foot.

Measurements: each direction is tested three times with each limb.

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Unit 2. Upper Quarter Y Balance Test (YBT-UQ)

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Dynamic tests have become increasingly popular in musculoskeletal assessments aimed at identifying high-risk injury situations, with many tests available for lower limb injury risk factors and only a few for upper limbs.

Among the upper limb assessments, the Closed Kinetic Chain Upper Extremity Stability test (CKCUEST) and the Upper Quarter Y Balance Test (YBT-UQ) are commonly used, both requiring strength, motor control, coordination, and stability. The YBT-UQ seeks to address limitations in other upper limb tests, particularly in evaluating range of motion and joint stability.

The YBT-UQ quantitatively analyzes a subject's ability to reach with a free hand while maintaining weight on the contralateral upper limb. This test simultaneously assesses joint stability, mobility (scapular and thoracic), proprioception, strength, and lumbopelvic stability. Studies have found no correlation between isokinetic strength and YBT-UQ performance, likely because one is performed in an open

kinetic chain and the other in a closed kinetic chain, with other qualities more influential in YBT-UQ results. (1, 2)

To date, few studies have examined the reliability of the test, but those that do report an excellent level of consistency. (Table 1)

Table 1. Reliability YBT-UQ Intraclass correlation coefficients (ICC).

Study	**Sample**	**Type of study**	**ICC**	
Gorman et al. 2012 (1)	Healthy adults (Age: 19-47)	Reliability Test - Retest	0.80-0.99	
Borms et al. 2016 (2)	Youths – *overhead sports* (Avg age: 21.6)	Reliability Test - Retest	0.92-0.97	
Borms et al. 2018 (3)	Volleyball, tennis, and handball players (Age: 18-50) Medial	Reliability Test - Retest	Dom. 0.97	Non-dom.

	Superolateral		0.98	0.97
	Inferolateral		0.98	0.98
				0.98

Procedure

First, the athlete can be shown an instructional video or a demonstration of the test. For the YBT-UQ, the athlete should lie in a prone position, barefoot, with feet shoulder-width apart and the trunk and lower limbs aligned (Figure 1). The athlete is instructed to maintain their body weight on both feet and one hand with the arm fully extended. In this starting position, the hand of the limb being assessed is placed at the center of the test directions, with the thumb in adduction. The free hand is positioned at the level of the medial displacement marker, located under the shoulder on the same side.

The athlete should attempt to reach as far as possible with the free limb in the medial, inferolateral, and superolateral directions while maintaining balance. A line passing in front of the shoulders marks the medial direction, while the inferolateral and superolateral directions are positioned at 135° relative to it.

The athlete completes a warm-up test, followed by three attempts in each of the three directions, while maintaining the push-up position

and original foot separation. Attempts are considered invalid and should be repeated if: (a) the athlete fails to maintain unilateral support (e.g., touches the ground with the free hand), (b) fails to maintain contact with the reach marker throughout the movement (e.g., pushes the marker), (c) supports their weight on the marker, (d) fails to return to the starting position with control, or (e) lifts a foot off the ground.

To enhance the reproducibility of the test, standardization of the movement sequence is recommended. The procedure begins with the right hand, which is the assessed limb, supported in place. This allows the left hand to initiate a medial reach, followed by an under-the-trunk reach in the inferolateral direction, then transitioning to a reach toward the superolateral direction. Finally, the movement concludes with a controlled return to the starting position, followed by a 30-second pause. The sequence is repeated three times for the right limb, then for the left limb. If the athlete is unable to complete the test according to the criteria within four attempts, it is considered a failure for that side. (1)

Instrument

The test can be performed using equipment like the Y-Balance test kitTM (Functional Movement Systems®, Chatham, USA) or the Octobalance® (checkyourmotion.com). These devices are designed to support the limb during testing. The Y-Balance Test Kit™ features a base with PVC or wooden arms that extend in the three movement directions, each equipped with a distance marker. In the Octobalance® utilizes an octagonal base that holds a tape measure, which extends from the inner edge of the marker displaced by the athlete. Both types of markers remain stationary at the maximum reach, ensuring accurate distance measurements.

However, with the Octobalance®, the starting point (0 cm) is measured from the edges of the base, resulting in absolute values that are smaller than those obtained with the Y-Balance Test Kit™, where the reach distance is measured from the center of the

directional arms. This difference contributes to a lower composite score, which is further influenced by the length of the upper limb, complicating comparisons between athletes.

The YBT-UQ can also be evaluated using measuring tapes positioned on the ground, adhering to the specified arrangement for each movement direction. In the absence of a marker, it is the examiner's responsibility to ensure the test is executed correctly and to determine the athlete's maximum reach distance.

Analysis, interpretation, and visualization of results

The maximum distance reached (in cm) is recorded for each attempt in all directions, with the highest value selected for each direction.

The variables analyzed include the maximum normalized distance for each direction and the composite reach distance.

To normalize the reach distance, the maximum distance in each direction is divided by the length of the athlete’s upper limb and multiplied by 100. The length of the upper limb is measured from the spinous process of C7 to the most distal point of the third finger of the right hand, expressed in centimeters. The reach distance in each direction is then represented as a percentage of the upper limb length, facilitating improved comparisons between athletes.

To derive the composite reach distance, which offers a comprehensive assessment of test performance, the average of the three normalized distances is calculated and reported as the composite value. (1)

Research on the YBT-UQ has shown similar results between the dominant and non-dominant limbs across various studies involving different populations. This finding is significant, as the results from the non-injured limb could be used as reference values during rehabilitation for the injured limb.

Understanding published reference values categorized by age, gender, and/or sport is clinically significant for making comparisons and effectively classifying individuals' performance levels. (Table 1-2). (1-5)

Table 1. YBT-UQ reference values, SEM, and MDC.

Study	Sample	Ref values Normalized values		SEM (cm)	MDC (cm)
Gorman et al., 2012 (1)	Healthy adults (Age: 19-47)	Men	Women		
		97.2	95.2	2.9	8.1
	Medial	70.9	70.4	2.3	6.4

	Superolateral	84.2	82.7	2.2	6.1
	Inferolateral	85.1	83.9		
	Composite				
Borms et al. 2016 (2)	Youths – *overhead sports* (Avg age: 21.6)	Dominant (SD)	Non-dom. (SD)	Dom.	Dom.
	Medial	101.2 (7.32)	101.1 (6.16)	1.77	4.91
	Superolateral	73.1 (10.24)	71.5 (10.26)	Non-dom.	Non-dom.
	Inferolateral	96.1 (12.1)	96.4 (10.17)	1.41	3.91
	Composite	90.1 (7.56)	89.7 (6.02)		
Schwiertz et al. 2021 (4)	Children-Adolescents (Age: 10-17)	Male	Female		
	Medial			-	-

	Superolateral	93.1-104.5	93.5-99.5		
	Inferolateral	59.2-78.6	65.9-76.0		
	Composite	84.4-98.8	80.8-101.5		
		79.5-93.3	81.5-92.2		

Table 2. YBT-UQ reference values per sport

			YBT- UQ							
	(n)		Medial		Inferolateral		Superolateral		Composite	
			D	ND	D	ND	D	ND	D	ND
Volleyball										
18–25		19	104.21 (5.30)	104.67 (5.08)	93.65 (12.93)	93.47 (10.20)	72.14 (9.58)	73.08 (11.46)	90.00 (7.48)	90.41 (6.91)
26-33		11	101.12 (3.62)	102.21 (2.74)	95.19 (10.10)	95.68 (10.84)	73.34 (7.40)	71.52 (9.12)	89.89 (5.27)	89.80 (5.74)
34-50		6	100.39 (2.15)	102.83 (4.46)	90.84 (7.80)	91.71 (10.34)	65.58 (11.95)	66.23 (8.49)	85.60 (2.21)	86.92 (4.77)
Tennis										
18–25		20	103.45 (5.87)	103.23 (5.77)	90.55 (10.46)	94.08 (10.30)	69.10 (8.69)	68.10 (7.17)	87.70 (5.62)	88.57 (6.22)
26-33		6	105.17 (8.16)	104.73 (13.39)	94.70 (11.88)	101.29 (7.61)	75.64 (10.51)	79.08 (13.14)	91.83 (5.73)	95.03 (8.83)
34-50		7	103.77 (9.72)	100.29 (9.35)	84.94 (11.94)	92.08 (10.47)	63.86 (12.26)	66.53 (10.28)	84.19 (10.23)	86.30 (8.92)
Handball:										
18–25		24	102.23 (5.63)	104.61 (4.84)	91.82 (12.63)	94.05 (11.88)	71.08 (10.93)	71.66 (10.48)	88.12 (8.03)	90.11 (6.89)
26-33		9	107.21 (8.30)	105.90 (6.09)	91.68 (6.83)	96.16 (10.08)	64.22 (10.93)	66.78 (13.47)	87.70 (7.82)	89.61 (8.04)
34-50		4	111.47 (7.72)	111.02 (7.75)	103.12 (7.87)	102.60 (6.98)	72.72 (9.03)	77.35 (7.95)	95.77 (7.68)	96.99 (7.23)

n, number of subjects; D, dominant; ND, non-dominant

Results can be displayed using bar charts to track progress in each direction or present the composite score. Data from both limbs can be compared to assess the level of symmetry. (Graph 1-2).

Graph 1. Normalized data for movement in three directions at 15 and 20 weeks after an injury to the left upper limb. Symmetry percentage.

Graph 2. Composite value of each upper limb at 15 and 20 weeks after an injury to the left upper limb.

The YBT-UQ is a valuable tool for clinically assessing upper limb function. It helps identify movement limitations, functional deficits, stability issues, and/or asymmetries.

Upper Quarter Y Balance Test (YBT-UQ)

Instrument: Octobalance®.

Subject's position: the subject lies in a prone position, barefoot, with feet positioned shoulder-

width apart, the trunk and lower limbs aligned, and body weight distributed between both feet and one extended arm. The limb being assessed is positioned at the center of the testing directions, with the thumb in adduction. The free hand is placed at the level of the marker for medial displacement, located under the shoulder on the same side.

Execution: the subject reaches as far as possible with the free limb in the medial, inferolateral, and superolateral directions while maintaining balance.

Measurements: each direction is tested three times with each limb.

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Unit 3. Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)

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Following the widespread implementation of functional assessments for lower limbs, assessments for upper limbs have also been developed. Although most of these tests do not require a throwing position—the motion most associated with injury in sports characterized by a high incidence of upper limb pathologies—they still engage the entire kinetic chain.

Recently, the use of closed kinetic chain exercises for upper limb injury recovery has increased. This type of exercise can enhance electromyographic activity, improve joint stability through co-contraction of agonist and antagonist muscles, and benefit the proprioceptive system by involving multiple joints. (1-2)

Among dynamic tests, both open and closed kinetic chain, the test for assessing closed kinetic chain stability of the upper limbs is likely the most widely used for this region and is increasingly adopted by health

professionals and researchers. This assessment is straightforward for athletes to perform and comprehend, cost-effective, requires no specialized equipment, and evaluates essential parameters such as movement capacity, motor control, strength, and joint stability.

The CKCUEST has demonstrated excellent intra-rater reliability (ICC > 0.75) across various populations and fitness levels for metrics including the number of contacts, power output, and normalized values. (Table 1)

To assess the validity of CKCUEST, isokinetic evaluations and grip strength measured with a hand dynamometer have been used as the gold standard. CKCUEST average values have shown a strong positive correlation with the peak torque of internal and external shoulder rotators measured on an isokinetic device at speeds of 60º/sec and 180º/sec (r = 0.87-0.94) and with maximum grip strength (r = 0.78-0.79). (3)

Table 1. Reliability CKCUEST Intraclass correlation coefficients (ICC).

Study	Sample	Type of study	ICC
Goldbeck et al.,	Young students, men (Avg Age: 20.3)	Reliability	0.92

2000 (1)		Test - Retest	
Lee et al., 2015 (3)	Healthy adults (Avg Age: 29)	Reliability Test - Retest	0.97
Tucci et al., 2014 (4)	Subjects with or without subacromial impingement pain	Intersession reliability	0.87-0.96
	Subjects with or without subacromial impingement pain	Intrasession reliability	0.86-0.97
Sciascia et al., 2015 (5)	Youths with shoulder pain (Avg Age: 30)	Reliability Test - Retest	0.86
	Youths without shoulder pain (Avg Age: 29)	Reliability Test - Retest	0.85
de Oliveira et al., 2017 (6)	Healthy adolescents (Avg Age: 16.9)	Reliability Test - Retest	0.68-0.87

Procedure

The test is conducted in a closed kinetic chain, starting from a traditional push-up position, with hands 91.4 centimeters apart (equivalent to the original 36 inches) and placed on markers on the floor (indicated by 3.8 cm adhesive tape strips), and shoulders perpendicular to these markers (Figures 1 and 2). The subject is instructed to alternately touch the back of the opposite hand as quickly as possible, always returning to the initial position. The test begins with the start command from the examiner, who times the test. The number of contacts made is recorded until the evaluator gives the stop command after 15 seconds. During the test, the athlete should be vigorously encouraged to exert maximum effort.

As part of the warm-up, an initial test is conducted to identify and implement any necessary corrections. This is followed by three attempts at maximum intensity, with a 45-second rest period between each attempt. To minimize the impact of fatigue on performance during a short-duration, high-intensity test, a work-to-rest ratio of 1:3 is recommended. (1-2, 7)

The test is considered valid if the participant maintains a flat back, does not touch the ground with their knees, keeps their upper limbs perpendicular to the ground and over their hands, and keeps their feet shoulder-width apart.

For non-athletic individuals or those in poor physical condition for whom the test may be too demanding, it can be modified by allowing support on the knees. In this modified version, the test remains valid if the participant maintains a flat back and keeps their upper limbs perpendicular to the ground and over their hands. (4)

If the CKCUEST is being performed by someone with a shoulder injury, it should be stopped if they demonstrate incorrect body positioning, compensatory movements, or report any pain during execution. When the subject touches their contralateral hand at the end of the swinging motion, the axial load on the arm is nearly equivalent to their body weight.

Figure 1 and 2. CKCUEST test representation.

Analysis, interpretation, and visualization of results

The results of the three tests are averaged to obtain a single value. Additionally, calculations are made to obtain a normalized value and a power value. (1-2, 7)

It is suggested to normalize the results by dividing the number of contacts by the subject's height, as this accounts for the increased difficulty for shorter individuals when performing the test. However, this measure may not be adequate since all subjects start with their hands positioned 91.4 centimeters apart. Some researchers have proposed altering the position of the upper limbs for the test. In this modification, the subject starts in a push-up position with their hands shoulder-width apart and beneath them. Despite the different starting positions for each subject, the distance between contact points (91.4 cm) remains unchanged. (8)

To calculate the power for the CKCUEST, multiply the average number of contacts from the three attempts by 68% of the athlete's body weight in kilograms, which accounts for the weight of the arms, head, and torso. Next, divide the resulting score by 15, which is the duration of the test in seconds. This final result reflects the amount of work performed per unit of time. (1-4)

Published reference values for the test can be instrumental in establishing rehabilitation goals and facilitating the efficient tracking of progress. Generally, males tend to achieve higher scores, except in tests conducted with females utilizing knee support. Age-related

differences have also been observed, with performance in the CKCUEST decreasing as age increases, particularly when comparing the 18-25 age group to the 34-50 age group. No significant differences were noted within the intermediate age range. Additionally, no significant performance differences were found among volleyball, tennis, and handball players in the CKCUEST, despite the varying biomechanics of each sport. However, differences may arise in athletes from sports that emphasize lower extremity work. (Table 2). (4, 7)

Regarding the variability of the CKCUEST, a standard error of measurement (SEM) was observed, ranging from 1.45 to 2.76 for the average number of contacts, from 0.02 to 0.04 for the normalized value, and between 6.02 and 20.03 for the power value. The MDC was found to be between 2.05 and 3.91 for the number of contacts, from 0.03 to 0.06 for the normalized value, and between 8.52 and 28.32 for the power value. These values should be considered to understand the minimum change that could be deemed significant when using the test to assess shoulder performance changes. (Table 2). (7, 9)

Table 2. CKCUEST reference values and MDC.

Study	Sample	Contacts	MDC
Goldbeck et al., 2000 (1)	Young students, men (Avg Age: 20.3)	Test: 27.8	–
Roush et al, 2007 (2)	Young baseball players (Avg Age: 19)	Test: 30.41	–
de Oliveira et al., 2017 (6)	Healthy adolescents (Avg Age: 16.9)	Test - Retest: 25.6 - 28.0	6.01
Taylor et al., 2015 (8)	Young athletes, men (Avg Age: 19.3)	Test: 25.0	–
	Young athletes, women (Avg Age: 19.2)	Test: 22.9	–

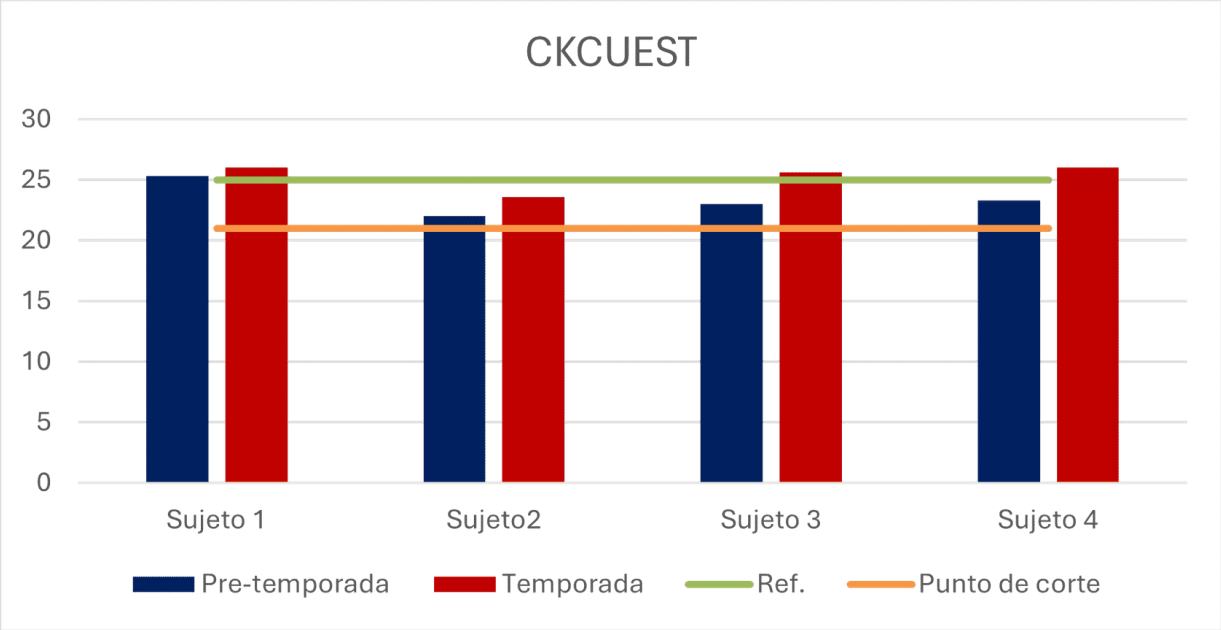
Tucci et al., 2014 (4)		Test - Retest:	
	Sedentary men	22.67 - 25.30	2.05
	Sedentary women	24.58 - 28.47	3.43
	Active men	27.97 - 31.97	2.82
	Active women		
	Men with subacromial impingement.	24.78 - 27.13	3.91
	Women with subacromial impingement.	10.10 - 11.82	2.76
		12.20 - 13.73	2.67

Borms et al., 2018 (5)	Volleyball, tennis, and handball players (Age: 18-50)	Avg (SD)	
	Men (18-25)	27.8 (2.8)	
	Men (26-33)	27.5 (2.7)	
	Men (34-50)	26.0 (2.0)	
	Women (18-25)	21.7 (3.7)	
	Women (26-33)	20.4 (4.3)	
	Women (34-50)	19.3 (4.5)	

In one study, athletes (average, SD; 22.5, 4.3 contacts) who scored below the cut-off point of 21 contacts (OR: 18.75) were found to be 18 times more likely to sustain a shoulder injury. (Table 3). (10)

Table 3.

Study	Sample	Cut-off point	Sensitivity	Specificity	OR
Pontillo et al., 2014 (10)	Young athletes (Avg Age: 19.6)	< 21.0 contacts (Avg: 22.5)	0.79	0.83	18.75



Sujeto = Subject | Pre-temporada = Preseason | Temporada = Season | Ref = Ref. | Punto de core = Cut-off Point

Graph 1. The number of contacts recorded for four young athletes at two points: preseason (blue) and season (red). The green line shows the reference value.

The CKCUEST is highly beneficial for a functional assessment of the upper limbs and can be implemented in sports settings during preseason and/or throughout the season to identify players at risk of injury and in rehabilitation processes to assess readiness to return to activity.

Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)

Instrument: tape measure and stopwatch.

Subject's position: a traditional push-up position, with hands 91.4 centimeters apart.

Execution: the subject alternately touches the back of the opposite hand as quickly as possible while always returning to the starting position after each touch.

Measurements: the number of contacts made within a 15-second interval.

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Unit 4. Assessment of lumbopelvic stability using an inertial device

Unit 4. Assessment of lumbopelvic stability using an inertial device

Core stability is defined as the ability to control the lumbopelvic region in response to internal or external imbalances, including forces generated by distal segments of the limbs and those resulting from expected or unexpected disturbances. (1)

Core muscle activity precedes most lower limb movements. The central nervous system activates trunk muscles, establishing a base for generating, transmitting, and controlling forces and movements from the core of the body to the extremities. (2.3)

Numerous studies have emphasized the importance of core stability in preventing injuries to the back and lower limbs. (4- 10). Research has also examined its impact on athletic performance and the specific adaptations caused by different sports on lumbopelvic stability. (5, 11-12)

The core plays a crucial role in hip abduction, helping to prevent internal rotation of the femur and, consequently, more distal imbalances in lower limb joints. This may explain the association between deficits in core stability and ACL injuries in young athletes. (6, 8, 10, 13-15)

At the lumbar level, insufficient coordination of core muscles can lead to decreased effectiveness in movements and compensatory patterns that may result in injury. Furthermore, a delayed muscular reflex response to an external load on the trunk significantly raises the risk of injury to the lumbar region. (16)

The complex interactions among the muscles and anatomical structures in the lumbopelvic and coxofemoral regions make it challenging to develop a single, valid, and reliable test for assessing core stability.

Evaluating stability during static and dynamic front planks with an inertial device has proven to be a simple and quick field test, yielding precise results and excellent inter-rater reliability (ICC: 0.97).

Procedure

The assessment of core stability using the inertial device includes two types of tests.

(A) Static front plank (Figure 1): this test involves performing four consecutive front planks, each lasting 30 seconds, with a one-minute rest between each. The only instruction for this test is to maintain the plank as stable as possible.

(B) Dynamic front plank (Figure 2): this test requires executing four consecutive planks, each lasting 30 seconds, starting and ending with five seconds of a bipodal plank, while alternating with a single-leg plank every five seconds. A one-minute pause should be allowed between planks for rest.

Figure 1: Static front plank.

Figure 2: Dynamic front plank.

The subject should wear appropriate sports clothing and footwear. The elbows should be positioned directly under the shoulders, with the trunk straight, and the feet shoulder-width apart. In the dynamic plank, the elevated toe should align with the heel of the opposite limb.

The test will be deemed invalid if: (a) the subject fails to complete the required 30 seconds of plank, (b) the subject slips and needs to

readjust their feet, or (c) the plank is not maintained in a horizontal position.

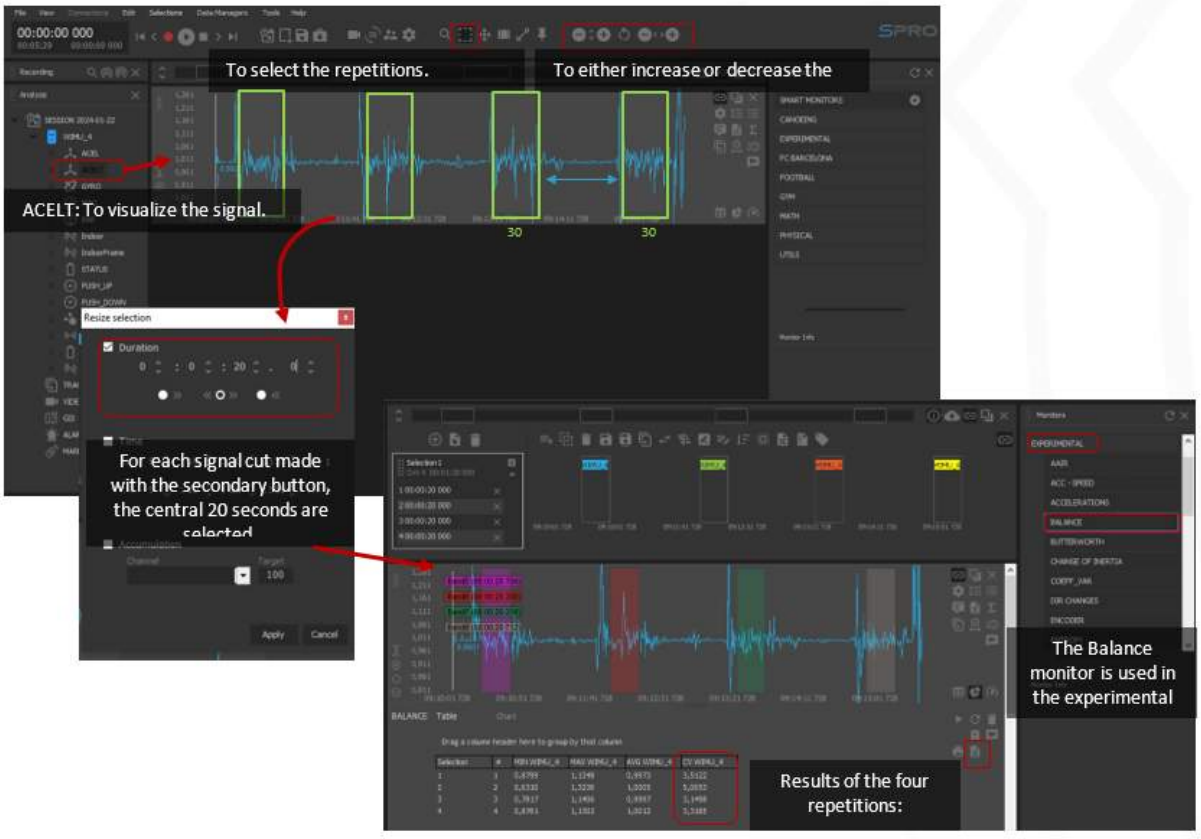
Instrument

Stability is measured using the WIMU PRO™ inertial device (RealTrack Systems, Almería, Spain). The WIMU PROTM unit is equipped with four triaxial accelerometers that detect and measure movements using a micro-electromechanical system, with a sampling frequency set at 1000 Hz. The device weighs 70 grams and measures 81×45×16 mm. For this study, we utilize the combined signals from the four accelerometers, each registering different intensities (ranging from ±0-2G to ±100G). 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 subject's waist at the L3/L4 level.

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). To minimize the influence of movement and adjustments at the beginning and end of the test, analysis focuses on the central 20 seconds of the accelerometric signal. The coefficient of variation (CV) is used to

analyze this segment. Four CVs are calculated, one for each repetition, to determine the median.



Lumbopelvic stability assessment conducted using an inertial device

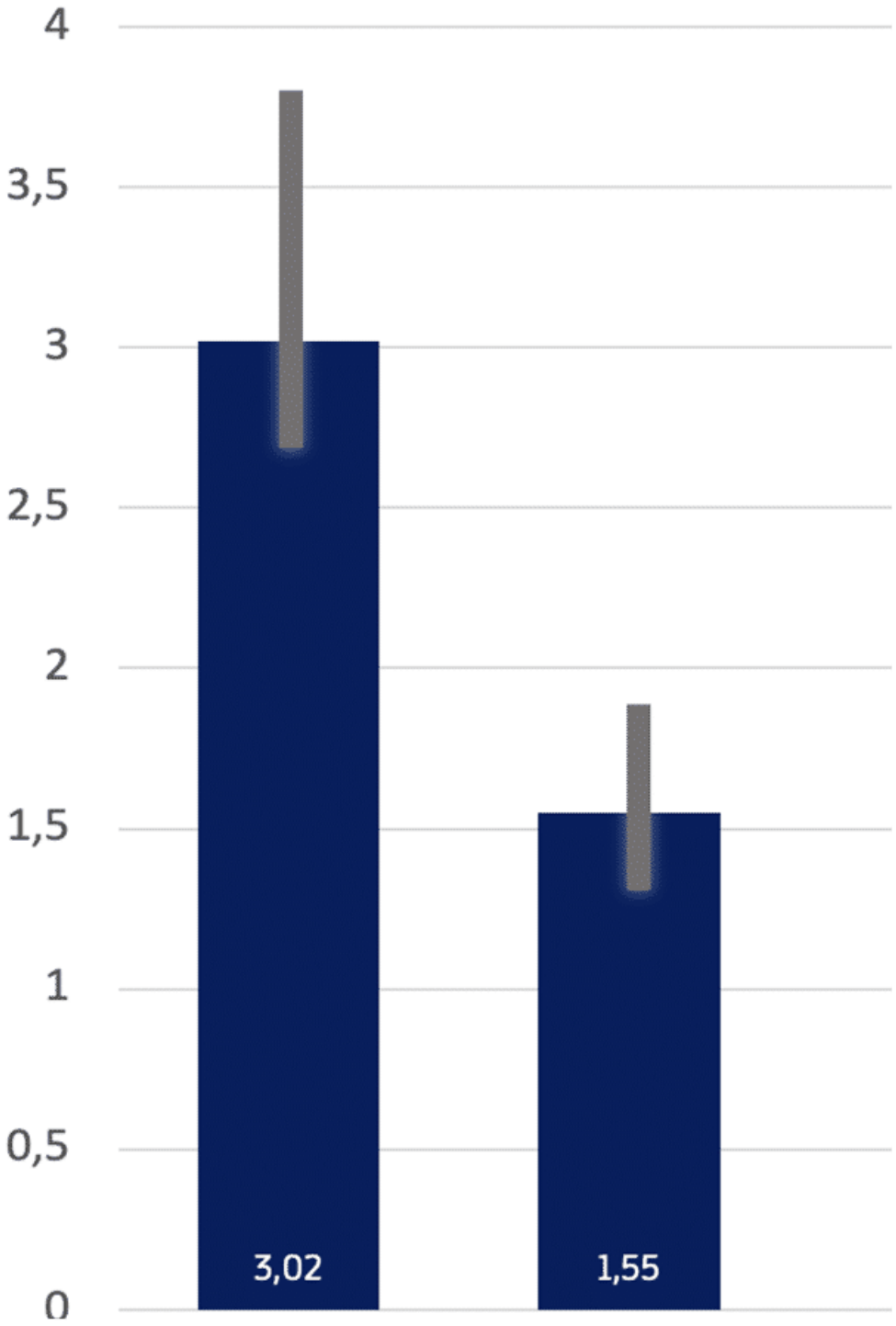
Instrument: strap, stopwatch, WIMU PROTM, and S PROTM software.

Subject's position: front plank.

Execution: (a) static front plank: four consecutive 30-second front planks, with one minute of rest in between. (b) Dynamic front plank: four consecutive 30-second planks, alternating between single-leg support every five seconds.

The recorded values have been shown to vary with age, with higher values observed in children, likely reflecting greater movement and reduced stability. These values decrease by 0.143 units per year. In adults, values below 1 are considered indicative of excellent stability, values between 1 and 1.5 are classified as average, while values exceeding 1.5 are associated with poor stability.

A bar graph is used to visualize the median of the four measurements. A vertical line is drawn to indicate the deviation from the best to the worst recorded values. This bar reflects the ability to maintain stability during the repetitions. (Graph 1)


4
3,5
3
2,5
2
1,5
1
0,5
0
3,02
1,55

Graph 1. Evolution of the static test during recovery from an injury.

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