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SEBT AND YBT DYNAMIC BALANCE TESTS

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ABSTRACT. A fundamental role in movement control is given by proprioceptive information from a multitude of mechanoreceptors that are integrated and processed by the human brain. Understanding proprioception and the test method, such as the threshold for detecting passive movement and reproducing joint position, are used to assess proprioception. The origin of the methods, test apparatus and procedures or protocols used in each approach are compared and discussed. Instability of a lower limb joint is a risk factor for these areas. Therefore, the development of proprioception can play an important role in injury prevention. The Star Excursion Balance Test (SEBT) is a dynamic postural control task that has gained notoriety in clinical and research settings, it is able to provide objective measures to differentiate deficiencies and improve dynamic postural control related to lower limb joint injuries. The clinical application of the SEBT led to the development of the Y Balance Test (YBT), both SEBT and YBT involve similar movements that are deemed to measure and challenge dynamic balance.

Keywords*: proprioception, Star Excursion Balance Test, Y Balance Test*

REZUMAT. ***Testele de echilibrare dinamică SEBT și YBT.*** Un rol fundamental în controlul mișcării este dat de informațiile proprioceptive de la o multitudine de mecanoreceptori care sunt integrați și procesați de creierul uman. Înțelegerea propriocepției și a metodei de testare, cum ar fi pragul de detectare a mișcării pasive și de reproducere a poziției articulare, sunt utilizate pentru a evalua propriocepția. Se compară și se discută originea metodelor, a aparatelor de testare și a procedurilor sau protocoalelor utilizate în fiecare abordare.

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Instabilitatea unei articulații inferioare a membrelor este un factor de risc pentru aceste zone. Prin urmare, dezvoltarea propriocepției poate juca un rol important în prevenirea leziunilor. Testul de echilibru al excursiei Stelare (SEBT) este o sarcină dinamică de control postural care a câștigat notorietate în setările clinice și de cercetare, este capabil să ofere măsuri obiective pentru a diferenția deficiențele și pentru a îmbunătăți controlul dinamic postural legat de leziunile articulare ale membrelor inferioare. Aplicarea clinică a SEBT a condus la dezvoltarea testului de echilibru Y (YBT), atât SEBT, cât și YBT implică mișcări similare care se consideră că măsoară și provoacă echilibrul dinamic.

Cuvinte-cheie: *propriocepție, Testul de echilibru Stea, Testul de echilibru Y*

Introduction

Postural control can be classified as static or dynamic. This is a complex process that requires central sensory processing, visual, vestibular, and somatosensory pathway information, as well as a resultant efferent response, which controls the recruitment of specific motor units (Bressel, Yonker, Kras & Heath, 2007).

Balance is the key to all functional movements. Any impairment of balance will decrease performance and increase the risk of injury and fracture as a result of daily activities. Thus, balance is of key clinical relevance for any rehabilitation program or prophylactic rehabilitation program (Zazulak, Cholewicki & Reeves, 2008).

There are many methods for assessing balance, but the number of tests for assessing dynamic balance is very small. The standardized test present for the clinical examination of balance focuses on static balance, while many daily activities require dynamic balance (Butler, Lehr, Fink, Kiesel & Plisky, 2013).

The central nervous system generates a movement plan. Feedback and feed-forward control mechanisms play vital roles in controlling movement and performing tasks such as SEBT and YBT. Stimulation of mechanoreceptors located in the skin, ligaments, muscles and joints, provides related feedback through the spinal pathways in terms of movement and position of joints in different segments of the body during movement (Winter, Patla & Frank, 1990). The motoneuron activation pattern is fine-tuned by feedback from these mechanoreceptors, which act either monosynaptically or through inhibitory interneurons and provide a corrective response to action.

The anatomical-functional substrate of the exercises is represented by the stimulation of the proprioceptive function of the organism, respectively of its capacity to transmit the position of the body and its segments, to analyze the respective information and to react (consciously or unconsciously) to the stimulation, through a movement proper. The information needed by the nervous system to assess posture, body balance and coordination is provided by receptors located in the muscles and joints, the vestibular apparatus and the visual analyzer (Prakash et al., 2017). Muscle and joint receptors are stimulated by movements of the musculoskeletal system. The vestibular apparatus provides information about the position of the whole body and is stimulated when the vertical posture of the body changes. The visual analyzer helps to orient the head and body in the environment. In this context, it is obvious that in case of injury to the joints and ligaments, the proprioceptors located at these levels are also damaged, which means that the information transmitted to the central nervous system is affected. As a result, the joint is suffering. Although the vestibular apparatus intervenes to balance the position of the body and the joint, over time stability, position control and joint functional capacity are lost. Loss of sense of position puts the joint at additional risk of injury. In these circumstances, the intervention of specialists in medical recovery is required, and the rehabilitation program must include, in essence, proprioceptive re-education.

Topic addressed

According to the literature, neuro-muscular reprogramming after a sprain is based on two theories whose principles complement each other: Freeman's (1965) theory and Thornard's (1996) theory.

According to Freeman's (1965) theory, after an acute sprain, the articular receptors (proprioceptors) are differentiated. As a result, proprioceptive information can no longer be transmitted or is partially transmitted to the central nervous system, which alters muscle reactions in feedback. Therefore, the knee muscles (hamstrings) contract to counteract the lesion movement and to position the knee joint at physiological amplitude.

Thornard (1996) showed by EMG recordings that normal muscle responses to stimuli appeared after 60 ms, while movement in the injured areas appeared first, after 20 ms. In this context, proprioceptive re-education in feedback has been rethought in feed-forward, which means that in re-education all proprioceptive information must be used to create motor schemes of anticipation in the central nervous system.

Therefore, in order for neuromuscular reprogramming to be as effective as possible, the two theories should be combined in order to require coordination and anticipation of muscle contractions. In order to implement such re-education, all proprioceptive information involved in the knee protection mechanism should be stimulated. We appreciated that an effective way to stimulate the proprioceptive system would be sports-specific exercises to "bombard" the CNS with motor experiences similar to those that athletes practice in sports.

Given the diversity of sports gestures of the researched subjects, we appreciated that jumping would be the common element in the sports practice of the subjects included in the research.

This test, known in the international literature as the Star Excursion Balance Test (SEBT), is a dynamic test commonly used by clinicians and researchers to assess dynamic balance and detect postural control deficits. At the same time, it identifies the pathological conditions in the lower limb and the effects of interventions through exercise programs. The test is also predictable, as it identifies people at high risk of injury consisting of injuries to the lower limb. Basically, the test is a useful tool to check both the primary and secondary prophylactic effects of injury prevention.

In this context, to which is added the fact that the literature considers it one of the best tools for measuring the dynamic balance of the lower extremity, we considered that it can be applied by us to monitor the performance of research subjects.

Note that in its current form, the SEBT has been reduced to three directions becoming similar to the Y Test. Although the directions of touch are the same (anterior, posteromedial, posterolateral) and participants move in similar patterns (modified SEBT test and Y test), research has shown that previous contact distances were different when comparing the two tests. Therefore, the two tools may not be directly comparable.

Star Excursion Balance Test (SEBT) is a simple, reliable and cost-effective test that is quick to administer and accessible in clinical settings to assess the dynamic balance of the lower limbs (Gribble & Hertel, 2003). SEBT can monitor the progress of rehabilitation, assess deficiencies after injury and can identify athletes at high risk of lower limb injuries. SEBT requires neuromuscular features, such as lower limb coordination, balance, mobility, and strength (Plisky et al., 2009).

In this test, balance is maintained on one lower limb and with the other lower limb it must reach along marked lines in eight different directions, which causes the subject's postural control, strength, range of motion and proprioceptive abilities (Lee, Kang, Lee & Oh, 2015). The distance reached in each direction is measured separately and interpreted as a representation of the dynamic equilibrium, providing an alternative for the evaluation of the dynamic equilibrium.

SEBT normative values (table 1) can provide objective measures to differentiate deficits and improvements in dynamic postural control related to lower limb joint injuries and has the potential to prevent the possibility of lower limb joint injury (Plisky, Rauh, Kaminski & Underwood, 2006).

Table 1. Data on the normal values of the Star Excursion Balance Test (Star Excursion Balance Test, 2017)

Direction	Normalized relative distances (expressed as a percentage of lower limb length)	
	Men	Women
Anterior (A)	79.2 +/- 7.0	76.9 +/- 6.2
Posterior (P)	93.9 +/- 10.5	85.3 +/- 12.9
Medial (M)	97.7 +/- 9.5	90.7 +/- 10.7
Lateral (L)	80.0 +/- 17.5	79.8 +/- 13.7
Anterolateral (AL)	73.8 +/- 7.7	74.7 +/- 7.0
Anteromedial (AM)	85.2 +/- 7.5	83.1 +/- 7.3
Posterolateral (PL)	90.4 +/- 13.5	85.5 +/- 13.2
Posteromedial (PM)	95.6 +/- 8.3	89.1 +/- 11.5

SEBT is a promising test of postural control that is used to assess physical performance, but also to detect deficiencies in dynamic postural control due to musculoskeletal injuries (e.g., chronic ankle instability), to identify high-risk athletes for injuries to the joints of the lower limbs, as well as during the rehabilitation of orthopedic injuries in healthy subjects (Gribble, Hertel & Plisky, 2012).

SEBT can be framed as a diagnostic tool in clinical practice and research (Star Excursion Balance Test, 2017). SEBT can be administered quickly and easily, the physiotherapist can determine if the patient has or has returned to normal levels of dynamic balance, it can also be used in physical training. It can be used to identify athletes who have not fully rehabilitated or normalized their dynamic balance after an injury (Plisky et al., 2006).

In an attempt to improve the reliability and utility clinic, the Y Balance Test protocol has been developed that addresses some of the limitations of traditional SEBT. Thus, the test procedure was modified to allow the participant to lift the heel off the ground. In addition, the original position was changed at the distal end of the longest finger to improve repeatability. Based on the reduction in the number of directions, the Y Balance test continues the efficiency of the SEBT. This device comprises a position platform consisting of three arms of different materials extending in the anterior, posteromedial and posterolateral direction (Fig. 1).

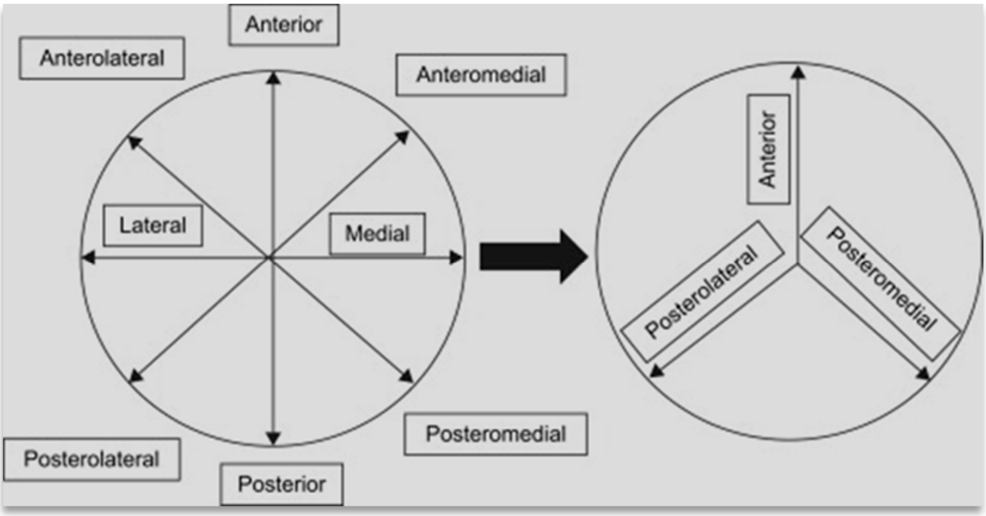

Fig. 1. Y Balance Test (Weingroff, 2013)

The clinical application of SEBT led to the development of the Y Balance (YBT) test. Plisky and collaborators (2009) used a Y, which signifies the directions of execution A, PM and PL, which in turn led to the development of YBT. It sits on a plastic center plate raised 2.5 cm from the ground and pushes a rectangular block with the foot along a length of 1.5 m, from a plastic tube, in each of the 3 directions. The touch distance is recorded as the point at which the indicator block is pushed by the position foot. Each arm of the device is marked in 5 mm increments. The participant pushes a coverage indicator along the device with the foot of his touching member and stays over the measuring tape after performing the test.

In order to make valid comparisons of the distances of reach of the SEBT between individuals or groups, normalized distances of the length of the lower limbs must be reached. This recommendation is based on the length of the lower limbs, measured from the anterosuperior iliac creast to the median ankle, being correlated with the performance of performance in each direction.

The Y test was developed to perfect the long process of performing the Star Excursion balance test. As such, most of the supportive research for the Y test is based on the investigations performed in the balance test on the Star race (fig. 2). However, the Y test not only proved to have a high level of test reliability, but also a sensitive indicator of the risk of injury among athletes (Shaffer et al., 2013).

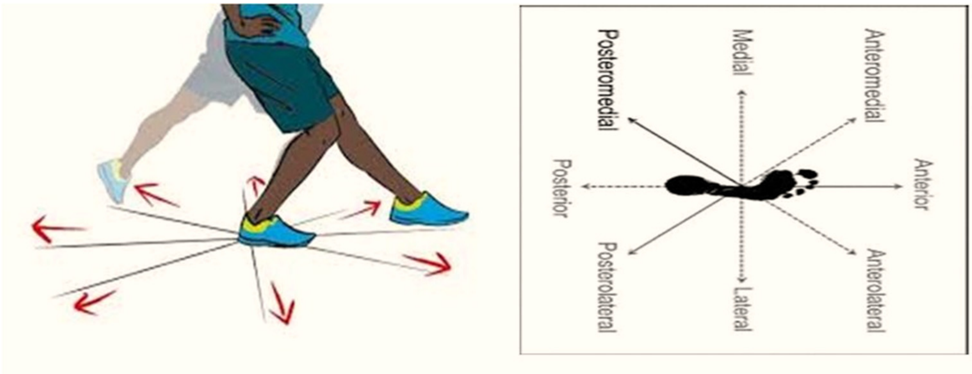

Fig. 2. Star Excursion Balance Test (Adiguzel, 2020)

The Y test is a simple test used to measure dynamic equilibrium. It was developed to standardize the modified star race test, to improve practicality and to make it commercially available. Since then, the Y test has become an extremely popular test due to its simplicity and reliability (Alnahdi, Alderaa, Aldali & Alsobayel, 2015).

YBT also requires endurance and coordination, which can increase its sensitivity to injury prevention. In addition, each direction of touch activated the position of the muscles of the lower limbs. In the anterior direction the medial and lateral vastus in the posterolateral direction, the femoral biceps and the anterior tibia and in the posteromedial direction. The Y test requires the athlete to balance on one leg, reaching simultaneously, as far as possible, with the other leg in three separate directions: anterior, posterolateral and posteromedial. Therefore, this test measures the endurance, stability and balance of the athlete in different directions.

The composite score of the Y test is calculated by summing the three directions of touch and normalizing the results to the length of the lower limb, while the asymmetry is the difference between touching the right and left limb.

Although the injury or surgery does not appear to have any impact on the test's performance in athletes, the test has been shown to have strong relationships with the knee flexor and the strength of the hip abductor. Although little research has been done on the Y test and the risk of athletic injury, most of the hypotheses regarding the risk of injury are drawn from research on the star race balance test, due to its great resemblance to the Y test.

For example, it has been suggested that an anterior asymmetry of more than 4 cm during the star stroke balance test was predicted to predict who is at risk for lower limb injury. Further research has also shown that the poor performance of the star stroke balance test is related to chronic instability of the knee.

Balance, otherwise known as 'postural control', can be defined statically as the ability to maintain a support base with minimal movement and as dynamic as the ability to perform a task while maintaining a stable position. In a chaotic sports environment, the ability to maintain a stable position is vital not only for the successful application of skill, but also for reducing the risk of injury. As a result, it can be of great interest to test and monitor the dynamic stability of an athlete.

In contrast, feed-forward controls have previously been described as anticipatory actions that occur before sensory detection, and feedback and feed-forward control may vary between SEBT and YBT, resulting in differences in touch distances in the Forward direction. YBT asks the participant to sit in an elevated position on a center plate while pushing a sliding block. In SEBT, the participant puts downward pressure through the touching leg only at the end of the direction of execution.

The SEBT balance test and the Y balance test (YBT) (table 2) have three common coverage directions: anterior (ANT), posteromedial (PM) and posterolateral (PL). Research has shown that performance on the ANT execution direction of SEBT differs from that on YBT.

Table 2. Mean distance vs Relative distance

Direction	Mean distance				Relative distance			
	P value		Effect size		P value		Effect size	
	Affected	Healthy	Affected	Healthy	Affected	Healthy	Affected	Healthy
A	0.001	0.006	1.52	0.84	<0.001	0.005	1.39	0.85
P	0.001	0.041	1.03	0.58	0.001	0.029	1.04	0.63
M	0.001	0.002	1.40	1.00	<0.001	0.002	1.30	0.98
L	<0.001	<0.001	1.37	1.59	0.003	<0.001	0.94	1.54
AL	0.011	0.005	0.76	0.86	0.012	0.006	0.74	0.83
AM	0.356	0.077	0.25	0.49	0.002	0.009	1.00	0.79
PL	0.001	0.830	1.18	0.06	<0.001	0.833	1.18	0.06
PM	0.050	0.013	0.55	0.74	0.064	0.018	0.52	0.69

In the touch direction A, participants receive visual feedback from the touch foot and can observe the marked touch distance. In the PM and PL directions, visual awareness is reduced and therefore the inability of the participants to perform as in the A direction. However, during the YBT, participants were able to reach similar distances to the SEBT, due to their contact with the sliding block. Another possible reason for running distances observed in the PM and PL directions refers to the location of the cover leg on the sliding block of the YBT.

Participants were instructed not to place the foot above the tube and to place the plantar surface of the touching foot on the medial side of the sliding block. This leads to their support being kept closer to their center of gravity during the YBT than along the SEBT measuring bands, reaching similar distances in the PM and PL directions. In the A direction, the foot was placed on the side of the sliding block, the center of gravity was shifted and the touch distances were reduced compared to the SEBT.

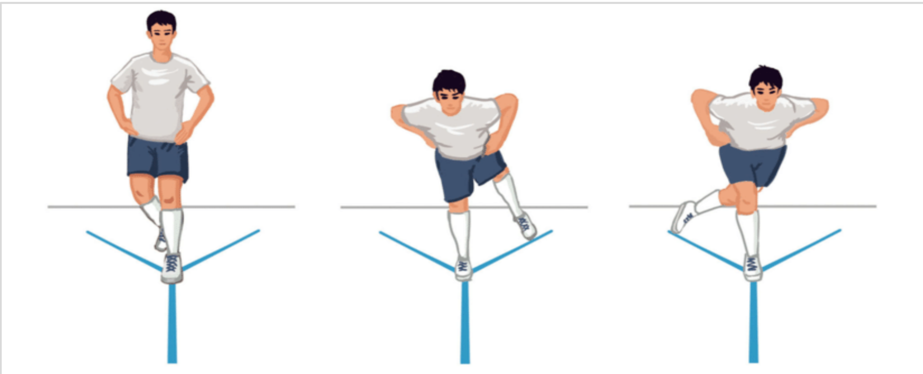

Fig. 3. Y balance test-YBT (Guo et al., 2021)

Increasing the stability of the knee through static proprioceptive exercises also determines the maintenance of the body in the situation when it is or is not subject to attempts to unbalance. By increasing the instability during the exercises, a better stability of the neuromuscular system is obtained. Therefore, the effect of these exercises is to improve the perception of body positions as a whole, by activating static proprioceptive receptors in the joints (static mechanoreceptors such as Ruffini corpuscles) and slow muscle fibers that have a dominant endurance component.

The protocol can be established by reference to the training sessions for a period of 4 weeks. The period may be preceded by one week dedicated to testing the subjects studied (initial testing) and followed by one week during which the final testing is performed.

The proprioception programs were based on the following principles:

- preparation / heating of the structures that were to be requested through walking exercises and active stretching of the adductor muscles, hamstrings, quadriceps and sural triceps, with a duration of 10-12 minutes;
- symmetrical exercise of the lower limbs;
- stressing the knees with the legs bent; the flexion angle of the calves on the thighs was varied.

However, its purpose is common: it applies both to the prevention of injuries and to the re-education / reintegration of sports after an injury. The effect is to increase the stability of the knee.

Proprioceptive exercises are of two types: static and dynamic.

We mention that proprioceptive reeducation through static exercises is most frequently used in reeducation programs applied to the studied pathology; some authors even call it the classic form of therapeutic intervention.

It is important to understand that each time the test is performed, it must be done in a consistent environment so that it is protected with a surface that is not affected by wet or slippery conditions. If the environment is not consistent, the reliability of repeated tests at subsequent data may be substantially impaired and may result in worthless data.

Before starting the test, it is important to make sure that you have the following items:

- ✓ Reliable and consistent test installation (minimum 2x2 meters).
- ✓ Test coordinator.
- ✓ Y balance test kit, or sticky tape and a measuring tape.
- ✓ Performance record sheet.

Participants must warm up thoroughly before the start of the test. The heaters must correspond to the biomechanical and physiological nature of the test. In addition, sufficient recovery (3-5 minutes) is required after heating and before the start of the test.

Warm-up exercises play a key role in preventing musculoskeletal injuries. Thus, by increasing the local temperature, there is an increase in the flexibility of these structures by up to 20%. In addition, adequate heating increases cardiovascular parameters and achieves the mental preparation of the subject for the exercises to be performed. As a result, the whole body is prepared for intense physical activity. For these reasons, the subjects benefit from a warm-up program. It runs for 10-12 minutes and is composed of walking and stretching exercises. Stretching exercises can consist of dynamic stretches performed during the practice of knee-specific movements.

Based on the notions of anatomy, according to which most of the muscles that control the movements of the knee are at the level of the thighs and only a few at the level of the leg, we applied stretching exercises located to these muscle groups to the researched subjects. Thus, the four muscles of the anterior thigh (the right femur, the vastus intermedia, the vastus lateralis, the vastus medialis) were targeted, which together make up the quadriceps muscle, with a major extensor role of the knee. Stretching was also applied to the muscles of the posterior thigh (femoral biceps, semimembranosus, semitendinosus, gracilis and tailor), as well as to the calf muscles (gastrocnemius, popliteal, plantar).

Due to the large volume of the thigh muscles, compared to other muscle groups that act on the knee joint, muscle pain occurs less frequently in these muscle groups. Attention is paid to the symmetrical, balanced load of the anterior and posterior thigh muscles, as it is known that the quadriceps muscle is stronger but less flexible than the posterior thigh muscles, and the tendency of practitioners and subjects is to stretch the posterior thigh muscles. The effects of this unbalanced approach are felt immediately by intense, persistent pain, but also at a distance by the installation of chronic fatigue and decreased strength of the posterior thigh muscles, so we avoided inducing these unwanted effects.

Researched subjects may perform 10-minute stretching exercises as part of the recovery program. Also, as in any other exercise program, it is taken into account that progression is an important condition in ensuring the success of a stretching program. The progression was gradual, moving from an easier task to a more difficult one. The level of working speed also varies. The intensity of the stretches was controlled by monitoring the associated pain.

Using a pain scale from 0 to 10, the initial stretching of a certain muscle group is considered easy when, performed on a certain muscle group, it is associated with a mild pain, located only in one point (intensity from 1 to 3 on the pain scale). The extension is moderate, when the subject feels an increased or medium pain in the stretched muscle (intensity between 4 and 6 on the pain scale) and becomes intense when the pain intensity is between 7 and 10 on that scale. Usually, the pain dissipates as the duration of the stretch prolongs.

Researchers' studies have shown that more intense stretches compared to lighter ones produce more significant increases in flexibility and musculoskeletal endurance. Stretches can be performed at various angles of the hip and knee and up to the full stroke of the movement to ensure an elongation, respectively a progressive increase in muscle flexibility.

Remember that the warm-up can be structured efficiently and strategically and the content or exercises should reproduce in the most accurate way those of the session for which the athletes are preparing.

To plan for effective warm-up, the test coordinator must first understand the mental, physiological, and biomechanical requirements of the training or sports session before attempting to prepare the athlete for these precise requirements. In most circumstances, these requirements are identified during the needs analysis. For example, if you are planning a warm-up for a maximum of one repetition test, then you may want to consider the mental, physiological, and biomechanical requirements of that session. For mental training, the coordinator can encourage athletes to rest well and bring self-motivational music to listen to while testing takes place - as it has been repeatedly shown to improve performance. The coordinator can adopt a warm-up routine with physiological requirements such as high strength exercises, endurance, long rest. Regarding biomechanical training, stretching, dynamic movements and exercises similar to those performed during the warm-up program would be appropriate.

Alternatively, if the coordinator designs a field-based heater for a short and fast technical session for football, then the heater should be specially designed for that session and therefore may look very different from the previous test example. Mental training can be very different, because the mental training of players can be stimulated by competing with other players. Physiologically, if the technical session requires high workloads, with short recovery periods and thus a high cardiovascular demand, then the warm-up should aim to produce similarly or even reproduce the intensities to which athletes will be exposed. From a biomechanical point of view, the movements adopted should have biomechanical similarities with the movements that will be predominant during the technical session. This may include long strokes, changes of direction, jumps and twisting movements.

With his hands firmly placed on his hips, the athlete must then be instructed to slide forward as far as possible with his right foot and return back to the starting vertical position.

Touch distances should be recorded to the nearest 0.5 cm.

They should then repeat this with the same foot for a total of three successful touches. After completing three successful touches with the right foot, then they are allowed to repeat this process with the left foot.

Once the athlete has made three successful touches with each foot, they can then move on to the next test direction.

The test coordinator should record the reach of each attempt to calculate the composite score.

With the test completed and all performance recorded, the test coordinator can then calculate the test performance scores using any or all of the following equations:

- Absolute touch distance (cm), the sum of the three touches;
- Relative (normalized) touch distance (%) = Absolute touch distance / limb length x 100;
- Compound touch distance (%) = Sum of the 3 touch directions / 3 times limb length x 100.

Conclusion

The results suggest that both SEBT and YBT can be used clinically to measure dynamic balance, performance scores in a certain direction of execution should not be used alternately between SEBT and YBT. As the administration of SEBT and YBT protocols varies in the literature, the detailed specific methodology should be carefully observed by physicians, physiotherapists and researchers when interpreting dynamic equilibrium scores. Further research is needed to establish normative values for SEBT and YBT and to determine the limits of dynamic equilibrium testing.

A difference was observed on the distance A between SEBT and YBT, without differences on the PM and PL directions. Achieving the values set for SEBT in sports, healthy populations and those with injuries to the joints of the lower limbs cannot replace the values of YBT performance. It is important to note that there are differences between these assessment tools although it is not established whether one test is more clinically appropriate than the other.

The Star Trip Balance Test (SEBT) is a widely accepted method of assessing dynamic postural stability. The Y Balance Test (YBT) is a commercially available device for measuring balance that uses three (anterior, posteromedial and posterolateral) of the eight SEBT directions and has been supported as a method of assessing dynamic balance. The claimed benefits of YBT are that it takes less time to complete testing and has a standard protocol and high reliability. To date, no study has compared the achievement of achievement in these tests in a healthy population.

Both SEBT and YBT involve similar movements that are considered, measuring and causing dynamic equilibrium. Despite the similarity between the tests, so far no researcher has evaluated performance in both tests in the same group of participants.

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