Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXII, ISSUE 2, 2022, Romania
The journal is indexed in: ERIH PLUS, Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

Science, Movement and Health, Vol. XXII, ISSUE 2, 2022
June 2022, 22 (2): 165 - 171
Original article

The Star Excursion Balance Test (SEBT) in knee sprain recovery

ROȘU Bogdan[1], CORDUN Mariana[1]

Abstract

The aim was to highlight the effects of proprioceptive training on lower limb balance in subjects with lower limb injuries but also in healthy subjects, and to evaluate the effectiveness of proprioceptive programs based on postural instability to reduce knee sprains by developing proprioceptive control. These findings indicate the improvement of proprioceptive control which may be a key factor in reducing knee sprain.

Methods. The research was performed on 30 subjects, male and female, employees of the Ministry of National Defense, distributed in two experimental groups: G1 and G2.

*Results***.** SEBT has become a dynamic test used in clinical trials and research. The results of the research showed validity for SEBT.

*Conclusions***.** Knee sprain is a trauma that occurs frequently among athletes. Like athletes, the Ministry of National Defense employees represent a population at high risk of injury or recurrence.

Keywords: knee sprain, postural control, neuromuscular control, dynamic balance test.

Introduction

This dynamic postural control test has received attention in clinical and research settings is the Star Excursion Balance Test (SEBT, figure 1). Specialists recommend, with correct instructions and practices by subjects and normalization of contact distances, SEBT to be used to differentiate deficits and improve dynamic postural control related to lower limb injuries and induced fatigue, and has the ability to prevent lower limb injuries.

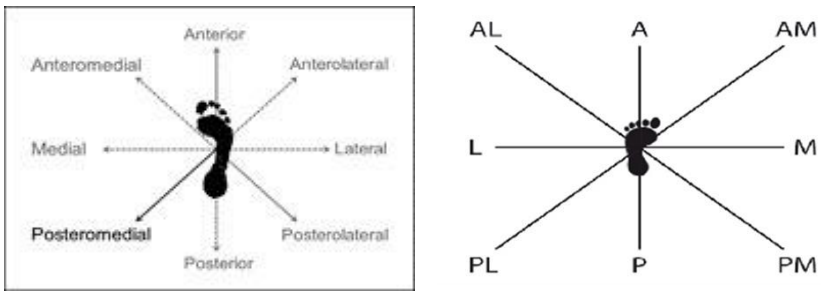

Figure 1. SEBT(www.researchgate.net)

Star Excursion Balance Test (SEBT) is a tools for testing and assessing dynamic balance. SEBT is a specific test for joint injuries and is applied and described for over 22 years (Gribble and Hertel, 2003).

Researchers are continuously committed to investigate and analyze the biomechanical and neuromuscular factors that contribute to joint damage and their early recovery (Prakash et al., 2017).

We mention here injuries such as the anterior cruciate ligament injury without contact at the knee joint and the development of chronic instability of the ankle. SEBT has ability to report the postural control problems between limbs, both among the healthy population and among populations with lower limb joint injuries (Plisky et al., 2006).

In this context, adding the fact that the literature considers it one of the best tools for measuring the dynamic balance of the lower extremity, we considered that we can also apply it to monitor the performance of researched subjects (Munro et al., 2010).

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 indicated that previous contact distances were different when comparing the two tests. Therefore, the two instruments may not be directly comparable (Alnahdi et al., 2015).

[1] National University of Physical Education and Sports, Faculty of Physical Education and Sport, Bucharest, Romania
Email: rosubogdan81@yahoo.com

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Vol. XXII, ISSUE 2, 2022, Romania
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Standardized testing (Gribble, Hertel and Plisky, 2012) must meet the following conditions:

• Lines drawn on the ground (figure 2).
• Starting position on the central point.
• Hands positioned on hips.
• Moving along the line and touching the line easily.
• The subject does not rest or pause on the line.
• The body weight is not transfer to the leg that reaches the maximum distance on that line.

Figure 2. SEBT, lines drawn on the ground

Implementation of SEBT in the medical recovery- SEBT has been shown to be an effective test for highlighting chronic unilateral instability of the ankle and knee, but it has also been used to monitor patients with painful femur-patellar syndrome. The opinions of specialists converge towards the use of this test in other pathologies of the lower limb that may lead to disorders in terms of body stability. The test can also be predictable, as it can determine deficits and balance asymmetries in unipodal support, which help specialists in making decisions that are prophylactic, preventing injury.

Anterior, posteromedial and posterolateral directions appear to be important in identifying individuals with chronic ankle and knee instability, and athletes at higher risk of injury.

When the person shows a significant decrease in balance while standing on the affected lower limb, compared to the healthy lower limb, the star's balance test highlights the loss of dynamic postural control (Hegedus et al., 2015).

SEBT requires endurance, flexibility, neuromuscular control, basic stability, balance and proprioception. It proves to be an excellent test for physical and clinical examinations. SEBT is an excellent tool that helps us adapt our rehabilitation programs and sports training programs to address specific mechanical, sensory and functional issues.

It is a dynamic balance test that offers a significant challenge for athletes and physically active individuals, used to assess physical performance and to detect deficiencies in postural control.

How to perform SEBT-protocol:

1. The properly equipped subject is required to stand in the center of the star and wait for additional instructions, shoes removed to avoid measurement errors. You can perform some practical tests as a learning effect, you can show video instructions to increase the efficiency of the test protocol and standardize the instructions, you can perform the control test to improve the image in performing the test.

2. SEBT was described as a rehabilitation test consisting of placing the subject in the center of the star, in a standing position. The right foot is the touch leg and the left foot is for balance, the athlete must do it the circuit, in a clockwise. After the balancing on the right leg is done, the athlete must do it the circuit, in the counterclockwise (figure 3).

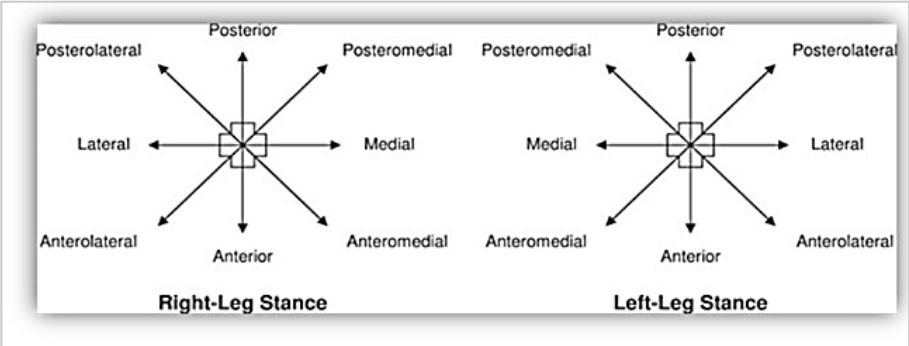

Figure 3. SEBT directions of movement (www.physio-network.com)

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3. With the hands positioned at the hips, the subject must to reach with the foot, far as possible along the drawn line and with the tip of the foot of the lower contralateral limb lightly touch, in turn, each line (branch of the star), trying to slide as far away from the center of the star as possible along one of the eight directions before returning to the starting position. Throughout the test, the hands remain fixed on the hips and a squatting position is maintained on the lower support member, and the heel remains in constant contact with the support surface.

4. Mark with a pencil or chalk the point at which the subject touches the line of that direction of movement. The subject returns to the original vertical position. The distance between the maximum point reached and the center point is measured in centimeters. Repeat the movement and the measurement procedure with the same lower limb in all 8 directions of movement. After each movement performed in one direction, return to the center point. The lower support member is changed and the movement and measurement procedure are repeated with the other lower limb, in each direction, performing again the 8 movements whose length is measured. The correct execution of the movements in the 8 directions represents a complete circuit.

5. Repeat the movements with the same foot for all eight other directions, and then change the leg.

6. To complete a full circuit this process must be performed three times on one leg, three circuits in the previous direction for the right leg and three for the left, keeping the same direction of movement.

7. After performing the three circuits, the subject moves away from the test area.

8. Record the distance to reach each successful attempt and calculate the subject's SEBT score when the test is finished.

Failure to follow one of these instructions resulted in the test being repeated in the direction in which the execution failed.

The protocol involves making 3 complete circuits with each leg. Thus, 3 performances are measured and recorded for each direction performed with each foot (distance 1 - at the first determination, distance 2 - at the second determination and distance 3 - at the third determination). The subject is then allowed to move away from the test area (Herrington et al., 2009).

In order to ensure the reproducibility of the measurement, we created a support for this test. I covered the floor with linoleum and drew on this support four lines intersected in the same central point, thus obtaining 8 branches, which represent the 8 directions of movement; the lines are extends from a central point and have 45 °, to each other.

The test subject must maintain balance on one lower limb (sitting on one lower limb) in the middle of the star test, while using the foot of the other lower limb to successively touch the 8 different directions, named, depending on foot orientation, as follows: anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral direction.

The objective is to determine the subject to set a base of support on the position member and to maintain it, while the opposite member makes a maximum trip in one of the mentioned directions.

Scoring system- once the test is completed and all measurements are recorded, SEBT scores can then be calculated using this equations:

Average distance in each direction (cm) = distance 1 + distance 2 + distance 3/3

Relative distance (normalized) in each direction (%) = Average distance in each direction / lower limb length x 100

$$\textit{Total score} = \frac{A+AL+L+PL+P+PM+M+AM}{8} \times 100$$

After these calculations, resulting in a total of 16 scores.

We took as a benchmark the values offered by Gribble et al. (2003), shown as a percentage of the length of the lower limbs, because from the literature, all bibliographic references refer to them, being considered normative values (Table 1). We mention that these data were obtained on sedentary subjects (Gribble et al., 2003).

Table 1. Data on the normal values of the Star Excursion Balance Test (www.exercise.trekeducation.org)

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

To compare the performance of an individual's limbs, comparisons can be made between the absolute touch distance on each limb. However, the reach distances must be normalized to the length of the limbs of each participant, measured from the anterosuperior iliac column to the medial ankle, being correlated with the touch performance. This performing is expressed as a percentage of limb length. The body height can be also correlated with touch distance.

The muscular activity of the medial vastus was higher in the anterior direction than in the other directions. The activity of the lateral vastus muscles was lower during the lateral excursion compared to the other directions. The activity of the hamstrings was higher in the anterolateral direction than in the anterior, anteromedial and medial directions. The activity of the femoral biceps muscles was higher in the posterior, posterolateral and lateral directions compared to the anterior and anteromedial directions.

Muscle differences between certain SEBT-specific travel distances can be helpful to specialists, who can decide which directions of travel can be used in patients with specific conditions that have a lack of muscle strength.

An important factor is also the gender. After different fatigue protocols, it was found that there was no difference in performance between the sexes.

In conclusion, the performance of SEBT became more consistent and more pronounced after fatigue. Fatigue changes the effectiveness of the ability to contract extrafusal muscle fibers that alter neuromuscular control. Specifically, during local muscle fatigue, nociceptors are active through metabolic products of muscle contraction, including bradykinin, potassium, and lactic acid. Basic idea, it is that fatigue can influence SEBT performance.

Fatigue is a factor that could affect the dynamic postural control measured with SEBT.

SEBT's ability to differentiate the effects of external influences and interventions- in addition to identifying problems in dynamic postural control. SEBT can be used to highlight the influence of external interventions and influences on dynamic postural control. These comparisons demonstrate that SEBT can be used to address effective methods of recovery and prevention of lower limb joint injuries in clinical settings. Taping and orthoses are devices used to increase the stability and biomechanics of the joints, which show increased postural control (O'Sullivan et al., 2009).

It is understood that the touch distance will be affected by limb length and sex.. Thus, there is a considerable percentual difference between the two lower limbs or between the subjects with injuries and the healthy, control ones.

The location of the foot, affects the different muscles of the thigh, which contribute to balance in different directions of movement:

• The medial vastus is most active in the anterior area.

• The lateral vastus is the least active in the lateral area.

• The hamstring is most active during anterolateral movement.

• The femoral biceps was most active during the posterior and posterolateral movement.

These directions of touch help us to direct our clinical reasoning and train specific muscles, using targeted directions of movement, in order to influence them.

Because the performance on SEBT varies by sport, gender, and age, specialists must collect normative data using different populations (in addition to those who practice different sports, even military, youth, the elderly, etc.). With normative data and objective studies resulting from SEBT, we can determine lesions for each population (Calatayud et al., 2014) .

All directions have the ability to identify movement deficits in participants compared to healthy controls, however, the posteromedial direction is the most representative for the overall assessment.

The anterior direction is more affected by dorsiflexion and plantar skin sensation, which means that mechanical limitations and sensory deficits influence this movement.

The posteromedial and posterolateral direction is more affected by eversion and balance control.

The deficit in performance, before the implementation of a medical rehabilitation protocol, was confirmed, the injured lower limbs producing a weaker dynamic postural control than the healthy limbs for posteromedial, posterolateral and lateral directions.

Patients with chronic ankle instability are susceptible to increased use of torso flexion during the execution of the previous movement, suggesting a strategy to compensate for reduced ankle control by manipulating the pelvis and the trunk.

Reconstruction of the anterior cruciate ligament- anterior cruciate ligament injuries are common in pathological conditions of the lower limbs, and many studies about anterior cruciate ligament problems. The performance of SEBT compared with the performance of the healthy limb, in the anterior, lateral, posteromedial and medial directions, the limb with anterior cruciate ligament problems showed weaker dynamic postural control than the healthy limb, patients have low resistance of the quadriceps, which showed a reduced ability to touch in the anterior directions (Clagg et al., 2015). But upon returning to work, we hope that there will be no differences from one limb to another. This requires that this test be instituted earlier in our recovery plans.

Patellofemoral pain syndrome- SEBT performance was compared in the anterior direction due to its ability to cause a high level of quadriceps muscle activation, dorsiflexion in the ankle joint and a greater tension of the patellofemoral joint. There were shorter touch

distances, this finding demonstrating a lack of dynamic postural control of those with femuropatellar syndrome (Aminaka et al., 2008).

This direction of touch (anterior) is usually the most limited and highlights the patient's reduced ability to walk on slopes and stairs.

Use of SEBT to detect clinical deficiencies- SEBT was initially designed as a rehabilitation tool for pathological diseases of the joints of the lower limbs, specialists use this tool for diagnosing and detecting the risk of injury (Ahlden et al., 2012). SEBT can be a diagnostic tool in 4 clinical situations:

1) the ability to prevent the risk of injury.

2) the ability to differentiate patients with diseases of the joints of the lower limbs from healthy patients.

3) the ability to differentiate the influence of certain factors on sports performance.

4) the ability to demonstrate clear and objective results following the application of the SEBT.

Establishing these qualities will help specialists evaluate and establish the best way to implement SEBT in coordinating lower limb joint injuries. At the same time, it helps to carry out a comprehensive review of the general purpose of evaluating the effectiveness of SEBT as a tool for diagnosing and preventing joint injuries.

Working hypothesis

The application of a kinetic intervention protocol consisting of static proprioceptive exercises stimulates the maintenance of the body in balance in unbalanced situations and increases the stability of the knee joint in Ministry of National Defense workers with a history of sprained knee or predisposition to injury.

The purpose of the research

The proprioceptive system stimulated by specific exercises can restore segmental stability through static and dynamic tasks.

Participants

The population groups approached, respectively employees of the Ministry of National Defense services, underwent a complex evaluation using the star balance test, which is a novelty in our literature and a program of proprioception exercises used both as a means of primary prophylaxis, as well as therapy and secondary prophylaxis, prevention of recurrences in knee sprain in workers in the Ministry of National Defense services.

We emphasize that the detection of knee instability and its treatment before joint trauma is particularly important for this professional category who must be in very good physical condition to cope with regular physical tests and regular requests for training.

Methodology

Research methods

The research was performed on 30 subjects, male and female, employees of the Ministry of National Defense, distributed in two experimental groups: G1 and G2. Both groups were selected based on common criteria, namely: volunteers, who currently carry out a program of continuous physical-military training, aged between 25 and 45 years and with a length of service of at least 5 years in the practice of the physical activities previously mentioned. Healthy people were included in group G2. The G1 group was put together also based on specific criteria that we present below.

Common inclusion criteria

- the Ministry of National Defense employees, who are currently carrying out a continuous physical-military training program;
- ages between 25 and 45 years;
- seniority of at least 5 years in practicing a sports activity;

Criteria for inclusion in group G1

- at least one history of a previous knee injury;
- without knee surgery;
- without knee pain greater than or equal to 4, on VAS scale (visual analog scale).

Exclusion criteria from group G1

- ages under 25 and over 45;
- persons who have suffered injuries / surgeries in the knee (sprains, resections or ablations of the meniscus, etc.).

Healthy people were included in group G2.

The program applied to the researched subjects included:

1.*Warm-up program* - with a duration of 10-12 minutes and consisted of:

● low-speed walking exercises, walking and high-speed walking variants;

● stretching targeting:

- the muscles of the anterior thigh (right femur, intermediate vastus, lateral vastus, medial vastus), which together make up the quadriceps muscle, with a major extensor role of the knee;
- posterior thigh muscles (femoral biceps, semimembranosus, semitendinosus, gracilis);
- calf muscles (gastrocnemius, popliteal, plantar);

2. *A program of proprioceptive reeducation through static exercises = the classic form of therapeutic intervention* in the studied pathology.

The program consisted of *static proprioceptive physical exercises to destabilize* the body performed with the lower limbs in a closed kinematic chain.

Proprioceptive exercise protocol

Weeks 1 and 2:

- posterior, anterior and lateral destabilizations (left / right), - 4 series lasting 45 seconds, 2 for each leg.

Weeks 3 and 4:

- posterior, anterior and lateral destabilizations (left / right), - 4 series lasting 1 minute.
- and an altitude component, consisting of a unipodal support on a device 70 cm high.

Destabilization on increasingly unstable planes, from bipodal support and then from unipodal support, using a series of accessories such as: bicycle, stepper, balance board, balls (double load).

To evaluate the researched subjects we performed a series of anthropometric and functional measurements, Body Height and Body Weight based on them we

calculated the body mass index (Table 2) using the formula (BMI = current G / I²) and Lower limb length

BMI: for F = 19-25 kg / m2, for B = 20.5-25 kg / m2

Table 2. Interpretation of the body mass index (UN, 2003) and WHO (www.researchgate.net)

BMI value kg / m²	Interpretation
< 18.5	Hypo ponderal, weak
18.5 – 24.9	NORMAL
25 – 29.9	Excess weight
30 – 34.9	Moderate obesity
35 – 39.9	Severe obesity
> 40	Morbid obesity

3. *SEBT* - ***The Star Excursion Balance Test***

The results

Group 1

The sports practiced by the subjects included in the experimental group were diverse: gymnastics 3 subjects (20%), martial arts 2 subjects (13%), judo 2 subjects (13%), football 2 subjects (13%), boxing 2 subjects (13 %), rowing, tennis, athletics and handball, 1 subject (7% each).

Analyzed individually, on each sport practiced by the researched subjects, the figures are small and seem insignificant, only systematized in pivot sports and contact sports, all figures acquire significance, as all sports practiced by G1 group subjects are characterized by an increased risk of sprained knee injuries.

Group G2

The sports practiced by the subjects included in the experimental group were diverse: judo 3 subjects (20%), football 2 subjects (13%), boxing 2 subjects (13%), athletics 2 subjects (13%) and gymnastics, basketball, volleyball, triathlon, martial arts, handball, 1 subject (7% each).

Discussion

SEBT has become a dynamic test used in clinical trials and research. The results of the research showed validity for SEBT, considered a representative uninstrumented dynamic balance test to prevent the risk of injury to the joints of the lower limbs, to identify the deficit of dynamic postural balance in patients with disorders of the joints of the lower limbs and subjects without joint injuries lower limbs. Specialists should be confident in using SEBT as a functional test for lower limb joints.

Clinicians and researchers commonly use the Star Excursion Balance Test (SEBT) to assess dynamic balance. Anterior, posteromedial, and posterolateral directions appear to be important in identifying individuals with chronic knee instability and athletes at higher risk of lower limb injury.

Conclusions

Knee sprain is a trauma that occurs frequently in athletes. Like athletes, the Ministry of National Defense employees represent a population at high risk of injury or recurrence. The sensory impairment caused by a sprain alters the sensorimotor integration that leads to the reorganization of motor control, consisting in decreased stability of the knee joint and postural stability.

The average seniority in practicing a sports activity is significantly close to the two groups, taking into account the type of employees. This is explained by the fact that keeping the staff active implies undertaking of regular specific tests of effort, involving a permanent physical training.

The average seniority in service within the Ministry of National Defense structures is 13.46 years for women (15 years for group G1 and 12.1 years for group G2), while for men the average is 15.41 years (15.11 years for G1 and 15.75 years for G2).

The body mass index registered a normal average value in both groups in the tests (initial and final), with initial values of 22.62 and final values of 22.66 of group G1, respectively with initial values of 23.15 and final values of 23.07 of group G2.

Proprioception plays a key role in balance control, and knee proprioception is very important. Proprioceptive re-education improves stability and balance control and reduces recurrences. Postural stability is considered a predictive factor of chronic knee instability and dynamic stability as an intrinsic risk factor for injury.

Significant increases in average distances and normalized relative distances in almost all directions, as well as increases in the total score in both groups, highlight the effectiveness of the program applied to both people who have experienced a sprained knee and those at risk of injury.

The research hypothesis is confirmed: applying a kinetic intervention protocol consisting of static proprioceptive exercises, performed with the lower limbs, stimulates the body to keep in balance in unbalanced situations and increases the stability of the

knee joint in the Ministry of National Defense employees with a history of knee sprain or predisposition injury.

Authors´ Contribution

All authors have equally contributed to this study and should be considered as main authors.

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