Validity of Star Excursion Balance Test as Dynamic Balance Test In Subjects with Non-Operative Anterior Cruciate Ligament Injury

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Abstract

Background: The anterior cruciate ligament (ACL) injury is the most common knee injury that might occur during exercise. An ACL causes a balance disorder that can be considered as a risk factor for recurring injury. Identification of balance disturbances in subjects with ACL injury should be conducted to minimize the risk of re-injury.

Objectives: this study aims to determine the validity of star excursion balance test with biodex balance system SD as a gold standard

Method: This study is a diagnostic test with cross-sectional study approach. The number of research sample was 20 respondents selected as control group, five people with ACL injury as the case group. All subjects were examined with the biodex balance system SD (Overall Stability Index) and star excursion balance test (% MAXD).

Results: The result of the correlation analysis between the overall stability index and %MAXD was not significant with r = -0.316; p = 0.175. Hence, the cut-off point could not be determined due to the insignificant correlation, thus the sensitivity, specificity, positive predictive value, and negative predictive value of the star excursion balance test could not be determined.

Conclusion: Star excursion balance test was invalid as a dynamic balance test if the Biodex Balance Test SD was used as a gold standard.

Keywords: *validity, overal stability index, %MAXD, anterior cruciate ligament injury*

Introduction

Sports injuries are the most common type of injury. Reaserches have stated that the number of sports injuries make up about 21% of the injury cases in the world. Sports injuries can lead to long-term disability or dysfunction especially in patients with knee injuries. The most often structures involved are the anterior cruciate ligament (ACL) injuries in 20% of the knee injury incident, and 46% of the knee ligament injury incidences. An anterior cruciate ligament injury results in knee instability, which inhibits an athlete from playing in the field and can lead to early retirement [1,2].

The anterior cruciate ligament injury causes a proprioceptive disorder and it is suspected to be caused by mechanocarceptic damage to the joints and ligaments. Sensory input from proprioceptive, vestibular, and visual plays a role in maintaining static or dynamic balance. Proprioceptive, vestibular, and visually impairment can lead to a imbalance in the body. Identification of a balance disorder in subjects with ACL injury should be performed to minimize the risk of re-injury [1–3].

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Dynamic balance plays a pivotal role as the athlete moves and reacts quickly to the conditions that occur in a sports game. Athletes often experience a perturbation that disturbs his balance either from an opposing player or from himself as he changes position and direction. The perturbation is strong and requires stability. Athletes with a good balance have superior performance compared to ordinary people. Dynamic balance disturbances have been reported as a result of injury to athletes. Standardized assessment to measure and evaluate balance is needed to determine an athlete's readiness to return in the field 4,5.

The identification of balance disorders can be assessed in various ways, i.e., clinically, by tools, or by using a valid and reliable scale. Objective examination to determine the condition of balance can be done by using biodex balance system SD. This tool can be used to assess the balance in static format and semi-dynamic. Stability index (SI) is obtained from the dynamic balance test to determine how well the patient controls their balance in both anterior/posterior (A/P) and medial/lateral (M/L) directions. Balance assessment is expressed by overall stability index (OSI). Biodex balance system SD is a valid and reliable tool for assessing dynamic balance[6,7].

The most common test used for balancing in athletes is the star excursion balance test (SEBT). This test requires balance on one foot of support (single leg stance) to achieve the maximum range that can be reached by the opposite leg. The distance that can be reached by the participants is an index of dynamic balance. The further the distance, then the balance control is also better. The mean value of the reach distance (% MAXD) is a description of the dynamic balance value. Star excursion balance sensitive test identifies a reach distance deficit as a dynamic balance in subjects with chronic ankle stability, patellofemoral pain syndrome, and anterior cruciate ligament deficiency. Implementation of this test uses a simple tool, thus it can be done anywhere. SEBT is a potential option as a cost-effective tool and reliable to assess the balance deficit in various pathological conditions of the lower limbs [8]. A study to assess the validity of SEBT in assessing dynamic balance has never been conducted before. Thus the researchers aim to determine the validity of star excursion balance test with biodex balance system SD as a gold standard.

Method

This research is an observational analytic study with cross-sectional study approach. The study was performed at the Rehabilitation Installation Unit of Universitas Airlangga Hospital Surabaya from July to October 2014. The sample unit was subjects with ACL injury that fulfilled the inclusion criteria (male patients with unilateral ACL injury for >6 weeks at the age of 17-30 years, having a minimum exercise routine of three times a week, able to understand and follow the instructions, and willing to participate in this research by signing an informed consent).

The subjects consisted of five patients with unilateral anterior ACL injuries and five healthy people as the control group, thus we obtained 20 respondents for the sample units. The balance assessment was performed with the biodex balance system SD and star excursion balance test. The examination was finished in a day. The protocol of this study was approved by Dr. Soetomo Teaching Hospital, Surabaya, Indonesia. Data analysis was performed using Pearson correlation test with SPSS for Windows version 17 (SPSS, Inc., Chicago, IL).

Results

General Characteristics of Subjects

The general characteristics of the subjects were shown in Table 1. The average age of the subjects in the control group was 26.60±3.24 years, and 23.20±3.73 years in the case group,. The average height of the controls was 173.60±5.72 centimeters, and the average height of the subject with ACL injury was 169.40±5.27. The average weight of the control group was 70.40 ± 11.17 kilograms and 65.00±5.37 kilogram on the subjects with ACL injury. The mean body mass index of the controls was 23.26 ± 2.67 kg/m^2 and 22.74 ± 2.56 kg/m^2 on subjects with ACL injury.

Table 1. General Characteristics of Subjects

Variable	Groups	Minimal	Maximal	Mean
Age (years)	Control	22	30	26.60±3.24
	Case	20	30	23.20±3.73
Height (cm)	Control	167	181	173.60±5.72
	Case	163	171	169.40±5.27
Weight (kg)	Control	63	86	70.40±11.17
	Case	57	70	65.00±5.37
BMI (kg/m2)	Control	19.0	26.3	23.26±2.67
	Case	18.0	24.7	22.74±2.56

The Results of Overall Stability Index and %MAXD

The balance of the subjects that was measured using the biodex balance system SD produced the overall stability index (OSI) on both limbs of control and case groups. The results of OSI and %MAXD are shown in table 2.

Table 2. Examination Results of Overall Stability Index and % MAXD

Variable	Group	Minimal	Maximal	Mean
OSI	Control	0.4	0.7	0.550±0.097
	Case	0.5	1.2	0.786±0.286
% MAXD	Control	0.76	0.98	0.863±0.901
	Case	0.66	0.83	0.772±0.076

OSI: overall stability index

MAXD: maximum distance

The mean of OSI in the control group was 0.55±0.097, with an OSI. The mean OSI on the injured subjects was 0.786±0.286. The balance of the subjects measured using the Star excursion balance test on both limbs of control and case groups resulted in %MAXD. The mean of %MAXD in the control group was 0.863±0.901 with a %MAXD. The mean of %MAXD in the case group was 0.772±0.076.

The Association of Overall Stability Index with %MAXD

The association of OSI with %MAXD was assessed using Pearson correlation test. Correlation analysis of OSI with% MAXD was not significant with r = -0.316, p = 0.175 (table 3.).

Table 3. Association of OSI with % MAXD

Test	r	p
Pearson correlation	-.316	.175

The cut-off point could not be determined due to the insignificant correlation, thus the sensitivity, specificity, positive predictive value, and negative predictive value of the star excursion balance test could not be determined.

The Difference of Overall Stability Index and %MAXD in Subjects with Anterior Cruciate Ligament Injury and Control Group

Overall Stability Index in control and case groups was tested using T-test, the difference was significant with p = 0,031. The% MAXD score in the control and case groups was analyzed using T-test, thus a significant difference was found with p = 0.025.

Discussion

This study applied the postural stability test protocol and a single leg stance. The normal value of OSI on subjects with the age of 17-35 years was 0.82-2.26. The OSI range below the upper limit of normal values in healthy subjects ranged from 0.4 to 0.7 and from 0.5 to 1.2 in the subjects with an injury. These findings showed that the normal range of values that was used could not distinguish the presence of a balance disorder in the case group. This was likely to occur because the normal values used were determined by the normal population at the age of 17-35 years. The subjects of the study were physically trained people, thus the physical performance was better than normal people who did not practice any regular physical exercise. Therefore, the OSI values obtained were smaller than the normal range of values that already existed. Determination of the OSI normal range in the physically trained subjects as in the athlete was necessary in order to detect balance disorders using BBS.

The balance of the subjects was measured using the star excursion balance test on both limbs of control and case groups that resulted in %MAXD. The %MAXD range in the control group ranged from 0.76 to 0.98, while it ranged from 0.66 to 0.83 in the case group. The cut-off point of %MAXD could be determined if there was a significant correlation with the value of the gold standard. The reference value of the overall stability index (OSI) as measured by the current biodex balance system could not be used to set subjects with high activity levels or athletes as the gold standard of balance. This is due to the absence of a normal range of OSI values in the athlete population or subjects with high activity level. Thus, this study could not determine the cut-off point of % MAXD. Studies to determine the normal range of OSI values in a population of physically trained subjects such as athletes were required to be used as a reference in terms of the balance value in the population. The study to determine the normal value of %MAXD has never been performed, however, the assessment of the normal range of %MAXD component has been done previously, covering the distance assessment on anterior, anterolateral, anteroposterior, posterior, posteromedial, medial, and anteromedial. Research to determine the reliability needs to be performed before the study to determine the normal value of %MAXD in the athlete population was performed.

There was no significant correlation between OSI with %MAXD; OSI showed semi/dynamic balance, meanwhile, MAXD showed dynamic balance. The results of this study differed from the research by Bakhtiari (2012) [9] that a significant correlation was found between static balance as assessed by flamingo balance test and dynamic balance assessed by SEBT.

The OSI assessment was obtained from an examination with the biodex balance system SD (BBS), the subjects were asked to stand on one foot on a fixed platform then maintained a single-leg stance while adjusting the position of the balance point drawn on the screen. There was no change in the center of gravity and in a base of support, thus the balance assessed using BBS was a static balance. In contrast to SEBT, subjects were required to stand on the limbs, while the contralateral limbs tried to reach the range as far as possible in the prescribed direction and then returned to the starting point by maintaining a balance on the limb of the pedestal. The test described the dynamic balance of the ability to maintain a balance when the body performed a functional movement.

Static balance control is required to maintain anti-gravity positions such as standing or sitting whereas dynamic balance is necessary to stabilize the body when the surface while the body rests or when the body moves on a stable surface. There might be sudden changes (perturbation) of balance when a person is currently conducting an activity, thus a balance disorders occurs. When a perturbation happens in healthy people, then the body reacts with a variety of mechanisms in order to maintain the balance, it depends on the direction and magnitude of perturbation experienced by the person. If the perturbation is small or occurs slowly or when standing still, then the ankle creates a movement in an effort to center the mass in a stable position. If the perturbation occurs suddenly and strong or while performing the movement, thus the hip is used to maintain the balance [10]. Previous research [11] reported that inappropriate static balance assessments were used

to assess dynamic balance in the absence of movement at the center of gravity due to the response of muscular activity [12]. However, this study found no significant correlation between OSI and %MAXD. The absence of significant correlation caused the cut-off point of SEBT to not be able to be determined. Therefore, the sensitivity, specificity, positive predictive value, and negative predictive value of star excursion balance test could not be determined.

The star excursion balance test is considered sensitive in detecting deficits of dynamic balance in patients with leg injuries such as chronic ankle instability (CAI), ACL injury, and patellofemoral pain syndrome [8]. There was no significant difference between the normalized reach distance between the control and case groups. The %MAXD score describing the dynamic balance in the subjects with ACL injury was lower than the control group in this study, there was a significant difference with $p = 0.025$. Significant differences of balance index in subjects with ACL injury were obtained from the research by Herrington (2009) [2] compared to the control group.

The study by Chen et al (2011) [13] compared the balance of 15 patients with CAI with the control group using SEBT. The reach distance of the control group was greater than the subjects with CAI. Another study found that subjects with CAI achieved a significantly smaller reach distance when resting on injured limbs compared to non-injured limbs as well as other subjects without CAI [2,13,14].

Significant differences were also found in the overall stability index score using the Biodex Balance System SD, where the OSI values of subjects with ACL injury were higher than the control group. This illustrates that the balance deficit in subjects with ACL injury could be identified with the biodex balance system SD tool and could be determined by star excursion balance scale.

Conclusion

Star excursion balance test is invalid to be used as a dynamic balance test when biodex balance system SD is set as the gold standard, in which star excursion balance test cannot be used to replace the biodex balance system SD.

Ethical Clearance: The study protocol was approved by the Ethical Commission to conduct basic science/clinical research in Dr. Soetomo General Hospital Surabaya, Indonesia. The present study was carried out in accordance with the research principles. This study implemented the basic principle ethics of respect, beneficence, non-maleficence, and justice.

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References

1. Lee H-M, Cheng C-K, Liau J-J. Correlation between proprioception, muscle strength, knee laxity, and dynamic standing balance in patients with chronic anterior cruciate ligament deficiency. Knee. 2009;16(5):387–91.
2. Herrington L, Hatcher J, Hatcher A, McNicholas M. A comparison of Star Excursion Balance Test reach distances between ACL deficient patients and asymptomatic controls. Knee. 2009;16(2):149–52.
3. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. J Orthop Sport Phys Ther. 2006;36(12):911–9.
4. Bhat R, Moiz JA. Comparison of dynamic balance in collegiate field hockey and football players using star excursion balance test. Asian J Sports Med. 2013;4(3):221.
5. Butler RJ, Queen RM, Beckman B, Kiesel KB, Plisky PJ. Comparison of dynamic balance in adolescent male soccer players from Rwanda and the United States. Int J Sports Phys Ther. 2013;8(6):749.
6. Kelly BM. DeLisa's Physical Medicine & Rehabilitation: Principles and Practice. JAMA. 2011;306(2):214–5.
7. Rohleder TR, Lewkonia P, Bischak DP, Duffy P, Hendijani R. Using simulation modeling to improve patient flow at an outpatient orthopedic clinic. Health Care Manag Sci. 2011;14(2):135–45.
8. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J Athl Train. 2012;47(3):339–57.
9. Bakhtiari R, Sephavand NM, Ahmadabadi MN, Araabi BN, Esteky H. Computational model of excitatory/inhibitory ratio imbalance role in

attention deficit disorders. J Comput Neurosci. 2012;33(2):389–404.

10. Kloos AD, Givens D. Exercise for impaired balance. 2013;
11. Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. J Orthop Sport Phys Ther. 1998;27(5):356–60.
12. Radaei F, Gharibzadeh S. Relationship between bone mineral density and balance disorders in osteoporotic patients. Front Bioeng Biotechnol. 2013;1:5.
13. Chen C-Y, Hsu A-T, Guo L-Y, Lin C-F, Chen Y-A. Postural control and lower extremity contribution during star excursion balance test in athletes with chronic ankle instability. Formos J Phys Ther. 2011;36(4):263–73.
14. Olmsted LC, Carcia CR, Hertel J, Shultz SJ. Efficacy of the star excursion balance tests in detecting reach deficits in subjects with chronic ankle instability. J Athl Train. 2002;37(4):501.