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The Impact of an External Load of Football Equipment on Dynamic Balance as Assessed by the Modified Star Excursion Balance Test

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ABSTRACT

International Journal of Exercise Science 11(4): 797-805, 2018. Ankle sprains are common injuries, especially for football players, and may result in ankle instability, which can limit performance and increase injury risk. Ankle stability return to play criteria is often assessed under loaded conditions, even though previous research suggests loaded conditions affect dynamic balance. The purpose of this study was to evaluate dynamic balance under loaded conditions. A modified Star Excursion Balance Test (SEBT), incorporating anterior, posterior medial and posterior lateral reach directions under the loaded condition of NCAA Division III football equipment was evaluated. Thirty male collegiate football players completed the modified SEBT under loaded and non-loaded conditions. Scores for the three reach directions on the SEBT were computed for loaded and non-loaded conditions. Repeated measures ANOVA was used to compare reach directions under loaded and non-loaded. Under loaded conditions, participants had significantly shorter posterior lateral reach distances for the left (98.05 ± 12.73 cm vs. 89.30 ± 10.45 cm, $p = 0.00$) and right (103.77 ± 12.78 cm vs. 99.07 ± 13.50 cm, $p = 0.00$) legs and significantly shorter reach distances for the right leg in both the anterior direction (84.58 ± 5.64 cm vs. 80.57 ± 13.73 cm, $p = 0.02$) and composite dynamic balance score (105.99 ± 12.99 vs. 102.30 ± 14.28, $p = 0.009$). The addition of 6.2 kg of external load significantly affected dynamic balance assessed by the modified Star Balance Excursion Test. These findings suggest that return to support assessments should involve sport-specific conditions when determining readiness of return to play.

KEY WORDS: SEBT, rehabilitation, athletic training, Y-Balance Test

INTRODUCTION

Ankle injuries may account for up to 45% of all athletic injuries, 73% are ankle sprains in football (3, 8). Of the various types of ankle sprains, inversion ankle sprains are most numerous and are categorized as excessive inversion and plantar flexion, damaging many of the lateral ligaments and muscles of the ankle joint (1, 8, 11, 17). Damage to the muscles and ligaments most often causes ankle joint instability because the damaged ligaments become stretched, a condition referred to as to ligamentous laxity (1, 19). The ligamentous laxity and thus, destabilized ankle joint, may negatively impact ankle kinesthesia as demonstrated by an individual's decreased ability to detect ankle motion during dynamic joint positioning tests. This suggests that destabilization of the ankle joint may not only be mechanical in nature as evident by ligamentous laxity, but also contain a neurological component as demonstrated by decreased proprioception (19). It is estimated that 40-75% of individuals who experience a lateral ankle sprain will develop residual symptoms, which include pain during activity and injury recurrence (19). The National Athletic Trainers' Association (NATA) position statement on ankle sprains in athletes outlines guidelines for functional tests to determine when an athlete may return to play. An athlete's functional dynamic balance is often determined by the athlete's ability to remain balanced through movement. Various balance tests are often administered to assess whether an athlete possesses the required ankle stability before returning to play (8, 14).

The NATA outlines three predominant tests used in assessing return to play readiness, which include single leg balance test, the toe or heel raise test, and the Star Excursion Balance Test (SEBT). The single leg balance test evaluates the patient's ability to maintain balanced with eyes open and eyes closed, which essentially tests the patients' visual, vestibular and somatosensory systems through the amount of time they can maintain balance; a time of 25 seconds or greater is considered normal. The toe or heel raise test assesses the endurance and function by performance of 60 repetitions per minute of the muscles of the lower leg, although this test is more dynamic in nature and does not accurately evaluate the lateral motions that an athlete is exposed to in sport (8). While these tests may provide insight as to the athlete's ability to maintain their balance in a static position, they do not assess the athlete's ability to maintain balance while moving, which is essential for sport (8).

The SEBT assessment is a dynamic balance assessment of the lower extremities, which is unlike the single leg balance test and to or heal raise tests which are more static tests (5). The SEBT assesses dynamic postural control by performance of unilateral maximal lower extremity excursions through either eight vectors; a modified version of the SEBT (sometimes referred to as the Y-Balance test) assess unilateral maximal lower extremity excursions in three vectors, which are anterior, posterior-medial, and posterior-lateral (5). A larger excursion suggests better dynamic postural control, balance, and functional performance (4). Dynamic tests may be a more appropriate test to assess readiness to return to play because a dynamic assessment may provide more information on functional restrains during dynamic tasks (19).

When evaluating an athlete's readiness to return to sport, athletic trainers often assess an athlete's dynamic balance using various functional tests under non-loaded conditions (14). Non-loaded conditions means that the athletes wear shorts and a t-shirt and not the athletic equipment required for their sport. Football requires an athlete to wear approximately 6.2 kg of equipment. This is noteworthy because previous studies have shown that external loads applied to an individual may negatively impact their dynamic balance (15). Specifically, Sell et al. (2013) examined the dynamic nature of soldiers under the external loads of body armor and found the addition of external loads added to one's person will reduce dynamic postural balance and place individuals to the limits of their stability (15). The addition of an external load can even affect static stability, as observed by Schiffman and colleagues (2006) (16). The researchers found static stability may decrease, as indicated by an increase in postural sway, which may begin with an additional 6.2 kg of an external load. Thus, the purpose of the current study was to assess the impact of an external load on dynamic balance.

METHODS

Participants
The current study was approved by the University Institutional Review Board and complied with the standards of the Helsinki Declaration. Power analysis indicated that a minimum of twenty participants was needed to give 70% power to detect differences in means at $p < 0.05$. Additional subjects were recruited to account for any issues with missing data or drop-out. All participants gave written, informed consent. Participants (n = 30) in this study included healthy male Division III college football players, 18 to 25 years of age. Participants were recruited through use of a flyer at the University campus. Participants were fully cleared to participate in their sport by their athletic trainer. Participants were required to complete a physical activity and readiness questionnaire (PAR-Q) and a medical history questionnaire to determine their capability to participate in the study (7) and whether medical clearance from a physician was necessary, determined by their PAR-Q responses.

Protocol
Prior to testing, participants had their height and weight measured using a Seca Scale stadiometer (model Detecto 439). Body Mass Index (BMI) was collected using a Tanita Bioelectrical Impedance Analysis (BIA) Scale (model TBF310). The participant's leg length was measured using a Singer vinyl tape measure (model 00258) to measure the distance from the center of the ipsilateral medial malleolus to the anterior superior iliac spine on both legs. This measurement was taken to normalize leg length data for each participant (4).

Dynamic balance of both lower extremities as assessed by the modified SEBT (sometimes referred to as the Y-Balance test) under a loaded condition and non-loaded condition. The non-loaded condition consisted of wearing shorts and a t-shirt with no shoes. No particular guideline has been established for the conditions a participant is to be tested by the NATA, though athletes often wear shorts and t-shirts, which is the present protocol for training outlined by NATA (8).

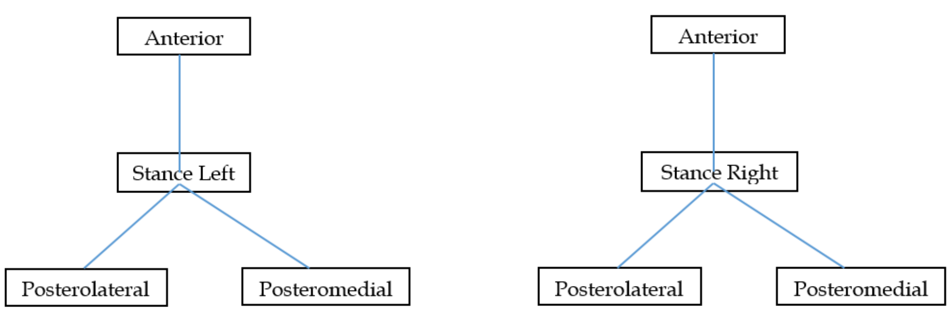

Figure 1. Star Excursion Balance Test (SEBT) set-up

The loaded condition involved the participant donning traditional football equipment that had cumulative load of 6.2 kg. Traditional football equipment involves a helmet, kneepads, shoulder pads, chinstrap, thigh pads, game jersey, game pants, t-shirt, hip pads, tailbone pad, game socks, and a belt (2). The order of the testing conditions was randomized. The two testing sessions were separated by 7 days.

The modified SEBT assesses dynamic balance in three directions: anterior (A), posterior medial (PM) and posterior lateral (PL). The modified SEBT requires the participant to stand at the center of a grid laid on the floor with three reach lines in the form of a Y (Figure 1). The angle between the anterior and posterior medial directions is 135° and the angle between the posteromedial and posterior lateral directions is an angle of 90° (18). The lines were constructed with standard tape measures and white tape on the floor.

To prepare for the SEBT, participants watched a brief instructional video prepared by the primary investigator. This ensured that all participants received a standardized introduction to the test. The video showed the primary investigator explaining the performance directions, test rules and scoring. The primary investigator then performed the SEBT. The participants performed 4 practice trials under each condition. To perform the test, participants stood with the most distal part of the big toe at the cross of the Y at the beginning of the anterior tape measure; the posterior reach was performed with the most posterior part of the heel at the cross of the Y at the beginning of the posterior tape measure. Participants were barefoot and had both of their hands placed at their hips. To perform a reach rest, the participants were instructed to reach as far as possible along each of the three reach lines, make a light touch on the line with the most distal part of the big toe and return the reaching leg back to the center while maintaining a single-leg stance with the other leg (18). If a trial was discarded due to a failed attempt, an additional attempt was allowed until three successful trials were recorded and then averaged.

Participants performed three trials in each direction on each leg. The test started with the right leg as stance leg followed by the left leg in successively the A, PM and PL reach directions. Participants were allowed to rest 5 minutes between each trial. A trial was not counted if the participants (1) took weight on the reaching foot; (2) failed to bring back the reaching foot to the starting position without losing control; (3) failed to keep both hands on their hips; (4) failed to keep the stance foot at the same place; or (5) failed to keep the forefoot and heel of the stance foot on the floor.

Recommendations for SEBT analysis suggest normalizing reach distance for length of stance limb by dividing a participant's standing leg length (determined by baseline assessment) and multiplying by 100. Thus, the maximum distance for each of the three excursions per leg in each direction was recorded by placing a standard tape measure (Singer vinyl tape measure, model 00258; www.singerco.com) at the most distal reach distance achieved via foot tap of the non-stance limb for both the loaded and non-loaded conditions (13). The scores of the maximum reach distance in each direction were averaged and then normalized by dividing the average by the leg length and multiplying it by 100. This process was repeated for each leg. A composite score for each leg was created by taking the average of all three direction scores of the left and right in order to compare the loaded condition to the non-loaded condition (13).

Statistical Analysis

A repeated measures ANOVA was used to compare the composite scores between the loaded and non-loaded conditions. The level of significance will be $p < .05$ was applied to all statistical analysis using SPSS version 22.0 to process data.

RESULTS

Thirty (n = 30) healthy male adults 17 to 25 years of age who were current Division III college male athletes, fully cleared to participate in their sport by an athletic trainer participated in the present study. Descriptive data for all participants (n = 30) are listed in Table 1.

Table 2 displays the results of the SEBT testing under loaded and non-loaded conditions. The average dynamic balance composite score for the right leg in the loaded condition was significantly lower compared to the non-loaded condition (102.30±14.28 cm vs. 105.99±12.99 cm, $p = 0.009$). In the posterior lateral direction, the average normalized reach distance under the loaded condition was significantly lower than in the non-loaded condition (left leg: 89.30 ±10.45 cm vs. 98.05 ±12.73 cm, $p = 0.00$; right leg: 99.07±13.50 cm vs. 103.77±12.78 cm, $p = 0.00$). In the anterior direction for the right leg, the average normalized score for the loaded condition was significantly lower compared to the non-loaded condition (80.57±13.73 cm vs. 84.58 ±10.51 cm, $p = 0.02$). There were no significant differences for any of the other directions, though a trend to significance was noted when comparing the average normalized score for the right leg in the posterior medial direction ($p = 0.07$).

Table 1. Descriptive statistics of Division III male college football players.

Variable	Minimum	Maximum	Mean
Left leg length (cm)	87.00	105.00	93.57±4.070
Right leg length (cm)	87.00	106.00	93.45± 4.290
Height (cm)	170.00	190.50	181.77±5.380
Weight (kg)	72.12	137.89	104.32±17.03
Body Mass Index (kg/m²)	24.30	43.00	31.55±4.920
Percent Body Fat (%)	10.30	43.00	20.90±7.360

Note: n = 30

Table 2. SEBT reach distances in Division III collegiate football players with and without the addition of football equipment.

Variable	Mean (cm) Non-Loaded	Loaded	p-value
Composite Score, Right Leg	105.99±12.99	102.30±14.28	0.009*
Composite Score, Left Leg	96.29±9.77	98.06±11.87	0.29
Posterior Medial, Right Leg	109.71±10.92	107.18±9.65	0.07
Posterior Medial, Left Leg	108.54±11.34	105.42±9.65	0.06
Posterior Lateral, Right Leg	103.77±12.78	99.07±13.50	>0.01*
Posterior Lateral, Left Leg	98.05±12.73	89.30±10.45	>0.01*
Anterior, Right Leg	84.58±10.51	80.57±13.73	0.02*
Anterior, Left Leg	82.29±10.96	79.90±11.74	0.10

Note: n = 30; n = 29 for posterior medial data; Note: * denotes significance, $p < .05$

DISCUSSION

The findings of this present study are very meaningful because current return to play evaluation criteria do not consider the addition of external load required in sport. Athletic Trainers are currently assessing and evaluating an athlete's dynamic balance using non-loaded conditions when determining readiness to return to sport. However, the results of the present study suggest that an athlete's dynamic balance is affected by the addition of external load, the addition of 6.2 kg of an external load will lessen an athlete's reach distance on the modified SEBT, thus decreasing the dynamic balance. Therefore, the results of the present study suggest that when evaluating an athlete's dynamic balance to determine readiness to return to play, a more accurate evaluation may include an external load in the form of equipment as required to participate in sport.

In present study, the addition of 6.2 kg of external load significantly shortened the reach of the right leg in the anterior and posterior lateral directions as well as the left leg in the posterior lateral directions. These results are consistent with previous research. Specifically, Sell et al., (15) examined the dynamic nature of soldiers under the external loads of body armor, which is more representative of this study (15). The author's findings were consistent with the findings of this study in that they concluded the addition of external loads added to a person might reduce dynamic postural balance and place individuals to the limits of their stability (15). Therefore, the results of the present study significantly add to the body of knowledge in that the addition of 6.2 kg external load may affect one's dynamic balance (10, 16).

While significant differences in reach were found in posterior lateral and anterior reach directions between the non-loaded and loaded condition, there were no significant differences found for the posterior medial reach direction for the left leg or the right leg. These findings are inconsistent with findings by Ozunlu, Basari, and Baltaci (2009), which examined the effects of carrying extra load on ankle stability in adolecent basketball players. The authors found only posterior medial components of the SEBT had significant difference between loaded and non-loaded measurement.

The inconsistences between the present study and the study performed by Ozunlu (12) may be due to the way in which the load was applied. The study conducted by Ozunlu (12) included 20% of body weight added externally to the posterior of the participants in the form of a weighted backpack, whereas the present study consisted of a standard 6.2 kg load for each participant distributed vertically. The 20% posteriorly distributed load used by Ozunlu (12) may have affected balance differently than the more evenly and vertically displaced load utilized in the present study, thus causing different results to be found. Furthermore, the external load used by Ozunlu (12) was 20% of the participant's body weight; the 6.2 kg used in the present study was approximately 4.50% to 8.60% of participant's body weight, which is less than that used by Ozunlu (12). Thus, inconsistencies may be due to the differences in the load used as well as the differences in the way the load was distributed. However, the findings in the present study may be more meaningful because the external load used in the present study was that of football equipment and thus, the external load is more representative of not only the amount of load but the distribution of load that football athletes experience during their sport (12). Lastly, the present study found that only the posterior-lateral and anterior reach directions as well as the right leg composite score were significantly affected by the addition of 6.2 kg of external load.

While the present study suggests that the addition of 6.2 kg of external load as applied by football equipment can affect dynamic ankle balance, what still is unknown is how this may affect an athletic trainer's ability to determine if an athlete is or is not ready to return to sport. The posterior lateral reach direction was significantly reduced under the loaded conditions and the anterior reach direction on the right leg, but the meaningfulness of these significant changes regarding approving or withholding an athlete for return to play are unknown. Thus, more research is needed to understand the magnitude of change needed under the loaded condition to withhold an athlete from return to play.

There were several limitations with the present study. First, the authors tested the athletes in bare feet and on a flat, solid surface, which may not be representative of the field of play for all athletes. To address this limitation, future research should not only consider sport-required external load, but may also consider the sport's required footwear as well as ground surface type of the athlete's sport, as this may affect dynamic balance. A second limitation of the present study was that the authors did not consider if the changes in dynamic balance were cause by the amount of external load or the way in which the external load was distributed on the athlete's body; the majority of the 6.2 kg weight was on the participants head and shoulders in the form of the helmet and shoulder pads. Also, the present study did not consider how the football helmet may have affected the participant's visual sense, which in turn, many have affected their performance on the modified SEBT. To address this limitation, future research may include a comparison group wearing a 6.2 kg vest because the vest would provide an even distribution of weight on the participants' body because earlier research as indicated that the way in which weight is distributed can affect balance (12). Furthermore, the present study did not consider leg dominance as a co-variate as this data was not collected or previous injury history of the athlete.

Future studies may consider the effect of an earlier ankle injury. Additionally, range of motion of the hip, knee and ankle was not measured. Future studies should consider including range of motion measurements as earlier research has indicated that variances in reach directions may be affected by differences in ankle dorsiflexion range of motion between subjects (4). Lastly, the current study did not standardize the time of day in which the modified star excursion test was performed. This is a noteworthy limitation because previous research suggests that healthy individual's dynamic postural control scores as measured by the SEBT were better in the morning (1000 hours, 1500 hours, and 2000 hours). Therefore, future studies should consider implementing a protocol that standardizes the time of day the assessment are made when testing protocol is done on multiple days (6).

In conclusion, the present study found that the addition of a 6.5 kg external load in the form of football equipment significantly reduced dynamic stability performance on the modified star excursion balance test. The National Athletic Trainers' Association (NATA) position statement on ankle sprains in athletes outlines guidelines for functional tests to decide when an athlete may return to play. Therefore, NATA may begin to consider revising their position statement to require the athlete to be assessed with the external load that is appropriate for their sport in order to more accurately determine readiness to return to play.

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