THE EFFECTS OF MULTIAXIAL AND UNIAXIAL UNSTABLE SURFACE BALANCE TRAINING IN COLLEGE ATHLETES

TRACEY C. EISEN, JEROME V. DANOFF, JAMES E. LEONE, AND TODD A. MILLER

Department of Exercise Science, The George Washington University Medical Center, Washington, District of Columbia

ABSTRACT

Eisen, TC, Danoff, JV, Leone, JE, and Miller, TA. The effects of multiaxial and uniaxial unstable surface balance training in college athletes. J Strength Cond Res 24(7): 1740–1745, 2010—The purpose of this study was to compare the effects of 2 different types of unstable surface balance training (uniaxial on a rocker board [RB] and multiaxial on a dynadisc [DD]) on balance in division 1 collegiate athletes in sports that are at high risk for ankle sprains. Subjects (n = 36) consisted of male soccer players and female volleyball and soccer players who were equally and randomly assigned to 1 of 3 groups (CON, DD, and RB). Balance training consisting of balancing on 1 leg on either the RB or DD, while repeatedly catching a 1-kg ball was performed 3 times per week for 4 weeks. Balance was tested with the Star Excursion Balance Test (SEBT) before, halfway through, and at the completion of the balance training. Control (CON) subjects also were given the balance test but did not participate in the training. A 3-way repeated analysis of variance revealed that no group individually changed SEBT scores from pre (CON, 0.98 ± 0.086; DD, 0.98 ± 0.083; RB, 0.97 ± 0.085) to post (CON, 1.00 ± 0.090; DD, 1.01 ± 0.088; RB, 1.02 ± 0.068) after balance training. When the 2 treatment groups were combined (DD and RB), the p value decreased and came closer to significance (p = 0.136). When all 3 groups were combined, there was a significant difference in SEBT scores from pretraining (CON + DD + RB; 0.98 ± 0.085) to posttraining (CON + DD + RB; 1.01 ± 0.082), which likely indicates low statistical power. The increase in physical activity the subjects experienced during the return to in-season activity, may have contributed to the significant differences in SEBT scores over time but not between DD or RB training.

Therefore, a threshold level of physical activity may exist that is necessary to maintain balance during the off-season.

KEY WORDS functional ankle instability, star excursion balance test, proprioception

INTRODUCTION

Ankle sprains are common in sports involving running and jumping, particularly when in close proximity to other players (29). A usual mechanism for such injury is landing on another player’s foot when jumping, which forces the foot rapidly into plantarflexion and inversion, stretching and sometimes tearing the lateral ligaments of the ankle (31). Other risk factors of ankle injury are numerous, including intrinsic factors, such as unstable postural sway, muscle weakness and imbalance, poor flexibility or a hypermobile ankle joint, poor proprioception, previous predisposing injury, gender, and anatomical malalignment of the ankle and foot (5,9,17,22,26,35), and extrinsic risk factors, such as shoe type, taping, orthotics worn in footwear, and playing surface (37,38). Functional instability has been defined as “the occurrence of recurrent joint instability and the sensation of joint instability because of the contributions of any neuromuscular deficits,” (17) and becomes evident in up to 20–42% of the patients suffering from an acute ankle injury (4,19).

Balance is an individual’s ability to maintain his or her center of gravity within the base of support (39). Stabilization of postural equilibrium is maintained by continuous afferent and efferent signals within the sensorimotor system with feedback from somatosensory, vestibular, and visual inputs (3). Of the 3 classes of afferent nerves responsible for providing proprioceptive feedback (nerves in the ligaments and joint capsule, skin, or muscle tissue), muscle afferents are thought to play the most important role (33). Motor skill training, which includes balance training, promotes the neuromuscular mechanisms responsible for the co-contraction of agonist and antagonist muscles that enhance joint stability by increasing the sensitivity of feedback pathways and shortening the onset time of these muscles; this increased joint stiffness results in less joint displacement and thus less
strain on joint structures (3,21). The ability to involuntarily increase joint stiffness when in an unstable situation has been shown on multiple occasions to reduce the rate of ankle sprains in athletes (3,4,12,21,26–28,30,38). For example, implementation of balance board training in Dutch volleyball players resulted in a significantly lower incidence of ankle sprains per 1,000 playing hours, when compared to a control group that did no balance training (36).

To stimulate reflex joint stabilization, some believe that activities should focus on sudden alterations in joint positioning (26). Unstable surfaces provide these sudden alterations and make training more dynamic, and possibly more applicable to a sporting context (21). A commonly used unstable surface is a rocker board (RB), which is a flat, wooden surface, typically placed on a half cylinder or a dowel to allow for uniaxial movement along 1 axis of the ankle. With this type of device, the direction of training is determined by the position of the foot relative to the dowel beneath the board. In contrast, an ankle disc, that is, a dynadisc (DD), is a flexible plastic pillow filled with air that allows for multiaxial ankle movement in all axes of the ankle, regardless of foot position on the disc. The muscles that stabilize the ankle to prevent any unwanted motion are the invertors and evertors (such as the tibialis posterior and peroneal muscles) and plantarflexors and dorsiflexors (such as the gastrocnemius and the tibialis anterior) (31). Although uniaxial balance training and multiaxial balance training have both been shown to be effective at increasing balance, no studies have been found that compare the effects of uniaxial vs. multiaxial balance training. Therefore, the purpose of this study was to determine whether mult vs uniaxial balance training lead to differences in measured balance.

METHODS

Experimental Approach to the Problem
As stated earlier, some researchers argue that a sudden alteration in joint positioning is effective at stimulating reflex joint stabilization (26). If this is in fact the case, one might expect that a device designed to induce these alterations in joint position multiaxially, such as the DD (Fitball brand, Allegro Medical, Scottsdale, AZ, USA) (Figure 1) might be more effective at stimulating reflex joint stabilization than a device designed to induce these alterations uniaxially, such as the RB (Exertools, Rohnert Park, CA, USA) (Figure 2), which allows for 12.5° of inversion and eversion only. To date, no research has been performed that compares the effects of uniaxial vs. multiaxial balance training on balance. For this reason, the DD and RB were selected as the balance training devices in this study. With respect to balance testing, a dynamic test may be more sports specific than a purely static test because athletes are exposed to situations where balance is dynamically challenged every time they step, run, or jump (21). For this reason, a dynamic test, the Star Excursion Balance Test (SEBT) was used to test balance before, during, and after 12 sessions of multiaxial or uniaxial balance training.

Subjects
Subjects were athletes from the George Washington University (GWU) in Washington, DC, USA. Subjects were informed of the experimental risks and signed an informed consent document before the investigation. The investigation was approved by the Institutional Review Board for use of Human subjects at GWU. Subjects were members of the women’s volleyball, men’s soccer, and women’s soccer teams, ages ranged from 18 to 22 years. Subjects were all athletes who at the start of data collection were resuming athletic team practice and strength and conditioning sessions after an 8-week break from regularly scheduled physical activity. Data collection occurred throughout the late winter and early spring months, simultaneous with the start of the spring playing season for all subjects in this study. Subjects were attending regular practices and organized strength and conditioning sessions 2–3 times per week. Soccer and volleyball were chosen because of 16 college sports observed between 1988 and 2004 by Hootman et al. (20); these had the highest rates of ankle sprains, according to the National Collegiate Athletic Association Injury Surveillance System (20). All of these teams were out of season during data collection, so outside training was easily controlled, because it consisted mainly of strength and conditioning and agility sessions.

The subject pool of 44 participants was reduced to 36 after multiple participants were excluded because of existing or new injuries incurred during the time of data collection. Participants (n = 36) were recruited via an informational session at a regularly scheduled strength and conditioning session for each of the participating teams. Subjects completed a preparticipation data form solely to identify issues that could affect the outcome of the investigation, and to determine which leg was usually used as the support for a single limb activity such as kicking. Exclusion criteria
included anyone who had any lower back injury, leg injury, or a concussion as recently as 4 weeks before data collection, hypertension, recurrent fainting, or was simultaneously involved in an outside balance training program. Any subjects who experienced a leg, back, or head injury during the course of the investigation also were excluded.

To achieve stratified randomization, subjects first completed the baseline balance test and were then ranked by the investigator from the lowest to the highest %maxd (this outcome measure is explained in the testing procedures). Each subject was assigned a number depending on pretest score, sequentially from highest to lowest (1–36). Based on ranking, scores were classified as top third (numbers one through 12), middle third (numbers 13–24), and lowest third (numbers 25–36). Individuals in each of these sections were randomly assigned to 1 of the 3 experimental conditions: control (CON), RB, and DD.

**Procedures**

**Balance Testing.** Balance testing consisted of the SEBT, as previously described by Bressel et al. (5), Buckley et al. (6), Gribble et al. (14), Hertel (18), Kinzey (25), Plisky (32), and Robinson (34). Briefly, the SEBT consisted of 8 lines of cloth measuring tape adhered to the floor with clear packing tape 45° apart from each other, in the shape of an asterisk. Before testing, the lengths of both lower extremities of each subject were measured by the investigator from the anterior superior iliac spine of the hip to the distal end of the medial malleolus (14). While testing, subjects stood on one leg in the middle of the star and reached as far as possible with their toes of the opposite leg, holding their hands on their hips, and keeping the heel of the stance leg on the ground. A mark on the tape was made by the investigator with an erasable marker and the distance was read from the center of the star to the mark (14).

After each reach, the distance was recorded and the mark erased so that the subject did not use that mark as a target for the next trial. Subjects performed only the posteromedial reach, because this component of the SEBT is highly representative of the performance of all 8 components of the test in limbs with and without chronic ankle instability (14). The subject first practiced the test 3 times, waited 5 minutes, and then performed the test 3 times. The 3 lengths were averaged to find the reach length that was used in the analysis. Hertel et al. (18) also used the averages of 3 reach lengths to determine balance. They applied factor analysis and analysis of variance (ANOVA) to compare the reach directions and concluded that there was sufficient redundancy in the test procedure for any single direction to suffice as a valid representation of lower extremity functional performance.

To normalize the reach length, the investigator divided the reaching distance by the length of the stance lower extremity, then multiplied by 100. This number, abbreviated as %maxd, represents the reach distance as a percent of limb length (14,18). Testing was performed for both limbs and occurred on the initial day of data collection and after the 6th and 12th training sessions. Testing was conducted when the subjects reported to their sport’s scheduled strength and conditioning session before any other activities began.

**Balance Training.** Subjects in each testing group reported at their scheduled time to participate in their regular strength

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre</th>
<th>Post</th>
<th>Change</th>
<th>p Value</th>
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</thead>
<tbody>
<tr>
<td>DD (n = 12)</td>
<td>0.98 ± 0.083</td>
<td>1.01 ± 0.088</td>
<td>0.031 ± 0.080</td>
<td>0.337</td>
</tr>
<tr>
<td>RB (n = 12)</td>
<td>0.97 ± 0.085</td>
<td>1.02 ± 0.068</td>
<td>0.046 ± 0.076</td>
<td>0.348</td>
</tr>
<tr>
<td>CON (n = 12)</td>
<td>0.98 ± 0.086</td>
<td>1.00 ± 0.090</td>
<td>0.021 ± 0.059</td>
<td>0.215</td>
</tr>
<tr>
<td>DD + RB (n = 24)</td>
<td>0.98 ± 0.084</td>
<td>1.02 ± 0.078</td>
<td>0.041 ± 0.078</td>
<td>0.136</td>
</tr>
<tr>
<td>DD + RB + CON (n = 36)</td>
<td>0.98 ± 0.085</td>
<td>1.01 ± 0.082</td>
<td>0.039 ± 0.072</td>
<td>0.007</td>
</tr>
</tbody>
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*DD = dynadisc; RB = rocker board; CON = control.
†Values are given as mean ± SE.
‡Denotes significant difference from pretest (p < 0.001).
and conditioning session, and the balance training was included at the end of the warm-up. Balance training occurred 3 times each week for 4 weeks, as 12 sessions have been shown to be the minimum number needed to result in balance improvement (16). No balance training was performed by subjects in the CON group. Subjects in the experimental groups paired up, and one partner balanced on the assigned surface, RB or DD. Balancing only was done on the predetermined stance leg. If the subject was on a DD, the stance foot was in the middle of the pillow. If the subject was on an RB, the stance foot was in the middle of the board aligned parallel to the dowel on the underside and the board was balanced so that neither the medial nor the lateral edge touched the ground. The partner stood 10 ft back (marked by tape on the ground) and tossed a 1-kg weighted ball underhanded directly to the balancing partner. When catching and then throwing the ball back to his or her partner, the participant attempted to stay on 1 leg on the given unstable surface, and if balancing on the RB, he or she attempted to keep the board balanced. Each partner performed 3 sets of 12 catches on the unstable surface. The athlete’s rest between sets was when the partner was doing the balancing. Throughout the data collection, subjects were asked not to practice the SEBT or perform any additional or other type of balance training outside of their sport or strength and conditioning.

**Statistical Analyses**

Power analysis based on preliminary data established that with a sample size of 36 subjects, statistical power was approximately 30%. A 3-way repeated ANOVA was conducted with group as a between subjects independent variable (the 3 groups were CON, RB, and DD) and time and limb as within subjects (repeated) dependent variables. Outcome measures were recorded as %maxd and change in %maxd throughout the testing. Significant F values, set at a p value of p ≤ 0.05, were subject to Tukey post hoc analysis. In addition, injuries were tracked to compare to national rates in these sports previously determined through a surveillance system (20). Intraclass correlation coefficient (2,1) of the SEBT was previously established at 0.87 (25).

**RESULTS**

With a starting subject pool of 44 and a final n = 36, the adherence rate was 81.8%. Five of the subjects excluded had previous injuries that disqualified them from participation and 3 of the subjects were excluded because of new injuries incurred during athletic team practices during the study period. None of these injuries were at the ankle joint. Performance on the SEBT was significantly different from the pretest to the posttest when all groups and sides were combined, p = 0.007 (Table 1). There was no difference for each group individually, though, and no difference between trained and untrained legs within subject (data not shown).

**DISCUSSION**

The results of this study show that individually, no group showed a significant increase in SEBT score over time. When the experimental groups are compared together against the CON group, the p score comes closer to significance. When all groups are combined, there was a significant difference pre to post. The lack of a significant difference in SEBT score for individual treatment groups could be the result of several possible factors. First, both Impivaara et al. (23) and Davlin (11) found that athletes have superior performance in dynamic balance tasks than do nonathletes. From this, one could speculate that the regular, high levels of physical activity that these athletes were exposed to could be an important contributor to improved dynamic balance. Subjects in this study were all athletes who at the start of data collection were resuming athletic team practice and strength and conditioning sessions after an 8-week break from regularly scheduled physical activity. Possibly the decreased level of activity preceding this study represented a detraining condition with respect to balance. As a result, the increased level of physical activity that occurred upon resumption of regularly scheduled sport participation may have lead to significantly improved scores on the SEBT.

The reporting of improvements in balance among a control group of subjects is not without precedent. Chaiwanichsiri et al. (8) used the SEBT as a balance training method for athletes for 3 d-wk⁻¹ for a 4-week period. Single leg stance time assessed at pre and posttraining improved for both the training group and the control group, but the training group demonstrated significantly greater improvement (p ≤ 0.015) than the control group. This suggests that there is either a treatment effect or practice effect with repeated execution of the SEBT. Because the Chaiwanichsiri study did not test midway through the training, it is difficult to determine if the SEBT score improvements were from the subjects getting better at performing the task, which would represent a practice effect or if the task actually increased subjects’ balance ability, which would represent a treatment effect. Therefore, it is difficult to determine if improvements on the SEBT in the current study were because of a practice or training effect. If it were a training effect, then this study could speculate that the regular, high levels of physical activity that occurred upon resumption of regularly scheduled sport participation may have lead to significantly improved scores on the SEBT.

Estimates based on preliminary data indicated that a subject pool of about 400 people would have been necessary to achieve a power of 70–80%. The changes in SEBT score measured were small compared with the overall variability of the scores. Therefore, true improvements might have been obscured resulting in a type 2 error.

If a possible contributor to the high variability in this study was sport selection. The SEBT is different from other
dynamic balance tests because it requires the subject to perform a maximal reach while balancing. Some sports may have a greater requirement for increased reach ability than others, so it might be practiced more; for example, one would expect a gymnast to be able to reach farther than a volleyball player because of the demands of the sport, though this has not been studied. A future study may have smaller $SD$, and possibly significant findings, if all subjects compete in the same sport.

The subjects used in this current study did not have an ankle injury in the 4 weeks before commencement of data collection, but functional ankle instability is a lingering complication of previous ankle injury (2) and not identifying people with a history of ankle sprains prevented the detection of this disability. In an earlier study, people with functional instability in 1 limb yielded significantly lower scores when performing the SEBT on that limb when compared with their other, healthy limb (7). This presents the possibility of a nonhomogenous subject pool that could have contributed to the high variability in this study. In future research, subjects should have a similar injury history, increasing the chance that they will start with similar scores on the SEBT.

As discussed, physical activity contributes to increased balance ability (11,23). One would expect that if persons are already skilled at something, they do not have as much potential for growth with training as would persons who are new to that skill. Another group of individuals who have not shown to benefit from balance training are subjects who have uninjured ankles (10,21), as was the case with the current study. A possibility for future research would be to use inactive or recently injured subjects, because they have been shown to benefit from balance training programs (4,15).

Injuries incurred during the data collection period consisted of a contact-related concussion, a contact-related low back muscular strain, and lower leg compartment syndrome. Ankle injury rate during this study was 0. National rates of ankle injuries per 1,000 athlete exposures from 1988–1989 to 2003–2004 according to the National Collegiate Athletic Association Injury Surveillance System for men’s soccer, women’s soccer, and women’s volleyball were 1.24, 1.30, and 1.01, respectively (20). One could deduce from this that this study’s training program was a contributing factor to ankle injury prevention, but further research is needed to decide this conclusively.

Twelve training sessions may have been sufficient in previous research (16), but it needs to be recognized that this protocol was different from others shown to help improve balance. Each training session only consisted of 1 exercise. One program proven to help balance involved 12 exercises on an assortment of different unstable surfaces (12). Another program involved a periodization scheme, which at times involved up to 13 different tasks on just 2 different surfaces, the floor and an RB (4). For a training program to contribute to improvements in balance, it needs to challenge the participant.

As previously stated, balance is an individual’s ability to maintain his or her center of gravity within the base of support (39). Dynamic balance is the ability to perform a task while maintaining a stable position (5). If performed correctly, the SEBT tests just that. The SEBT also may train dynamic balance; this needs to be further investigated. As mentioned, considerations for future research also include making subject pools more specific; however, using other populations could be used to determine if the same protocol could have different effects. Younger athletes, nonathletes, other sports, and different injury statuses should be explored.

**Practical Applications**

Because physical activity often results in an improvement in balance (11,23), the authors feel that the physical activity level of the subjects was an independent predictor of balance ability. Preseason balance ability is a significant independent predictor of ankle ligament injury (22), so physical activity, be it balance training or otherwise, needs to be maintained during any break in athletic participation to keep a high level of balance. Activities need to challenge the athlete enough to actually garner improvements in balance. Postural control appears to correlate with anaerobic and aerobic capacity (13), so activities that stress these components should be sufficient. The subjects in the current study participated in conditioning sessions 3 times per week, which included agility training, 3 or 4-mile-long runs, and strength training sessions 3 times per week that usually lasted for 1 hour. This level of activity was likely much higher than that which the subjects voluntarily performed during the off-season and is likely partially responsible for the improved balance in the control group. Because of the important role that general physical activity may play in maintaining balance, physical activity should be kept high during the off-season. Conventional training programs that focus on general fitness (i.e., strength, flexibility, power, and endurance) are likely to be adequate for maintaining balance. Finally, injury rates are significantly higher in the competitive preseason than in- or postseason (1,20,24), so the off-season is just as important as any other time in the athletic year to maintain physical activity.

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**References**


