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**ORIGINAL RESEARCH**

# CHANGES IN DYNAMIC BALANCE AND HIP STRENGTH AFTER AN EIGHT-WEEK CONDITIONING PROGRAM IN NCAA DIVISION I FEMALE SOCCER (FOOTBALL) ATHLETES

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## ABSTRACT

***Background:*** Lower extremity injury commonly affects female soccer athletes. Decreased dynamic balance and hip strength are identified risk factors for lower extremity injury. Little is known about how these factors adapt to a training stimulus in this population.

***Purpose:*** To retrospectively investigate changes in lower extremity dynamic balance and isometric hip strength in Division I collegiate female soccer athletes after participating in an eight-week strength and conditioning program.

***Study Design:*** Retrospective, non-experimental cohort study.

***Methods:*** As part of a standard testing battery, soccer athletes completed athletic performance pre- and post-testing separated by an eight-week off-season conditioning program consisting of overall strength and technical skill development. Testing included lower extremity dynamic balance assessment through the Star Excursion Balance Test (SEBT) and isometric hip abduction and external rotation (ER) strength testing, normalized to limb length and percent body mass, respectively. Athletes rested for one week prior to post-testing.

***Results:*** Seventeen healthy Division I female soccer athletes (age: 18.8 ± 0.9 years, height: 1.7 ± 0.06 m, mass: 68.0 ± 8.2 kg) completed the protocol. Significant improvements in SEBT composite reach distance were observed in the dominant (DOM) (3.6 ± 4.8%, 95% CI: 1.1 to 6.0) and nondominant (NDOM) (4.8 ± 6.1%, 95% CI: 1.7 to 7.9) limbs. Significant improvements in DOM hip ER strength (2.4 ± 2.3%, 95% CI: 1.3 to 3.6) and DOM SEBT anterior reach (2.1 ± 2.8%, 95% CI: 0.6 to 3.5) were observed. Large effect sizes were observed for DOM and NDOM hip ER strength gains (0.87 – 1.0), while small-moderate effect sizes were noted for the anterior reach direction (0.40 – 0.66). Further, DOM hip ER strength gains were significantly associated with DOM anterior reach performance improvements ($r^2 = 0.37$, $p < .01$).

***Conclusion:*** DOM hip ER strength gains appear to be associated with improved lower extremity dynamic balance on the ipsilateral limb for the SEBT anterior reach direction in collegiate, Division I female soccer athletes after an eight-week conditioning program. Future investigations should prospectively investigate intervention strategies to modify lower extremity injury risk factors in this population.

***Level of Evidence:*** 2b

***Key Words:*** Dynamic balance, hip strength, soccer, women

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**Review Board:** Your study has been granted a waiver of the process of informed consent.

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## INTRODUCTION

Women's participation in soccer has dramatically increased recently;[1] however, lower extremity injuries are a substantial concern for this population.[2-4] Injury risk factors have been investigated with efforts to identify reliable, valid means of assessment. Through these efforts, many risk factors have been identified, which include but are not limited to previous injury,[5] accumulated fatigue,[5] decreased hip strength,[6] and impaired lower extremity dynamic balance.[7] Balance can be described as one's capacity to safely sustain or move within the existing base of support, through processing a combination of motor and sensory information.[8] Lower extremity dynamic balance performance varies according to sport,[9] patient population,[10-14] and competition level.[15]

One common, accessible means for evaluating lower extremity dynamic balance is through the Star Excursion Balance Test (SEBT). This reliable test[16,17] assesses postural control with the athlete in single limb stance, while reaching with the non-weightbearing limb in three predetermined directions. Lower extremity dynamic balance, as assessed through the SEBT, has been described across a wide variety of athletic populations at risk for lower extremity injury[7,9,18] and has demonstrated improvement after a neuromuscular training program that included core stability exercises.[19]

SEBT performance is not only influenced by adequate postural control, but also ankle mobility[20] and isometric hip external rotation (ER), extension, flexion, and abduction (ABD) strength.[21,22] Impaired isometric hip ER strength has been identified as a risk factor for lower extremity injury in male and female intercollegiate cross-country and basketball athletes,[23] and hip ABD and ER strength are each predictive of ACL injuries in a heterogeneous cohort of male and female competitive club futsal, soccer, volleyball, basketball, and handball athletes (odds ratio 1.12 – 1.23).[6]

Various training programs have been utilized to address modifiable risk factors for athletic injury. Impaired landing mechanics are associated with decreased isometric hip strength.[24] However, landing strategies improved with a four-week, hip-focused training program consisting of plyometric, balance, and core stability exercises.[25] Additionally, multi-faceted training programs that include components of stretching, strengthening, plyometric training, and agility have been shown to decrease anterior cruciate ligament (ACL) injuries in female soccer athletes.[26,27]

In addition to injury risk modification, previous research has specifically focused on the influence of hip strengthening in various clinical populations. In those with patellofemoral pain, hip strength and patient symptoms improved with an eight-week training protocol that utilized motor control and strengthening strategies for the trunk and hip regions.[28] A similar outcome has been demonstrated in a similar patient population, with earlier patellofemoral pain reduction noted with hip strengthening prior to functional exercises when compared to quadriceps strengthening.[29]

Hip strengthening programs have also proven effective in postoperative rehabilitation. A focused hip strengthening program improved lower extremity dynamic balance in patients with ACL reconstruction at three months postoperative compared to a traditional program.[30] The eight-week training program included a series of weightbearing and non-weightbearing hip strengthening exercises, selected based upon results of prior electromyographical (EMG) studies. It seems as though interventions targeting proximal lower limb motor control and strength may improve known risk factors for lower extremity injury, including dynamic balance and landing mechanics, in specific populations. Examining the influence of different exercise protocols on injury risk factors within distinct athletic populations may allow for a directed, impactful model of exercise prescription.

Many soccer team-based training programs include some aspect of hip strengthening, along with exercises to target overall strength, power, and speed development. Athletic performance testing of lower extremity dynamic balance and hip strength can provide useful information for training program design and implementation. Little is known about how lower extremity injury risk factors, specifically dynamic balance and hip strength, respond to a multi-faceted training program in elite female soccer athletes. The purpose of this study was to retrospectively investigate changes in lower extremity dynamic balance and isometric hip strength in Division I collegiate female soccer athletes after participating in an eight-week strength and conditioning program. The authors' hypothesis was that lower extremity dynamic balance performance and hip strength would both improve with a multi-faceted training regimen.

## METHODS

This study was approved by the University of South Dakota Institutional Review Board. A waiver of consent was granted given the nature of this study. This study was a retrospective review of testing and sports performance records of National Collegiate Athletic Association (NCAA) Division I female soccer athletes from a Midwestern University. Subjects were included in the study if they were a female college-aged athlete, at least 18 years old, enrolled at a Midwestern University, on the women's soccer team roster and participated in an offseason training program led by their team's strength and conditioning staff.

## PROCEDURES

### Athletic Performance Testing

Athletic performance testing for lower extremity dynamic balance and hip strength was completed as part of a standard battery of tests for this cohort on two separate occasions, roughly two months apart, at the initiation and conclusion of an eight-week offseason conditioning program. Athletes were required to receive prior medical clearance from an authorized healthcare provider in order to participate. Athlete health and injury status were monitored throughout the duration of training by the team's athletic trainer, with participation in the training program modified if needed. Initial and post-testing order was consistently applied within the testing battery (Table 1).

**Table 1.** *Testing Procedures*

| Stations | Pre-test | Post-test* |
|---|---|---|
| Warm-up: Stationary upright bike (5 minutes) | • | • |
| Height | • | |
| Limb length | • | |
| Dynamic balance (Star Excursion Balance Test) | • | • |
| Isometric hip strength (Abduction, External rotation) | • | • |
| Body mass | • | • |

*Performed nine weeks after initial testing

Performance testing sessions occurred at the same general time of day in order to minimize diurnal variance in lower extremity dynamic balance performance,[31] on a hardwood athletic court surface.

Athletes began testing with a five minute warm-up on an upright, stationary exercise bike at a Borg's Rating of Perceived Exertion level of 13-15 (somewhat hard – hard).[32] During the warm-up, demographic data including age, playing position, limb dominance (defined as the limb used to kick a soccer ball), and educational year was collected.

### Star Excursion Balance Test

The SEBT protocol began with lower limb length (cm) measurement in supine with a cloth measuring tape, from the inferior aspect of the anterior superior iliac spine of the pelvis to the ipsilateral distal medial malleolus. The SEBT was constructed of three tape measures secured to the floor. The apex was defined as the anterior reach direction, while the two other tape measures (posteromedial and posterolateral reach directions) were secured 135° to the apex. The athlete then performed four SEBT warm-up[33] and three test trials for each limb in the anterior, posteromedial, and posterolateral directions while standing barefoot. Athletes performed test trials once their warm-up repetitions were completed, with trials named to stance limb and reach direction. The athlete stood on one limb with the great toe at the apex of the three reach directions (stance limb). The athlete's reach limb was positioned in non-weightbearing adjacent to the stance limb, then given instructions to maximally reach in the pre-determined direction. The examiner determined the maximal reach distance by reading the point on the tape measure reached by the athlete's great toe. Testing order remained constant, which included the right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral, and left posterolateral reach directions, respectively.

During the warm-up repetitions, athletes were instructed to maintain their hands on their pelvis, and heel of the stance foot in contact with the floor throughout the test. A demonstration was provided by the examiner prior to any practice trials, in addition to verbal descriptions of criteria for an unsuccessful trial as needed, which included losing

**Figure 1.** *Isometric strength testing of hip abduction*

balance, moving or lifting of the stance foot, shifting weight to the reach foot, or removing the hands from the pelvis. A test trial was repeated if any criteria for an unsuccessful trial were observed.

Measurements of reach distance were normalized[34] to the corresponding stance limb. An average of the three test trials was used to calculate the reach distance outcome for each limb and direction. The averaged reach distances, normalized to ipsilateral stance limb length, across all three directions was used to attain a composite lower extremity balance score.[9]

### Hip Strength

Isometric hip strength was assessed at both pre- and post-testing sessions with a handheld dynamometer (HHD) (microFET2, Hoggan Scientific, LLC. Salt Lake City, UT, USA). Hip ABD and ER strength were tested as previously described with slight modifications.[6] One warm-up repetition was performed prior to the test trials. The order of testing included three trials of right hip ABD, left hip ABD, right hip ER, and left hip ER. Athletes were allowed to rest approximately five seconds between each test trial, and 20 seconds between limbs. Each trial was performed as a "make" test.

Athletes assumed the sidelying position for assessment of isometric hip ABD strength, with a strap securing the athlete's pelvis (iliac crest) to a treatment table, while another strap was placed 10 cm proximal to the lateral femoral condyle and secured to the table with the hip in neutral position (Figure 1). The non-test limb was placed in a "position of comfort" during testing, or roughly neutral position. The HHD was placed under the thigh strap on the superior limb, and the athlete was instructed to exert maximal force into the HHD for five seconds. Athletes were placed in short sitting with hips and knees flexed 90°, with feet non-weightbearing for isometric hip ER strength assessment (Figure 2). A strap was placed around the distal thighs to secure the hips in neutral rotation. The HHD was positioned just

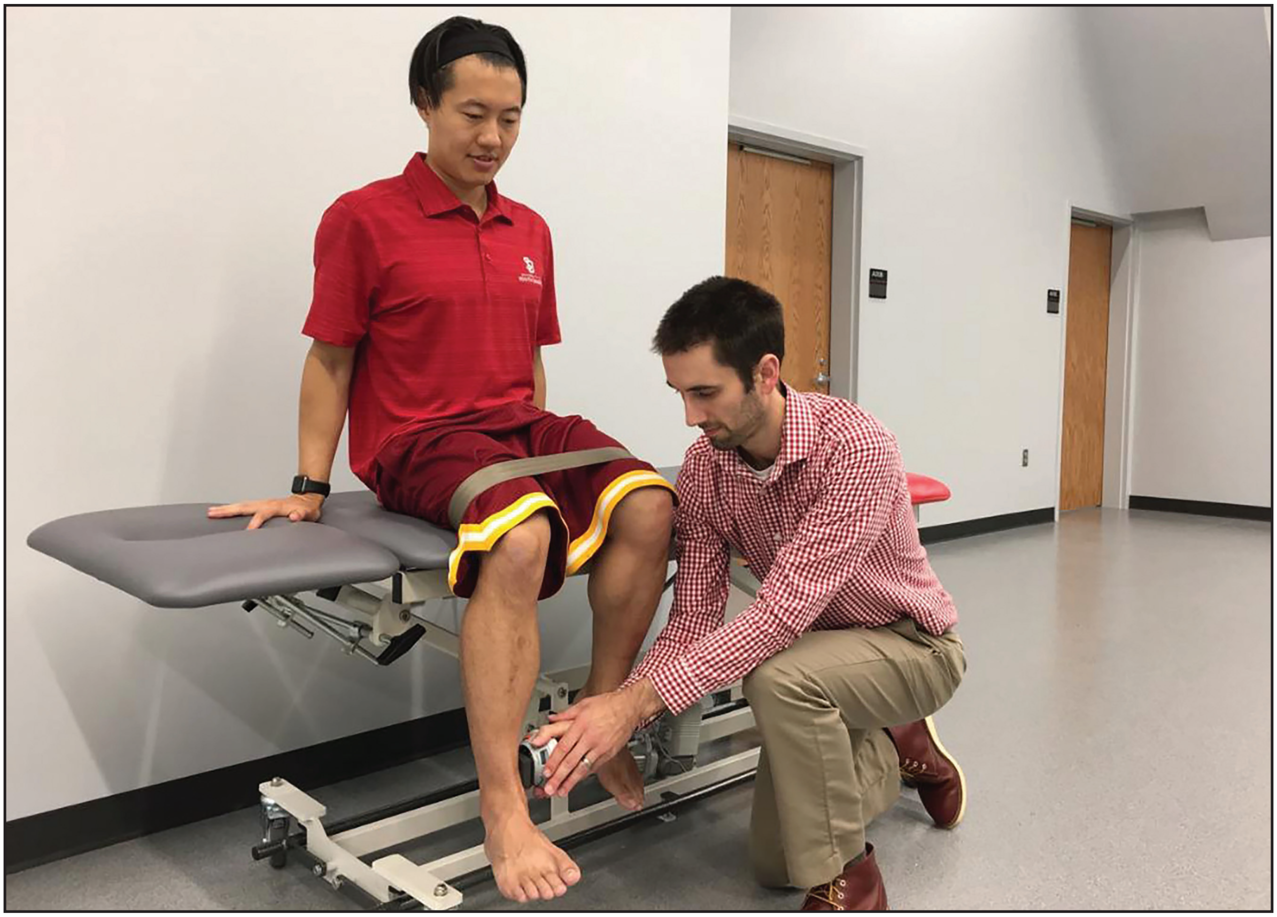

**Figure 2.** *Isometric strength testing of hip external rotation*

proximal to the medial malleolus, with instructions to push with maximal effort into the HHD for five seconds against manual resistance. Three test trials were recorded for both limbs in each direction, and averaged for data analysis, consistent with methods from a prior study.[6]

### Examiners

A physical therapist with four years of orthopedic and sports physical therapy experience led the testing procedures and provided in-person education and demonstration of testing procedures to the other examiners prior to initial testing. A physical therapy student examiner was assigned to each testing station, for both initial and post-testing. Standard error of measurement (SEM) was calculated using standard deviation (SD) and re-test correlation (r) values, where $SEM = SD\sqrt{1-r^2}$. Reliability testing of the examiners revealed good-excellent test-retest reliability for leg length ($r > 0.99$, $p < 0.0001$, SEM 0.98 cm), SEBT assessment ($r = 0.87$, SEM 0.55 - 4.1 cm), and isometric hip strength ($r = 0.88$, $p = 0.0006$, SEM 5.62 kg for ABD and $r = 0.87$, $p = 0.001$, SEM 1.81 kg for ER).

### Strength and Conditioning Program

Athletes completed an eight-week strength and conditioning program during this timeframe, consisting of two, four-week training blocks (Table 2). During this timeframe, athletes also participated in technical skills training with their coaches in individual and small group-based formats (Table 3). The strength program emphasized multi-joint exercises, trunk and lower body exercises, as well as power exercises at a frequency of 2-3 times per week. After the eight weeks of training, athletes were given one week to rest and recover from training. The athletes completed post-testing the following week.

## STATISTICAL METHODS

Analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC) and include descriptive statistics and Pearson correlations. Dependent ANOVAs were used to test the pre-post differences after observing relative symmetry in the score distributions.

**Table 2.** *Strength and Conditioning Program Exercises & Training Load*

| | Exercise Program | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Target of Exercise** | **Speed Strength** | **Total Body** | **Upper Body** | **Lower Body** | **Pull** | **Single Leg** | **Posterior Chain** | **Core Stability** |
| Exercise* | Hang Clean | Barbell Deadlift | Push Ups | Back Squat | Single Arm Row | Step Ups | Lateral Split Squat | 3-Way Planks |
| Frequency† | 3 | 2 | 3 | 2 | 2 | 2 | 3 | 3 |
| Sets | 4-6 | 4-8 | 4-8 | 4-8 | 3-4 | 3-4 | 3 | 3 |
| Reps | 2-3 | 3-5 | 2-10 | 2-8 | 5-12 | 5-12 | 6-12 | 10-30 sec holds |
| Intensity | Athletes were organized into lifting groups according to ability, and provided with guidance to progressively add resistance as indicated. Starting resistance was determined by using a conservative five repetition maximum approach during the initial session. The exercise duration for core stability exercises remained constant throughout the program. | | | | | | | |
| Warm-up | Dynamic movements in a yoga-flow pattern were performed prior to each training session. Squatting, lunging, quadruped, shoulder mobility, foam rolling, resistance band terminal knee extension, hip external rotator and abductor muscle activation exercises against gravity<br>Duration: 5 min | | | | | | | |

*The exercises listed are examples that were included in the training program. Variations of the exercises were performed over the course of the program in accordance with the target of the exercise;
†Training days per week

**Table 3.** *Training Program Overview**

| | **Weeks 1-4 (Block I)** | **Weeks 5-8 (Block II)** | **Week 9** |
|---|---|---|---|
| **Strength & conditioning program** | Warm-up, power, core, upper and lower body exercises (refer to Table 2 for program details)<br><br>Frequency: 3 days/week<br>Duration: 60 minutes/session | | Rest |
| **Technical and tactical training** | Individual technical training<br>• Dribbling, passing, & receiving with emphasis on accuracy<br>• Position-specific training<br>Small group tactical training<br>• 1 v. 1, 2 v. 2, 3 v. 3<br>• Small-sided games<br><br>Frequency: 2 days/week<br>Duration: 120 minutes/session | | Rest |

*Athletic performance testing completed at week 1 and week 10

## RESULTS

Seventeen athletes were included in data analysis (age: 18.8 ± 0.9 years, height: 1.7 ± .06 m, mass: 68.0 ± 8.2 kg). SEBT performance and hip strength pre- and post-testing results, along with effect sizes, are outlined in Table 4. The mean values for improvement and standard deviation of these measures are reported in Table 4, along with 95% CI. Significant differences were determined based on the 95% CI value not containing a zero value, thus rejecting the null hypothesis of improvements being due to chance alone. SEBT performance improved globally from pre- to post-testing; however, varied findings were observed with respect to limb dominance and reach direction. Significant improvements were identified in SEBT composite reach score in the dominant (DOM) and nondominant (NDOM) limbs. Significant improvements were seen in the anterior and posterolateral reach directions; however, this

**Table 4.** *Pre- and Post-Testing Results for Star Excursion Balance Test Performance and Isometric Hip Strength after Training*

| | Limb | Direction | Pre-Test | Post-Test | Change score | Cohen's *d* |
|---|---|---|---|---|---|---|
| **Star Excursion Balance Test, expressed as % LL** | | | | | | |
| | Dominant | COMP | 88.2 ± 6.3 (85.0, 91.5) | 91.8 ± 5.6 (88.9, 94.6) | 3.6 ± 4.8 (1.1, 6.0) | 0.59 |
| | | ANT | 71.8 ± 5.1 (69.2, 74.4) | 73.9 ± 5.3 (71.2, 76.6) | 2.1 ± 2.8 (0.6, 3.5) | 0.40 |
| | | PM | 100.0 ± 9.5 (95.1, 104.9) | 103.0 ± 6.8 (99.6, 106.5) | 3.0 ± 6.5 (-0.3, 6.4) | 0.37 |
| | | PL | 94.2 ± 8.3 (89.9, 98.5) | 99.2 ± 7.7 (95.2, 103.1) | 5.0 ± 8.0 (0.8, 9.1) | 0.62 |
| | Nondominant | COMP | 86.9 ± 6.6 (83.5, 90.3) | 91.7 ± 6.9 (88.1, 95.2) | 4.8 ± 6.1 (1.7, 7.9) | 0.71 |
| | | ANT | 70.3 ± 4.9 (67.8, 72.9) | 73.7 ± 5.2 (71.0, 76.3) | 3.4 ± 3.5 (1.6, 5.2) | 0.66 |
| | | PM | 100.6 ± 7.0 (97.0, 104.1) | 102.8 ± 7.9 (98.7, 106.9) | 2.3 ± 7.4 (-1.5, 6.1) | 0.31 |
| | | PL | 94.8 ± 9.9 (89.7, 99.9) | 101.8 ± 6.8 (98.3, 105.3) | 7.0 ± 7.6 (3.1, 11.0) | 0.85 |
| **Hip Strength, expressed as % BW** | | | | | | |
| | Dominant | Abduction | 35.0 ± 10.5 (29.6, 40.4) | 35.5 ± 9.6 (30.6, 40.4) | 0.5 ± 6.3 (-2.7, 3.8) | 0.05 |
| | | External Rotation | 11.2 ± 2.0 (10.2, 12.2) | 13.6 ± 2.9 (12.1, 15.1) | 2.4 ± 2.3 (1.3, 3.6) | 1.0 |
| | Nondominant | Abduction | 35.2 ± 9.7 (30.2, 40.2) | 34.0 ± 9.8 (29.0, 39.0) | -1.2 ± 6.7 (-4.7, 2.3) | 0.12 |
| | | External Rotation | 12.4 ± 1.9 (11.4, 13.3) | 14.4 ± 2.7 (13.0, 15.7) | 2.0 ± 2.1 (0.9, 3.1) | 0.87 |

Values expressed as mean ± standard deviation (95% confidence interval); COMP, composite score; ANT, anterior reach; PM, posteromedial reach; PL, posterolateral reach; %LL, percentage of lower limb length; % BW, percentage of body weight

was not observed for the posteromedial direction. Effect size magnitude order was consistent across DOM and NDOM limbs for SEBT composite score and individual reach directions, with the anterior reach direction demonstrating a small-moderate effect size (0.40 – 0.66).

Athletes demonstrated a significant improvement in isometric hip ER strength, but this trend was not observed for hip ABD. Large effect sizes were observed for DOM and NDOM hip ER strength gains (0.87 – 1.0). Further, DOM hip ER strength gains were significantly associated with DOM anterior reach performance improvements ($r^2 = 0.37$, $p < 0.01$), as described in Table 5. Thus, DOM hip ER strength increases explained 37% of the variance in DOM anterior reach performance gains.

## DISCUSSION

Rehabilitation professionals are often faced with the challenge of designing and implementing training

**Table 5.** *Pearson Correlations for Changes in Star Excursion Balance Test* (SEBT) Composite (COMP) Score and Anterior (ANT) Reach Performance, and Hip Abduction (ABD) and External Rotation (ER) Strength† for the Dominant (DOM) and Nondominant (NDOM) Limbs*

| | SEBT COMP DOM | SEBT COMP NDOM | SEBT ANT DOM | SEBT ANT NDOM |
|---|---|---|---|---|
| Hip ABD DOM | 0.35 (0.17) | 0.47 (0.06) | 0.59 (0.01)‡ | 0.51 (0.04)‡ |
| Hip ABD NDOM | 0.07 (0.79) | 0.004 (0.99) | 0.25 (0.34) | 0.34 (0.18) |
| Hip ER DOM | 0.39 (0.12) | 0.13 (0.63) | 0.61 (0.009)‡ | 0.34 (0.18) |
| Hip ER NDOM | 0.14 (0.6) | 0.27 (0.30) | 0.56 (0.02)‡ | 0.45 (0.07) |

Values expressed as *r* (p); *Percent limb length, †Percent body weight, ‡Significant Correlations at $p \leq 0.05$

programs that will achieve desired outcomes in a safe, efficient manner. Little evidence exists regarding a multi-faceted team-based training program's influence on lower extremity injury risk factor modification. This is one of the first investigations to examine training adaptations for hip strength and lower extremity dynamic balance in high-level female soccer athletes.

Various exercise protocols targeting the proximal and distal lower limb have been examined with respect to their associated influence on injury risk factors. Stearns and Powers[25] investigated changes in hip muscle performance after a four-week plyometric and balance exercise program in recreationally active females, which resulted in improved hip strength and drop-jump landing mechanics. However, several ankle strengthening protocols have not shown improvement in lower extremity dynamic balance in those with chronic ankle instability.[35] The improvements in hip ER strength and lower extremity dynamic balance in the current cohort were observed after completing a broad training regimen over an eight-week timeframe. Conversely, a similar degree of improvement was not observed for the SEBT posteromedial reach direction. This could in part be due to the lack of significant change in hip ABD strength in this cohort, as gluteus medius EMG activation has previously been shown to be greatest when performing the SEBT posteromedial reach.[36]

Improving SEBT anterior reach performance is of particular interest, as this has shown to be the reach direction with best ability to predict lower extremity injury in athletes.[7] The current study identified DOM hip ER strength gains being significantly associated with improved DOM anterior reach distance after training. Other investigations have similarly identified an association between hip strength and anterior reach performance in collegiate female athletes;[22] however, it was hip flexor and extensor strength that was fairly correlated, rather than hip ER strength. Hip flexor and extensor strength were not assessed in the current study, which may have offered further insight into training adaptations. Additionally, a hip strengthening-focused program was superior to traditional rehabilitation for improving anterior reach performance symmetry in those recovering from ACL-reconstruction.[30] The current training program included a multi-modal approach with core stability, hip strengthening, multi-joint, and power exercises. Similar exercises have been applied in previous investigations, resulting in improved lower extremity dynamic balance performance[19] and a reduced number of ACL injuries.[26,27] Findings in the current and previous studies support the notion that multi-faceted training programs can positively effect SEBT anterior reach performance and hip strength.

Pre-test SEBT performance values were similar to those found in a previous examination of Division I female soccer athletes for the composite and anterior reach directions; however, post-test values were somewhat increased, comparatively,[9] with mostly moderate-large effect sizes observed in lower extremity balance improvements. When reporting values for SEBT distances, it is important to consider the method used to calculate reach performance. Some studies report a single normalized maximal reach value in each direction,[7,37-39] which is then used to calculate a composite reach distance on each limb, while another computed the average of three test trials to attain normative data.[9] This discrepancy in statistical methodology can have a profound impact on the interpretation of study outcomes. Generally, using average values for reach distances will decrease the athlete's overall SEBT performance. When applying injury risk stratification, historically maximal reach distance scores in each direction have been reported.[7,37] The current study reported average reach distances observed in each direction across three test trials for comparison to a similar population in a previous study.[9] Standardized reporting of SEBT outcomes would improve generalizability across athlete groups.

SEBT performance relies in part on varying hip and thigh muscle activation patterns according to reach direcction.[36,40] Gluteus medius and maximus activation during the SEBT have been investigated with EMG analysis.[36] The gluteus medius is thought to contribute to hip ER strength, but primarily with the hip positioned in extension. Since the hip joint on the stance limb is positioned in flexion for the vast majority of the SEBT anterior reach, it is difficult to speculate if improved strength in this muscle group contributed to improved SEBT performance. The primary hip ER muscle group includes the piriformis, superior/inferior gamellus, obturator internus/externus, and quadratus femoris. These muscles are difficult to assess with EMG analysis due to their location and anatomical complexity. Future investigations into other muscle activation strategies on the SEBT may provide further insight for rehabilitation professionals to improve training program design and SEBT performance.

Comparisons of isometric hip strength testing methodology to the specificity of SEBT performance, along with the outcomes in other athletic populations must be examined. Hip ER strength performance in this group of high-level soccer athletes was similar to previous investigations examining athletes in other sports. Differences in study populations and testing protocols may account for some variances. Soccer athletes heavily use their lower extremities given the nature of their sport requiring running, cutting, jumping, and kicking activities. However, the mean hip ER strength values were slightly lower compared to basketball and track athletes.[23] Hip strength outcomes may have been influenced by testing position. Hip ER was tested with the athlete seated in 90° of hip flexion, similar to previous investigations.[6,21,22] During the SEBT, athletes rarely approach this degree of hip flexion. It would seem appropriate to explore other joint angles of isometric hip strength assessment, as it was previously reported that approximately 35° of hip flexion occurs when performing the SEBT in healthy female controls.[13] Similarly, hip ABD was assessed in a neutral position in the current study, while testing position of slight hip ABD has been applied previously.[6,23] It was found that isokinetic concentric hip extensor and flexor strength was not highly associated with SEBT performance in college female soccer athletes.[18] Considerations for differences between athletic populations and hip strength testing methods limit generalizability to a degree.

After eight weeks of training, measurements of risk factors for lower extremity injury significantly improved in this cohort. Hip ER strength and SEBT anterior reach improved bilaterally after training; however, only DOM hip ER strength gains were significantly associated with increases in DOM anterior reach. Previously, an association between hip ER strength and SEBT performance was only observed in the posteromedial reach direction in a cohort of high school-aged female lacrosse athletes.[21] Differences in sport-specific requirements and athletic population may have partially accounted for these variances. Specifically, soccer athletes' balance performance was greater when standing on the NDOM extremity during both static[41] and dynamic[42] activities when compared to the DOM limb. The DOM limb is typically defined by the side preferred for kicking, which leaves the NDOM, or stance limb, favored to provide dynamic stability during this activity. The authors posit that the DOM extremity had a greater potential for strength gains given lower pre-test values, which was reflected by a small, but larger increase in DOM hip ER strength when compared to the NDOM limb. The greater magnitude of DOM hip ER strength improvement may have led to a higher degree of association with DOM SEBT anterior reach performance gains. Also, the intent of the current investigation was to identify an association between hip strength and SEBT anterior reach performance training adaptations, rather than baseline performance correlations. A ceiling effect may have influenced outcomes for hip strength and SEBT performance gains, given a fit, healthy cohort of high level soccer athletes was studied. Different levels of trainability may exist in other athlete or clinical populations.

## LIMITATIONS

The ability to generalize this report is limited in several ways. The athletes were simultaneously participating in individual and small group-based technical training with their soccer coaching staff twice per week while completing the strength and conditioning program, which makes it difficult to discern which part of the training program had the most influence on testing results. Other limitations in methodology included the lack of a control group and small sample size, given the nature of this retrospective report. The lack of blinding is also a potential source of bias.

Allowing for a "rest" week between the cessation of the strength training program and post-test may have influenced outcomes to a degree, as fatigue level was not formally assessed amongst the athletes at the time of post-testing. Although injury risk factor markers did improve with training, it is inappropriate to speculate whether a change in injury rates would be observed given the scope of this study. The overall improvement in lower extremity balance and hip strength is difficult to interpret without substantial minimal clinically important difference or minimal detectable change data available for this population. Future research may work to identify clinically meaningful change in SEBT performance according to various athlete groups.

## CONCLUSION

Isometric hip ER strength and lower extremity dynamic balance as measured by the SEBT, with the exception of the posteromedial reach direction, improved after completing an eight-week strength and conditioning program in collegiate, Division I female soccer athletes. DOM hip ER strength gains appear to be associated with improved SEBT anterior reach on the ipsilateral limb. Future investigations should prospectively investigate lower extremity injury risk factors and intervention strategies in female soccer players.

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