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Neuromuscular Training Improves Performance on the Star Excursion Balance Test in Young Female Athletes

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Abstract

STUDY DESIGN—Controlled cohort repeated-measures experimental design.

OBJECTIVES—To determine if a neuromuscular training program (NMTP) focused on core stability and lower extremity strength would affect performance on the star excursion balance test (SEBT). We hypothesized that NMTP would improve SEBT performance in the experimental group and there would be no side-to-side differences in either group.

BACKGROUND—The SEBT is a functional screening tool that is used to assess dynamic stability, monitor rehabilitation progress, assess deficits following an injury, and identify athletes at high risk for lower extremity injury. The SEBT requires lower extremity coordination, balance, flexibility, and strength.

METHODS—Twenty uninjured female soccer players (13 experimental, 7 control) participated. Players trained together as a team, so group allocation was not randomized. The SEBT was administered prior to and following 8 weeks of NMTP in the experimental group and 8 weeks of no NMTP in the control group. A 3-way mixed-model ANOVA was used to determine the effect of group (experimental versus control), training (pretraining versus posttraining), and limb (right versus left).

RESULTS—After participation in a NMTP, subjects demonstrated a significant improvement in the SEBT composite score (mean ± SD) on the right limb (pretraining, 96.4% ± 11.7%; posttraining, 104.6% ± 6.1%; $P = .03$) and the left limb (pretraining, 96.9% ± 10.1%; posttraining, 103.4% ± 8.0%; $P = .04$). The control group had no change on the SEBT composite score for the

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right (pretraining, 95.7% ± 5.2%; posttraining, 94.4% ± 5.2%; $P = .15$) or the left (97.4% ± 7.2%; 93.6% ± 5.0%; $P = .09$) limb. Further analysis identified significant improvement for the SEBT in the posterolateral direction on both the right ($P = .008$) and left ($P = .040$) limb and the posteromedial direction of the left limb ($P = .028$) in the experimental group.

CONCLUSION—Female soccer players demonstrated an improved performance on the SEBT after NMTP that focused on core stability and lower extremity strength.

LEVEL OF EVIDENCE—Performance enhancement, level 2b-.

Keywords

core stability; core strengthening; injury prevention training; trunk neuromuscular control

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In the United States more than 3.1 million females participate in high school sports annually.[22] Soccer is ranked fifth in popularity, with over 346 000 female athletes having participated in the sport during the 2007–2008 school year.[22] As the popularity of women's soccer grows, the incidence of injury in high school sports has become more apparent. From 1995 to 1997, an estimated one quarter of female soccer athletes reported experiencing multiple injuries over a 2-year period, while over 72% sustain at least 1 injury.[28]

With such a high incidence of injury in female athletes, resulting in significant time lost and healthcare expense, the need to develop interventions with the potential to decrease injury risk is apparent. Several studies support the use of interventions such as neuromuscular training programs (NMTP) to reduce the incidence of lower extremity injuries.[9,11,15,17,31] The most effective programs emphasize several common components, including plyometric training in combination with biomechanical feedback and technique training.[9,31] Implementation of a NMTP that focuses on core stability exercises is advocated to prevent lower extremity injury, namely in female athletes who have deficits in trunk proprioception and neuromuscular control.[34] Importantly, poor core stability and decreased muscular synergy of the trunk and hip stabilizers have been theorized to decrease performance in power activities and to increase the incidence of injury secondary to lack of control of the center of mass, especially in female athletes.[11,33]

Targeted NMTP are designed to reduce injury risk, and include interventions that focus on increased control of the center of mass. As the center of mass moves away from the base of support, there is an increased potential for biomechanical deviations to occur in the lower extremity. An improved ability to control this movement has the potential to decrease excessive forces on the lower extremity and ultimately decrease injury risk.[34]

The star excursion balance test (SEBT) is a functional screening tool developed to assess lower extremity dynamic stability, monitor rehabilitation progress, assess deficits following injury, and identify athletes at high risk for lower extremity injury.[4,5,14,16,23,25–27] The SEBT requires neuromuscular characteristics such as lower extremity coordination, balance, flexibility, and strength.[2,5,16,27] Plisky et al[26,27] found that female athletes who had a composite reach distance on the SEBT of less than 94% of their limb length were 6.5 times more likely to have a lower extremity injury. As a result, the SEBT may be a useful tool to assess the efficacy of training programs designed to reduce injury risk.

The purpose of this study was to determine if an 8-week NMTP that focused on core stability and lower extremity strength could improve performance on the SEBT. We hypothesized that the neuromuscular training group would show significant improvements on the SEBT composite score that would not be seen in a control group. In addition, we hypothesized there would be no side-to-side differences in the SEBT composite score in either the experimental or the control group.

METHODS

Subjects

Twenty subjects (13 experimental, 7 control) with no prior history of lower extremity injury were recruited from 2 soccer teams to participate in this study. Data from prior work suggested that a minimum of 7 subjects in each group would be required to meet statistical power, with the alpha level set at .05 and beta at .80, assuming the mean difference would be a 10% improvement with a standard deviation of 7.5%. The subjects were allocated by team to participate in the experimental or control group. The subjects in each group were similar in terms of age, height, and body mass (TABLE 1). The subjects participated in an identical level of play and were exposed to similar soccer activity between pretraining and posttraining measurements.

To be included in the study, each subject had to be an active member of a soccer team at the high school or competitive level and free from injury prior to participation in the study. Subjects were excluded if they failed to complete the pretest or posttest, sustained an unrelated injury that limited their ability to complete the NMTP, or failed to participate in a minimum of 80% of the NMPT training sessions (13 of 16 sessions). Four subjects in the experimental group were excluded due to experiencing an injury unrelated to the NMTP (n = 1) or lack of training compliance (n = 3). These subjects were not retested at the 8-week follow-up. The data from 16 subjects (9 experimental, 7 controls) were used for final statistical analysis.

Procedure

Prior to testing, all subjects and their parent/guardian received and signed an informed consent approved by Cincinnati Children's Hospital Medical Center's Institutional Review Board, which stated how the subject's rights would be protected. Initial testing included all demographic and anthropometric assessments of height, mass, and limb length. Subjects were interviewed to determine prior injury history. The experimental group participated in 8 weeks of biweekly neuromuscular training, while the control group did not participate in the intervention or other training outside of their normal activities. Posttraining testing occurred 8 weeks after the pretraining test session.

Star Excursion Balance Test

Each subject completed a modified SEBT modeled after the methodology described by Plisky et al[27] on 2 occasions, 8 weeks apart. Subjects received verbal instruction and visual demonstration of the SEBT from the same examiner, who was not blinded to group assignment. The subjects stood on 1 lower extremity, with the most distal aspect of their great toe on the center of the grid. The subjects were then asked to reach in the anterior, posteromedial, and posterolateral direction, while maintaining their single-limb stance (FIGURE 1). Six practice trials were performed on each limb for each of the 3 reach directions prior to official testing.[14] On the seventh trial, the examiner visually recorded the most distal location of the reach foot as it contacted the grid in the 3 directions. The trial was discarded and the subject repeated the testing trial if (1) the subject was unable to maintain single-limb stance, (2) the heel of the stance foot did not remain in contact with the floor, (3) weight was shifted onto the reach foot in any of the 3 directions, or (4) the reach foot did not return to the starting position prior to reaching in another direction. The process was then repeated while standing on the other lower extremity. The order of limb testing was counterbalance randomized by the tester. The subject's limb length measurements, from the most distal end of the anterior superior iliac spine to the most distal end of the lateral malleolus on each limb, were taken and recorded. In previous work, the SEBT has demonstrated good intratester reliability, with an intraclass correlation coefficient (ICC) of 0.67 to 0.96.[8,14] Intratester reliability for this study on the SEBT composite score and all 3 individual reach directions was good to excellent (TABLE 2). The SEBT composite score was calculated by dividing the sum of the maximum reach distance in the anterior (A), posteromedial (PM), and posterolateral (PL) directions by 3 times the limb length (LL) of the individual, then multiplied by 100 $\{[(A + PM + PL)/(LL \times 3)] \times 100\}$.

Training Program

The NMTP was adapted from previous epidemiologic and interventional investigations that have reported reductions in lower extremity injury risk factors.[17,18] The exercises in this program were selected from injury prevention research to address lower extremity strength and core stability.[9,11,15,17–19,21,24] Core stability is defined as dynamic trunk control which allows for the production, transfer, and control of force and motion to distal segments of the kinetic chain.[13] The goal of this NMTP was to improve the athlete's ability to control the center of mass during dynamic activities.

The biweekly training of the experimental group was conducted by 4 physical therapists who were also certified strength and conditioning specialists, and 1 student physical therapist. The subject-therapist ratio was 4:1 for each session. The experimental group participated in biweekly training sessions for a total of 16 sessions during a competitive season. The NMTP took-place on 2 nonconsecutive days of the week over an 8-week time frame. Each session consisted of a 5-minute warm-up using an agility ladder, two 45-minute increments of lower extremity strength and core stability training, and a 5-minute cool-down that included static and dynamic stretches. The core stability component was divided into 5 phases of progressive exercises (TABLE 3). Two or 3 days were spent on each phase. The lower extremity strengthening program consisted of 2 groups of exercises which were performed on alternating training sessions (TABLE 4). These exercises were progressed using periodization techniques. This NMTP did not include exercises that emulated the SEBT.

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The NMTP was designed to gradually progress lower extremity strength and core stability by incorporating exercises that increase lateral trunk perturbations. The exercise progressions were developed from previous biomechanical investigations that reported reductions in knee abduction load in female athletes.[17–20] Initially, a low volume was used for the high-intensity exercises until correct technique was attained. When the athlete could perform the exercise with proper mechanics as determined by the instructor, the volume was increased. The instructors gave verbal and visual feedback with each exercise to the subjects. Athletes executed each exercise using only proper technique and were required to stop if they could not perform the exercise with correct biomechanics. The exercises were progressed from stable surfaces to dynamic surfaces such as Airex pads (Perform Better Inc, Cranston, RI), BOSU trainers (BOSU Balance Trainer [Fitness Quest Inc], Canton, OH), and Swiss balls (Perform Better Inc), to increase demands on lower extremity strength and core stability. The subjects were required to maintain proper technique, while external perturbations (ball toss, unanticipated movement to the base of support) were applied to increase difficulty of the task.

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Statistical Analysis

Unpaired *t* tests were used to assess for differences in demographic and anthropometric data between groups. The SEBT scores were used as the dependant variables. Group comparisons were done with a 2-by-2-by-2 mixed-model analysis of variance (ANOVA) to determine the effect of training (pretraining versus post-training), group (experimental versus control), and limb (right versus left) on the outcome of the SEBT composite and individual directions scores. Statistical analyses were conducted in SPSS, Version 15.0 (SPSS Inc, Chicago, IL). Statistical significance was established a priori at $P \leq .05$.

RESULTS

Comparison of the demographic data between the experimental and control group showed no significant difference in age, height, or mass ($P > .05$) (TABLE 1). Pretraining SEBT composite scores showed no significant side-to-side difference within subjects or between groups (experimental versus control) ($P > .05$).

There was a significant training-by-group interaction (F = 5.71, $P = .024$), with no effect of limb (F =0.51, $P = .479$) for the SEBT composite score. Subjects in the experimental group improved performance of the SEBT composite score on both limbs after 8 weeks of training, while no change was observed in the control group. Partial η^2 effect size was determined to be 0.169. Partial η^2 effect size statistics demonstrate the proportion of variance of the dependant variable explained by the independent variable. Values can range from 0 to 1, with small (0.01), medium (0.06), or large (0.138) effect size. The results indicate that there is a large effect size according to this classification.[1] The improvement seen on the SEBT occurred despite the NMTP not replicating the SEBT. The SEBT composite score improved from a mean ± SD of 96.4% ± 11.7% to 104.6 % ± 6.1% of limb length on the right lower extremity ($P = .03$) and from 96.9% ± 10.1% to 103.4% ± 8.0% of limb length on the left lower extremity ($P = .04$), following the NMTP. Conversely, there was no significant change in the SEBT composite score of either the right (95.7% ± 5.2% to 94.4% ± 5.2%; $P = .15$) or the left (97.4% ± 7.2% to 93.6% ± 5.0%; $P = .09$) limb in the control group (FIGURE 2).

Analysis of change in each individual reach direction revealed a significant interaction for group (experimental versus control) by training (pretraining versus posttraining) for both the right ($P = .008$) and left ($P = .040$) limb in the posterolateral direction, and the left limb ($P = .028$) in the posteromedial direction, for the subjects in the experimental group. No differences were seen for the right limb ($P = .226$) in the posteromedial direction and for neither the right ($P = .321$) nor left ($P = .193$) limb in the anterior direction for the experimental group. A summary of data is presented in TABLE 5.

DISCUSSION

Prior to training, both the experimental and the control groups of female athletes demonstrated similar performance on the SEBT in all measured variables. Following a NMTP, the SEBT composite score significantly improved in the training group compared to the control group, who did not participate in a NMTP. Improvement in the SEBT composite score in the NMTP group appeared to be dependent on an improvement in the posterolateral and posteromedial reach, as indicated by the independent reach analysis. No differences in reach were found in the anterior direction. Improvements in the posterolateral and posteromedial direction are likely the result of improved neuromuscular control and dynamic balance, and less related to lower extremity strength, as was suggested by Thorpe and Ebersole.[32]

The NMTP design was based on injury prevention research.[9,10,11,15,17–19,21,24,32] Each aspect of the NMTP was enhanced with verbal feedback and visual demonstration to improve the athletes biomechanical technique.[9,31] Current literature supports the use of NMTP that incorporate core stability as part of treatment programs to prevent injury of the ankle or knee.[16,34] Decreased neuromuscular control of the trunk appears to influence dynamic stability of the lower extremity during high-speed athletic maneuvers.[34]

In a systematic review by Thacker et al,[31] 6 prospective studies that addressed training programs that all proved to have reduced knee injuries were chosen. The 6 programs consisted of neuromuscular, proprioception, and/or acceleration training. Of the 6 studies, 4 were randomized controlled studies, but none reported blinding of the assessor or the details of the randomization of the subjects. The training programs demonstrated positive results, with significantly reduced knee injury rates compared to controls who did not participate in a training program.[31] Other studies have also confirmed improved postural control and balance following rehabilitation and training programs in individuals with chronic ankle instability.[5,16] The individuals in the NMTP in the current study showed improvements in the SEBT composite scores when compared to nontrained controls. However, its effect on knee or ankle injury rate was not assessed in this study. The SEBT may have the potential to be a corollary outcome measure that can be utilized to compare the efficacy of programs that reduce injury rates.[27]

Prior research indicates that isolated strength measures may not have an effect on the SEBT score. Thorpe and Ebersole[32] compared recreational and collegiate female soccer student athletes and found no difference in isokinetic strength. They also showed that there was a low to moderate correlation between SEBT performances and lower extremity strength. Therefore, other factors, such as muscle activation and proprioception, may have a stronger relative relationship to the SEBT performance than non–weight-bearing strength testing. In addition, neither group of the above study participated in a NMTP that might have contributed to the lack of change on the SEBT.

Robinson and Gribble[29] suggested that improvements in the SEBT were not due to strength or core stability but, rather, to increased knee and hip flexion on the stance limb. Their study consisted of 20 participants from a university setting who did not undergo any intervention program. Stepwise regression revealed that hip flexion and knee flexion, separately and in combination, accounted for 62% to 95% of the variance in reach distances.[29] It is important to consider that Robinson and Gribble[29] did not measure lower extremity strength. It is possible that participants who showed increased knee and hip flexion potentially had more lower extremity strength compared to the subjects who had less knee and hip flexion angles.

Sato and Mokha[30] looked at the effects of a core strength training program on ground reaction forces, stability of the lower extremity using the SEBT, and overall running performance in recreational and competitive runners. They did not find any improvements in SEBT after implementing a 6-week core strength training program. However, there are several differences that existed between this study and the current one. These included a lack of balance training and biomechanical feedback, a different definition of core stability training, and a different testing protocol for the SEBT.

Specific thresholds have been developed to screen for injury risk using the SEBT. Plisky et al[26,27] found that female athletes with less than 94% composite reach during the SEBT were upwards of 6 times more likely to experience an injury. Although the mean SEBT composite score for both groups was initially above the 94% threshold for injury risk, the NMTP focused on lower extremity strength and core stability training did improve the SEBT composite score. Individually, in the trained group, 7/18 of the limbs scored below the 94% threshold at pretraining. Posttraining, only 2/18 limbs were below 94% threshold. The 2 subjects who remained below the threshold posttraining were below 94% pretraining. Based on Myer et al,[19] the results are expected to be magnified in athletes who would fall below the injury risk threshold. This infers that participation in a NMTP that focuses on lower

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extremity strength and core stability may reduce the risk of injury. If a NMTP could improve SEBT measures, then athletes could be evaluated for SEBT composite reach before competition and be preventatively placed in a NMTP targeted toward deficits in lower extremity strength and core stability.

The SEBT may be a sufficiently sensitive tool for trained athletes that can be used prior to competition to assess neuromuscular factors more comprehensively than strength alone.[32] The SEBT has also been examined to determine the correlation between anterior cruciate ligament injury with the lack of postural control and was found to successfully demonstrate limitations in individuals who were anterior cruciate ligament deficient compared with asymptomatic individuals. Individuals who were anterior cruciate ligament deficient had significantly lower reach scores on both the involved and uninvolved extremity compared to uninjured controls.[6]

Following the NMTP, there was no difference in composite score between limbs in the control group or in the experimental group. This may be due to the design of the NMTP, which focused on the performance of exercises equally on each limb and likely contributed to the lack of a limb effect. Establishing limb symmetry was important because limb dominance and side-to-side imbalance in lower extremity measures have been found to be a risk factor for anterior cruciate ligament injury.[3,9]

The SEBT has successfully been used to demonstrate asymmetrical impairments in functional balance on the involved side in individuals with chronic ankle instability or anterior cruciate ligament deficiency compared to uninjured controls.[4,6,7,23] Training and rehabilitation programs have also been reported to reduce the side-to-side asymmetry in functional balance.[5,6,16]

Limitations

Study limitations should be taken into consideration. Four subjects were excluded from the experimental group, resulting in a 31% drop-out rate. Although it was a higher drop-out rate, the power analysis confirmed that the sample size was sufficient. Another limitation is the small number of adolescent female soccer players, which decreases the applicability to other populations. Finally, training was performed without the benefits of random assignment and without the blinding of the investigators.

Further investigation is necessary to determine if a NMTP that improves the SEBT composite score would reduce in-season injury rates. A randomized controlled trial with longitudinal injury tracking is needed to assess cause and effect to determine if the NMTP does indeed have an effect on in-season injury rates. A longitudinal study is necessary to determine if the NMTP has lasting effects on the subject’s strength and core stability.

Other implications for future research include utilizing the SEBT for assessment and screening tools for athletes. The SEBT is an easy and practical tool that may be used as a preseason screening tool to determine which athletes may be more at risk for a lower extremity injury. It may also be important to combine the SEBT with other screening tools to better determine which athletes may be in greater jeopardy of injury.

CONCLUSION

Neuromuscular training that focused on lower extremity strength and core stability significantly improved the composite SEBT scores in female soccer players. The SEBT composite score was enhanced to 103% following participation in the NMTP.

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KEY POINTS

FINDINGS

An 8-week duration neuromuscular training program that focused on lower extremity strength and core stability improved performance on the SEBT in female soccer players.

IMPLICATION

Further investigation is needed to determine if neuromuscular training that improves performance on the SEBT also decreases in-season injury rates in female athletes.

CAUTION

Training was performed in a small group within a narrow age range, without the benefits of random assignment and blinding of the investigators.

FIGURE 1.
Subject performing the star excursion balance test on the left lower extremity in the posterolateral direction.

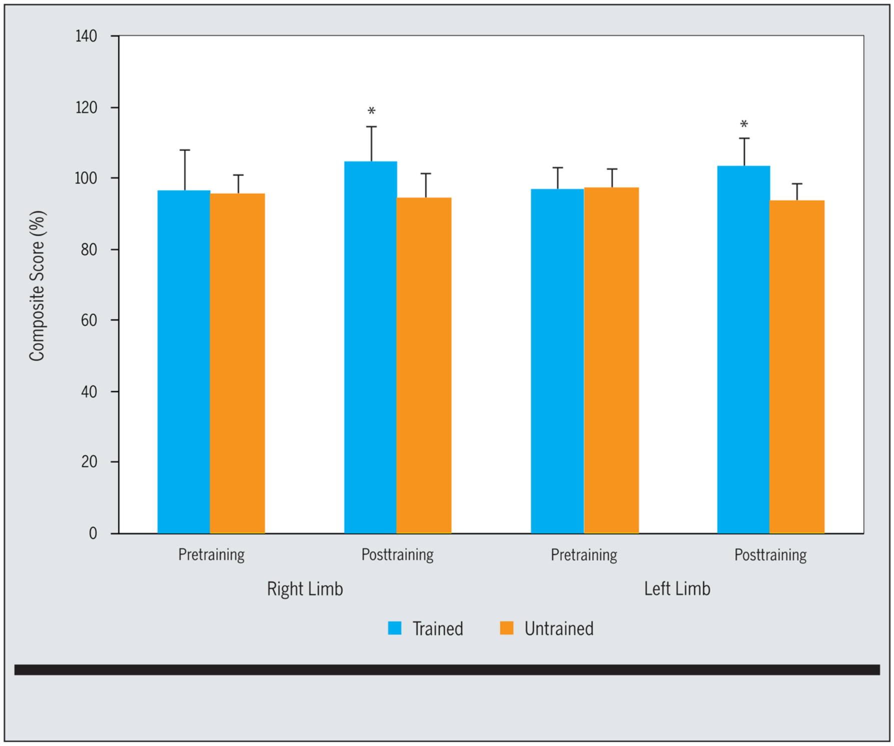

FIGURE 2.
The experimental group demonstrated a significantly higher star excursion balance test composite score on both limbs following the neuromuscular training program ($P \leq .05$). Error bars are ±1 SD.

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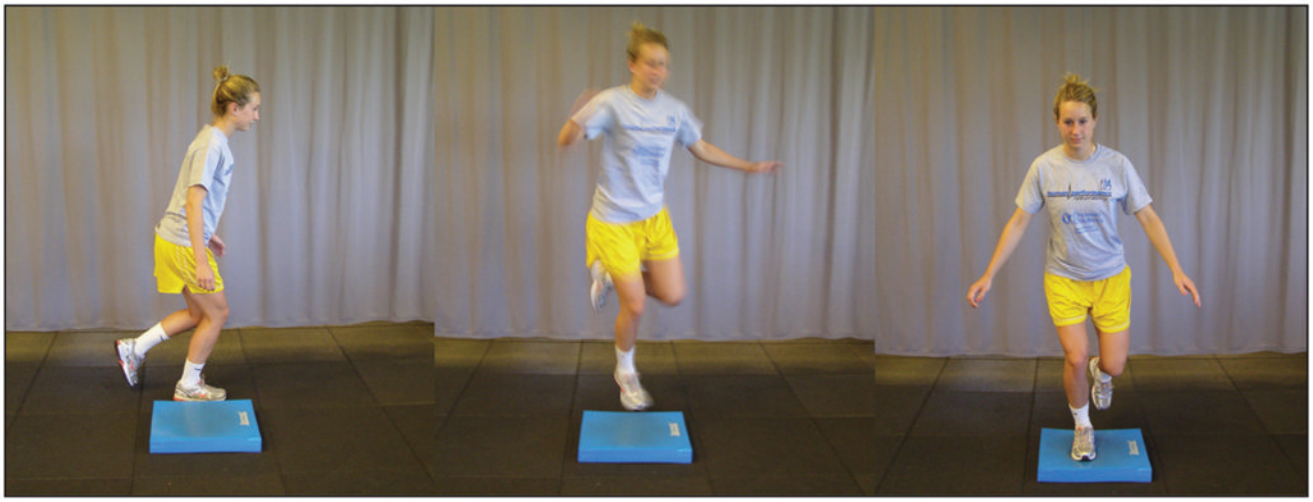

FIGURE 3.
Single-limb 90° Airex hop and hold (phase 2 in exercise progression).

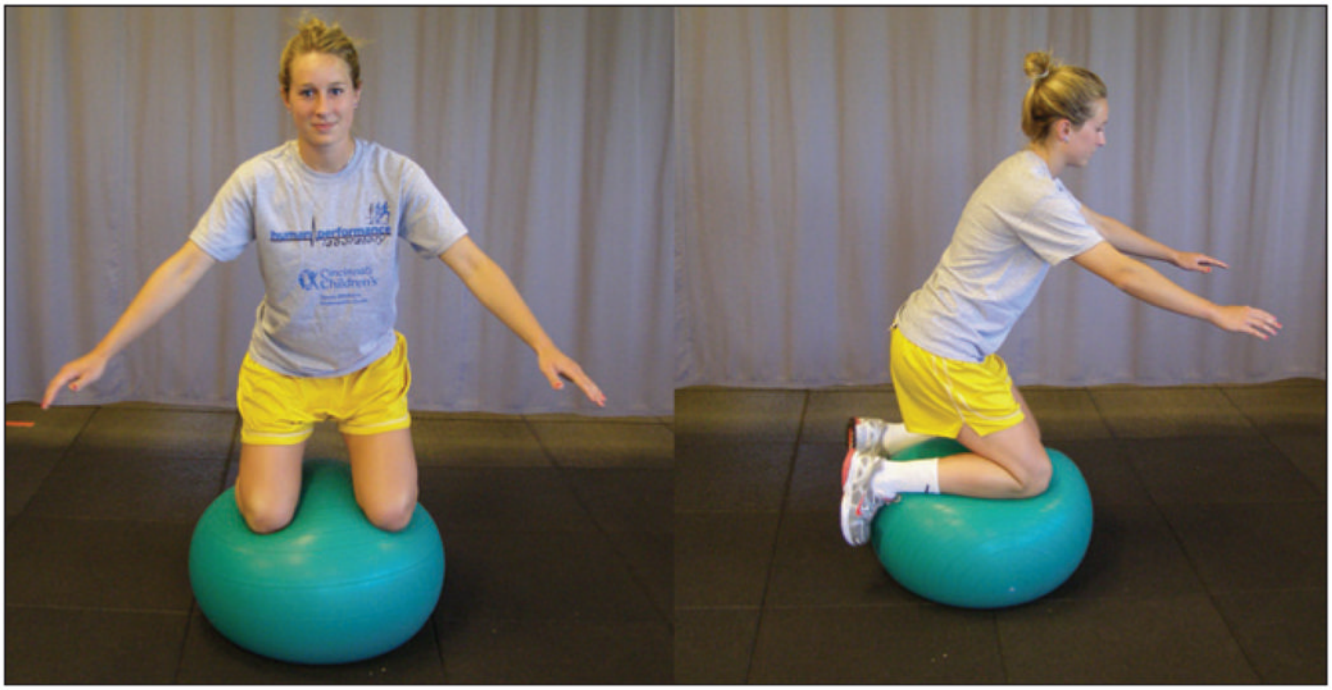

FIGURE 4.
Swiss ball bilateral kneel (phase 3 in exercise progression).

TABLE 1

Demographic Data

Variable	Experimental Group*	Control Group*	*P* Value†
Age (y)	15.4± 1.5	14.7± 0.8	.26
Height (cm)	163.9 ± 5.0	163.6 ± 4.8	.90
Mass (kg)	56.1 ± 6.1	51.5 ± 5.5	.14

*Values are mean ± SD.

†No between-group differences.

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TABLE 2

Intratester Reliability (ICC) on the Star Excursion Balance Test Composite Score and All 3 Reach Directions

Stance Foot	Anterior	Posterolateral	Posteromedial	Composite
Right	0.94	0.83	0.89	0.92
Left	0.96	0.81	0.90	0.96

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TABLE 3

Five Phases of the Core Stability Portion of Neuromuscular Training Program

Reference	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Hewett 1999,[10] Mandelbaum 2005[15]	Lateral jump and hold	Lateral jumps	Lateral hop and hold	Lateral hops	X-hops
Hewett 1999[10]	Step-hold	Jump single-leg hold	Hop-hold	Hop-hop-hold	Crossover-hop-hop-hold
Myer 2007[19]	BOSU (round) toe touch swimmers*	BOSU (round) swimmers with partner perturbations*	Prone bridge (elbows and knees) hip extension opposite shoulder flexion*	Prone bridge (elbows and toes) hip extension*	Prone bridge (elbows and toes) hip extension opposite shoulder flexion*
Myer 2007[19]	BOSU (round) double-knee hold	BOSU (round) single-knee hold	Swiss ball bilateral kneel (FIGURE 4)	Swiss ball bilateral kneel with partner pertubations	Swiss ball bilateral kneel with lateral ball catch
Myklebust 2003,[21] Petersen 2005[24]	Single-leg lateral Airex hop-hold	Single-leg lateral BOSU (round) hop-hold	Single-leg lateral BOSU (round) hop-hold with ball catch	Single leg 4-way BOSU (round) hop-hold	Single-leg 4-way BOSU (round) hop-hold with ball catch
Hewett 1999[10]	Single-tuck jump soft landing	Double-tuck jump	Repeated-tuck jump	Side-to-side barrier tuck jumps	Side-to-side reaction barrier tuck jumps
Mandelbaum 2005[15]	Front lunges	Walking lunges	Walking lunges unilaterally weighted	Walking lunges with plate crossover	Walking lunges with unilateral shoulder press
Hewett 1999[10]	Lunge jumps*	Scissor jumps*	Lunge jumps unilaterally weighted*	Scissor jumps unilaterally weighted*	Scissor jumps with ball swivel*
Mandelbaum 2005[15]	BOSU (flat) double-leg pelvic bridges*	BOSU (flat) single-leg pelvic bridges*	BOSU (round) single-leg pelvic bridges with weight*	Supine Swiss ball hamstring curl*	Russian hamstring curl with lateral touch*
Myklebust 2003,[21] Peterson 2005[24]	Single-leg 90° hop-hold	Single-leg 90° Airex hop-hold (FIGURE 3)	Single-leg 90° Airex hop-hold reaction ball catch	Single-leg 180° Airex hop-hold	Single-leg 180° Airex hop-hold reaction ball catch
Myer 2007[19]	BOSU (round) lateral crunch	Box lateral crunch	BOSU (round) lateral crunch with ball catch	Swiss ball lateral crunch	Swiss ball lateral crunch with ball catch
Myklebust 2003,[21] Peterson 2005[24]	Box double-crunch	Box swivel double-crunch	BOSU (round) swivel ball touches (feet up)	BOSU (round) double-crunch	BOSU (round) swivel double-crunch
Myer 2007[19]	Swiss ball back hyperextension*	Swiss ball back hyperextension with ball reach*	Swiss ball hyperextensions with back fly*	Swiss ball hyperextensions with ball reach lateral*	Swiss ball hyperextensions with lateral ball catch*

*Online video available and www.jospt.org.

TABLE 4

Example of Lower Extremity Strength Training Component of the Neuromuscular Training Program

Strength training, day 1	Strength training, day 2
• Dumbbell hang snatch	• Barbell hang cleans
• Barbell squat	• Sumo squat dumbell pick-up *
• Barbell bench press	• Dumbell incline press
• Assisted Russian hamstring curl *	• Gluteal/hamstring raise
• Dumbell shoulder press	• Dumbell back fly
• Hamstring curls	• Band ankle inversion/eversion
• Latissimus pull-down	• 30-cm box lateral step-down (heel-touch) *
• Lateral lunges	• Walking lunges
• Seated row	• Dumbell Ys and Ts *
• BOSU (flat), deep hold *	• Dumbell lateral raise

*Explanation of exercise in Myer et al.[17–18]

TABLE 5

Distance on the Star Excursion Balance Test for Each Direction

Direction/Limb/Group	Pretraining*	Posttraining*	*P* Value	Partial η^2†
Anterior				
Right			.321	0.070
NMTP	68.2 ± 11.0	71.7 ± 5.8		
CTRL	62.9 ± 4.4	61.7 ± 4.4		
Left			.193	0.118
NMTP	70.4 ± 6.6	70.4 ± 6.1		
CTRL	63.7 ± 6.8	59.7 ± 6.5		
Posteromedial				
Right			.226	0.103
NMTP	101.4 ± 16.4	107.4 ± 9.6		
CTRL	96.9 ± 8.3	95.0 ± 8.8		
Left			.028‡	0.299
NMTP	98.1 ± 15.6	105.6± 12.9		
CTRL	102.2 ± 11.7	97.1 ± 9.2		
Posterolateral				
Right			.008‡	0.405
NMTP	87.6 ± 13.6	99.2 ± 10.0		
CTRL	94.1 ± 10.2	93.7 ± 7.9		
Left			.040‡	0.269
NMTP	89.8 ± 13.0	99.2 ± 7.3		
CTRL	92.4 ± 7.5	91.4 ± 4.9		

Abbreviations: CTRL, control group; NMTP, neuromuscular training group.

*Data presented as mean ± SD cm.

†Effect size (>0.138, large effect).

‡Significant group-by-time interaction, with follow-up indicating a significant pretraining to post-training difference for the NMTP group (P<.05).