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Article Title: The Effect of Core Stability Training on Functional Movement Patterns in Collegiate Athletes

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Abstract

Context: Pre-participation examinations are the standard approach for assessing poor movement quality that would increase musculoskeletal injury risk. However, little is known about how core stability influences functional movement patterns. **Objective:** The primary purpose of this study was to determine the effect of an 8-week core stability program on functional movement patterns in collegiate athletes. The secondary purpose was to determine if the core stability training program would be more effective in those with worse movement quality (i.e. ≤14 baseline FMS score). **Design:** Quasi-experimental design. **Setting:** Athletic Training Facility. **Participants:** One-hundred collegiate athletes. **Main Outcome Measures:** Functional movement patterns included the Functional Movement Screen (FMS), Lateral step down (LSD) and Y balance test (YBT) and were assessed before and after the 8-week program. **Intervention:** Participants were placed into 1 of the 2 groups: intervention and control. The intervention group was required to complete a core stability training program that met 3 times per week for 8-week. **Results:** Significant group x time interactions demonstrated improvements in FMS, LSD and YBT scores in the experimental group relative to the control group ($p<0.001$). Independent sample t-tests demonstrate that change scores were larger (greater improvement) for the FMS total score and Hurdle step ($p<0.001$) in athletes with worse movement quality. **Conclusions:** An 8-week core stability training program enhances functional movement patterns and dynamic postural control in collegiate athletes. The benefits are more pronounced in collegiate athletes with poor movement quality.

Key Words: Postural control, prevention, movement compensations, sensorimotor, injury.

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Introduction

Musculoskeletal injuries are an inherent risk of athletic participation. Noncontact injuries represent approximately 20% of all injuries sustained during games and 40% of injuries sustained during practices.[1] Researchers have found that noncontact injuries occur because of high velocity movements coupled with the lack of preparatory muscle coordination and/or inappropriate reactive muscle activity.[2] Risk factors for noncontact injuries are therefore modifiable and have been identified through movement patterns, right-to-left asymmetries, and balance abnormalities.[3] The pre-participation examination is a standard approach for assessing movement quality that would increase musculoskeletal injury risk.[4, 5]

Athletes need an adequate amount of balance, core stability, and neuromuscular control to safely and effectively perform the necessary movements of their sport.[6] A fundamental movement pattern is a basic movement utilized to simultaneously examine muscle strength, flexibility, range of motion, coordination, balance, and proprioception.[5] Functional movement is defined as the ability to produce and maintain an adequate balance of mobility and stability along the kinetic chain while integrating fundamental movement patterns with accuracy and efficiency.[7]

The Functional Movement Screen (FMS) was developed to evaluate movement performance during 7 movement patterns.[8] Scores from each movement are summed for a maximal composite score of 21 and a composite score of ≤14 is suggestive of increased injury risk in male football players,[9] female collegiate athletes,[10] and male military candidates.[11] The lateral step-down (LSD) test can be used to rate the quality of movement based on the alignment of the trunk, pelvis, and knee [12] with scores ranging from 0 to 6.[13] The Y Balance Test (YBT) was developed to quantify dynamic balance in three reach directions.[14] Poor YBT scores have been shown to be a predictor of lower extremity injury.[3]

Neuromuscular control[15] and core stability[16] have emerged as potentially important intrinsic factors that affect an athlete's risk of injury. Several researchers have identified the importance of core stabilization as a key element for proper movement of the lower extremities, [17, 18] and promoting proximal stability for distal mobility.[19-21] However, Okada et al [22] found no significant correlations between core stability and

FMS scores. Core stability is a complex concept and has been defined as the ability to control the position and motion of the trunk over the pelvis and to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities.[19] Willson et al [23] demonstrated a relationship between trunk muscle activity and lower extremity movement such as jumping which suggests that decreased core stability may predispose an athlete to injury [19] and that core training may reduce such risk.[6, 19] Unfortunately, few studies have integrated core stabilization exercises into injury prevention programs.[6] While several investigations have quantified the effects of corrective exercises and general rehabilitation programs on movement quality.[24, 25] There is a paucity of information on the effects of a core stability training program on functional movement patterns.

Therefore, the primary purpose of this study was to determine the effectiveness of an 8-week core stability training program on functional movement patterns including FMS, LSD and YBT in collegiate athletes. The secondary purpose was to determine if the core stability training program was more effective in collegiate athletes with poor movement quality (i.e. ≤14 baseline FMS score) than collegiate athletes with good movement quality (i.e. >14 baseline FMS scores). We hypothesized that the group receiving core stability training would be effective at improving functional movement patterns relative to a control group, and that the effect of the training protocol would be greater in those who had poor movement quality.

Methods

Participants

This quasi-experimental study consisted of one hundred physically active and healthy male collegiate athletes between the ages of 18 and 22 that volunteered for this study. Collegiate athletes (basketball=40, futsal=40, volleyball=12, martial arts=8) were defined as students who participated in intercollegiate sports, were currently in their off-season, and that were training at least 3 times per week (>1.5 h/week). All participants were currently free from any kind of musculoskeletal injury, had not sustained any kind of musculoskeletal injury within the past 6 weeks, and had never undergone surgery for

a musculoskeletal condition.[26] Female athletes were not asked to participate due to cultural constraints, specifically the inappropriateness of a male researcher testing female participants.

Sample size was calculated based on previously published data,[27] using G*Power software (v.3.1.9.2). The analysis indicated that 72 total participants were needed to detect differences in Star Excursion Balance Test (SEBT) reach distances between groups, based on a (1-β=0.95, α=0.05), and an effect size of 0.79. We targeted an enrollment of 50 per group to allow for a 25% drop out rate. All participants were recruited from the university community using flyers and in class announcements. Participants were assigned to either the training group (60 male: age=18.1 ±.9 years, height = 176.5 ± 6.5 cm, weight = 69.3 ± 8.8 kg) or the control group (40 male: age = 18.03 ±.9 years, height = 176.5 ± 6.3 cm, weight = 67.9 ± 8.3 kg) based on their availability to participate in training. All participants completed all phases of the investigation. The university ethics review board approved the study, and all participants gave written informed consent before any data collection.

Procedures

All testing and training was done in the laboratory of sports sciences. This study was comprised of three phases: 1) pre-testing, 2) a supervised core stability training three times per week for 8 weeks, and 3) post-testing. Prior to pre-testing, participants were familiarized to all aspects of the study protocol and performed practice trials of all assessments. During pre- and post-testing, all examiners utilized the same verbal instructions. Once assigned, the intervention group was required to complete core stability training 3 times per week in addition to their usual training routine. The Control group received no intervention. They were instructed to maintain normal daily activities for the duration of the 8-week intervention. All participants were in the off season of their respective sports and none of the athlete's off season training programs included core stability training. Post-testing was conducted in a manner identical to pre-testing. All sessions were supervised by the one of researchers, who has qualifications as a personal trainer. The core stability training program included 8 exercises: 1) front plank, 2) quadruped exercise, 3) back bridge, 4) Side Bridge, 5) sit–up #1, 6) sit–up #2, 7) back extension #1, and 8) back extension #2 (figure 1).

Participants were instructed to maintain a neutral position of the spine while holding the correct exercise position. The intensity and volume of each core stability exercise were progressed gradually at a standard rate as previously described and shown in the Supplemental file.[27]

Tasks and measures

The Functional Movement Screen (FMS) is composed of the following seven tasks: 1) Deep squat (DS); 2) Hurdle step (HS); 3) In-line lunge (ILL); 4) Shoulder mobility (SM); 5) Active straight leg raise (SLR); 6) Trunk stability push-up (PU); 7) Rotary stability (RS). "Clearing" tests (impingement, press-up, and posterior rocking) are also included with the SM, PU and RS to expose other painful movements that may be overlooked while performing the primary FMS tasks. Additional details of each task have been published previously.[4, 5, 8] Each task is scored, and a 4-point scale (0–3) and on tests where left and right sides are measured, the lowest score is used, giving a total score out of 21.[4, 5, 8] A score of 3 was assigned if the participant performed a functional movement pattern with no movement compensation. A score of 2 was assigned if the participant performed a functional movement pattern, with some degree of compensation. A score of 1 was assigned if the participant was unable to perform or complete a functional movement pattern according to published guidelines, and a score of 0 was reserved for participants who had pain with the movement or presented with pain while performing a clearing test.[8] Screens were performed in a convenience order, and participants were given adequate rest to account for fatigue. The FMS has high intrarater and interrater reliability (ICC = .98) between an experienced and novice tester.[28, 29] Prior to study initiation, both examiners had several years of experience with FMS screenings. The examiners also conducted a pilot study of 10 participants to achieve an interrater reliability consistent with previously published values.

For Lateral step down (LSD) test, the tibial tuberosity of each participant was marked with a 1-cm sticker to facilitate its visualization during the test. The testing procedure was orally explained to each participant and followed by a demonstration. The side tested first was alternated between consecutive participants. Participants performed the test on a 15-cm step. Participants were instructed to keep the trunk

straight and hands on the waist and to bend the knee of the stance leg until the contralateral heel touched the floor next to the step. They were asked not to put any weight on the contralateral heel once it reached the floor and to immediately re-extend the knee and return to the starting position. Participants were also asked to try to maintain the knee of the stance leg over the second toe of the ipsilateral foot during the test while looking straight ahead but without visual (e.g. mirror) or auditory (e.g. verbal) corrective cues. Participants performed 5 practice repetitions followed by 5 consecutive test repetitions. Participants performed the test with a 2 second downward and a 2 second upward duration. The examiner was positioned 3 m in front of the participant during the test. The test was scored on a 7-point scale (0–6) according to the criteria outlined by Piva et al.[13] The examiner faced the subject and scored the test based on 5 criteria: 1) Arm strategy; 2) Trunk movement; 3) Pelvis plane; 4) Knee position and; 5) Maintain steady unilateral stance. Total score of 0 or 1 was classified as good, 2 or 3 was classified as medium, and ≥4 was classified as poor quality of movement.

Dynamic postural control was assessed using the Y balance test (YBT) which assesses an individual's ability to dynamically reach in the anterior (ANT), posteriormedial (PM), and posteriolateral (PL) directions. All participants were instructed to stand in single-limb stance on the dominant limb with the most distal aspect of their great toe at the center of the grid. Participants then completed 3 maximal reach distances in each direction while maintaining the single-limb stance. Scores were normalized by dividing the directional averages by a participant's leg length (distance from the ASIS to the medial malleolus). Prior to completion, participants practiced each distance three times. Test trials were discarded and repeated if the individual was unable to maintain a single-limb stance throughout the test, removed their hands from their hips, lifted their stance limb heel off the ground, or placed more than minimal weight onto the reach foot.[3] The YBT has high interrater and interrater reliability.[30]

Data analyses

Data were analyzed using SPSS statistical software 22 (IBM, Armonk, NY, USA). To assess the effects of the training program on individual FMS tests and YBT directions, separate 2 × 2 mixed-model

multivariate analysis of variance (MANOVA) were run with group (experimental or control) and time (pre and post) as the independent variables. If the MANOVA revealed significant differences, follow-up univariate 2×2 ANOVAs and pairwise comparisons were performed to identify specific outcomes that differed and the locations of those differences. For the FMS total score and LSD, separate univariate 2×2 ANOVAs were completed. Pre to Post change scores between quality movers (>14 Total FMS score) and poor quality movers (≤14 Total FMS score) within the experimental group were calculated using independent sample t-tests and bias corrected Hedges g effect sizes with 95% confidence intervals (CI). Hedges g effect sizes were interpreted as follows: less than 0.2 as small, 0.21–0.5 as moderate, and greater than 0.8 as large. For all comparisons, Statistical significance of $p \leq 0.05$ was employed. Minimal detectable change (MDC) scores were calculated to determine the minimal change required within our dependent variables to confidently determine that the change was due to the intervention. MDC scores were determined using intersession reliability and the standard error of measurement (SEM)] from the control group data collected during the pre and posttest. MDC scores were calculated as the SEM multiplied by the square root of 2. The standard error of the measure was calculated as the standard deviation from the 1st test multiplied by the square root of 1 minus the intersession reliability.[31]

Results

At baseline, participant demographics and pre-test scores did not differ between the groups ($p>0.05$). Significant group × time interactions were observed for FMS task scores ($F (7, 92) = 12.9$, $p= 0.001$) and YBT reach distances ($F (3, 96) = 25.2$, $p= 0.001$). The interactions demonstrate much larger improvements over time in the experimental group relative to the control group. Some but not all FMS scores drove the significant interaction and can be seen in Table 1. All of the individual YBT reach directions demonstrated a significant improvement following the experimental but no the control group. Additionally, a significant group × time interaction were identified for the FMS total scores ($F (1, 98) = 52.2$, $p= 0.001$) and LSD ($F (1, 98) = 67.7$, $p= 0.001$) highlighting improvement in the experimental but not in the control group. The significant improvements noted in the experimental group are further supported

by the medium to large effect sizes observed and the associated 95% confidence intervals that do not cross zero (Table 1). Finally, the improvements in total FMS score, DS, ILL, RS, ANT reach, PM reach, and LSD all exceeded the MDC score calculated from the control group data providing further evidence that the core stability training program resulted in meaningful improvements in functional movement quality and dynamic postural control.

Independent sample t-tests revealed that the core training program resulted in only two significant differences between high and poor quality movers: FMS total score (t_{58}=3.7, p=0.001) and HS (t_{58}=2.7, p=0.008). Both results suggest that the core stability training program was more effective for poor quality movers (Table 2). While the average change scores and effects sizes were larger in the poor movement quality group, the associated 95% confidence intervals of all variables overlap suggesting comparable effects on functional movement quality and dynamic postural control regardless of an individual's baseline movement quality.

Discussion

The primary purpose of this study was to determine the effect of an 8-week core stability program on functional movement patterns including FMS, LSD and YBT. Our results support our a priori hypothesis and demonstrate that an 8-week core stability program significantly improves functional movement patterns and dynamic postural control. The secondary purpose was to determine if a core stability program is more effective for individuals with poor movement quality at baseline (≤14 FMS total score). Our results partially support our a priori hypothesis as only the FMS total and HS change scores differed between high and low quality movers after the intervention.

Core stability is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities.[19] Core stability involves the Lumbo-pelvic-hip complex and is defined as the capacity to maintain equilibrium of the vertebral column within its physiologic limits by reducing displacement from perturbations and maintaining structural integrity.[21] For example, Hodges and Richardson [20] examined the

sequence of muscle activation during whole body movements and found that some of the core stabilizers (i.e., transverses abdominals, multifidus, rectus abdominals, and oblique abdominals) were consistently activated before any limb movements. These findings support the theory that movement control and stability are developed in a core-to-extremity (proximal-distal) and a cephalocaudal progression (head-to-toe). Core stability exercises are implemented according to the theoretical framework that dysfunction in core musculature is related to (musculoskeletal) injury; therefore, exercises that restore and enhance core stability are related to injury prevention and rehabilitation.[6]

The FMS, YBT and LSD were created to assess functional movement capacity and may indirectly measure intrinsic factors such as muscle strength and activation, neuromuscular control, and core stability [3, 12, 22]. Neuromuscular control[15] and core stability[16] have emerged as potentially important intrinsic factors that affect an athlete's risk of injury. Similarly, decreased core strength may contribute to injuries of lower extremity by reducing the ability of stabilizing the lower extremity. Multiple investigations have attempted to determine if movement quality is sensitive to change following interventions. For example, Bodden et al,[24] found that 4-week of corrective exercises were able to improve FMS scores. Similarly, Bagherian et al (in press) found significant improvement on Fusionetics functional movement patterns after 8 weeks of corrective exercises. However, Wright et al [25], found that a 4-week training program using body weight or resistance bands that focused on the quality of execution made little impact on the total FMS score on physically active children. The authors concluded that short-term interventions might affect specific isolated components of fitness but not FMS performance. Unfortunately, few studies have focused on the contribution of core stability to quality of movement patterns to date.[6, 18, 22] These results suggest that core stability programs can improve movement patterns.[6, 18, 22] Our results, which suggest that a core stability program can improve movement quality in collegiate athletes is consistent with the existing literature.

Several studies have examined the use of the FMS to predict injury in professional football players,[9] female collegiate athletes,[10] and Marine officer candidates.[11] All 3 studies identified a composite score of 14 points or less as a cutoff score to indicate increased injury risk. Similarly, a study conducted on collegiate

athletes competing in a variety of National Collegiate Athletic Association (NCAA) Division I and club sports found that participants with composite scores of 14 or less and a self-reported history of previous injury were 15 times more likely to incur an injury versus those scoring above 14.[32] Kiesel et al [9] found that football players with FMS scores ≤14 had an 11-fold increased chance of injury in comparison with players with scores >14. To the best of our knowledge, this study is the first study that investigate the effectiveness of core stability training on athletes with FMS scores ≤14 and >14. Based on the current results, the core stability program used may be more effective for individuals with poor movement quality (≤14 FMS total score) but that may be dependent on the outcome(s) used to asses intervention effectiveness. Further studies are needed to confirm our results and determine if improvements in movement quality due to core stability training reduce the rate of injuries.

It is important to note certain limitations of this study. First, the core stability training protocol was not individualized. Additionally, muscle activation, neuromuscular control, and core stability were not directly assessed. Also, the researchers and participants were not blinded to group assignment in this investigation and may have introduced an unconscious bias, particularly since the dependent measures are subjective in nature. Similarly, group assignment based on convenience is a limitation and may have introduced a sampling bias into the results. Future research is needed to confirm these initial results with blinded assessors and trainers, randomized group assignment, and a mix of male and female participants.

Conclusions

Eight weeks of core stability training are effective at enhancing functional movement patterns and dynamic postural control in collegiate athletes. Core stability training may be more effective for poor quality movers but further research is needed.

Conflict of interest

There are no conflicts of interest for any author.

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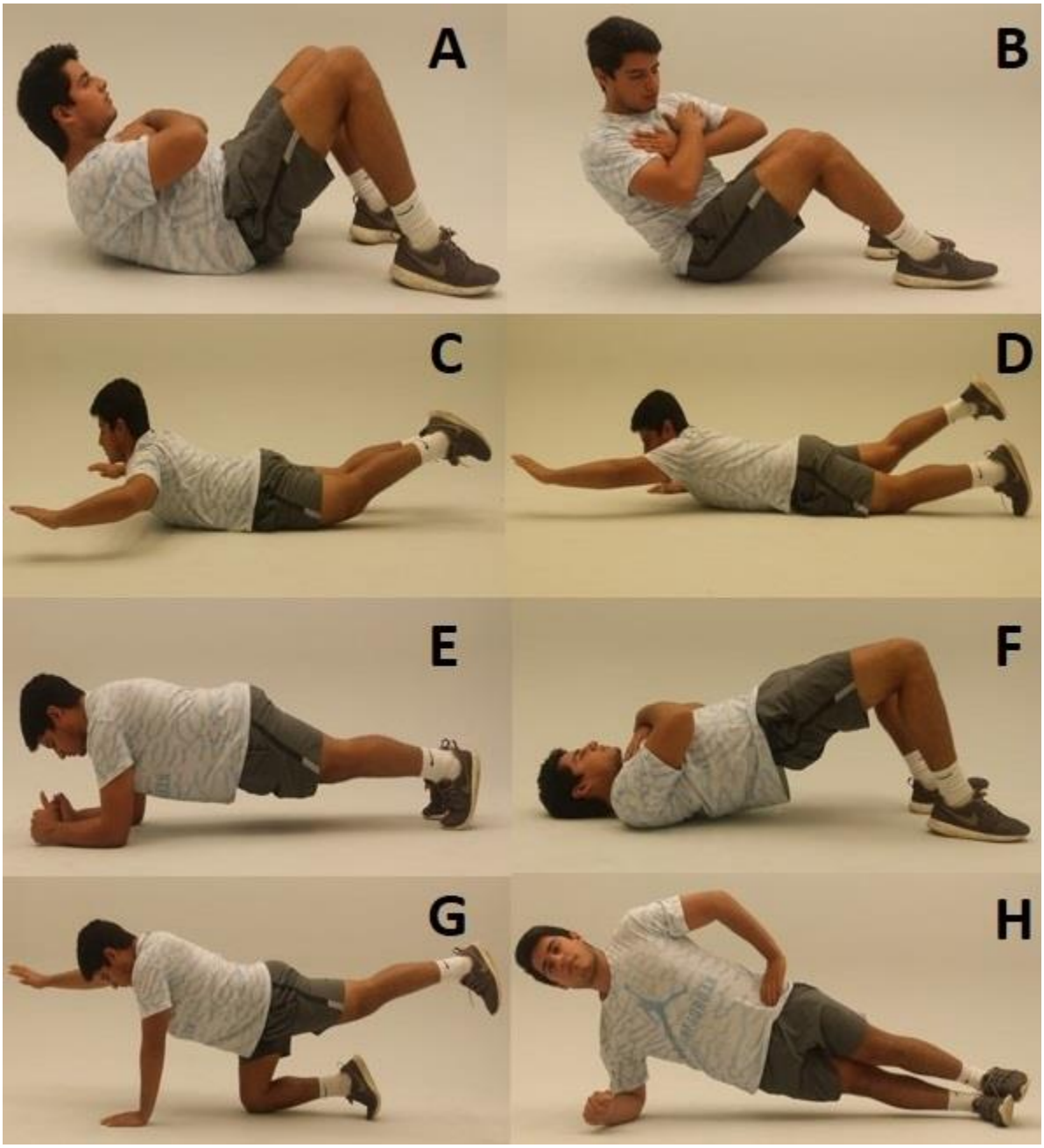

Figure 1. Core stability exercises: (A) Sit-up-1, (B) Sit-up-2, (C) Back extension-1, (D) Back extension-2. (E) Front plank, (F) Back Bridge, (G) Quadruped exercise, (H) Side Bridge.

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Table 1: Summary of participants' results for each assessment.

Variable	Experimental group (N=60)		Experimental Group Effect Size	Control group (N=40)		MDC
	Pre intervention	post intervention		Pre intervention	Post intervention	
FMS total score *†‡	14.4 ± 2.02	17.8 ± 1.7	1.68 (1.27 to 2.1)	14.6 ± 1.9	14.9 ± 2.08	1.22
Deep squat score *†‡	2.2 ± .7	2.8 ± .4	.81 (.43 to 1.18)	2.2 ± .6	2.1 ± .5	.59
Hurdle step score *†	2.3 ± .7	2.8 ± .4	.62 (.26 to .99)	2.6 ± .6	2.4 ± .5	.68
In-line lunge score *†‡	1.9 ± .6	2.7 ± .5	1.32 (.92 to 1.71)	2.02 ± .7	1.9 ± .6	.81
Shoulder mobility score	2.2 ± .8	2.3 ± .7	.08 (-.27 to .44)	2.1 ± .8	2.0 ± .7	.83
Active leg raise score	2.01 ± .8	2.3 ± .8	.29 (-.07 to .65)	1.9 ± .7	1.9 ± .8	.64
Push-up score †‡	2.1 ± .6	2.6 ± .5	.58 (.21 to .94)	2.1 ± .6	2.3 ± .6	.96
Rotary stability score *†‡	1.7 ± .5	2.4 ± .5	1.24 (.85 to 1.63)	1.8 ± .4	1.7 ± .6	.49
Anterior reach (%) *†‡	69.1 ± 4.6	73.6 ± 5.02	1.90 (1.47 to 2.33)	68.6 ± 5.3	69.4 ± 4.9	1.74
Posteromedial reach (%) *†	75.3 ± 8.7	81.01 ± 8.6	1.53 (1.12 to 1.94)	75.3 ± 6.4	75.8 ± .1	1.5
Posteriolateral reach (%) *†‡	82.9 ± 8.9	88.5 ± 8.4	1.57 (1.16 to 1.98)	79.6 ± 7.8	80.3 ± 8.1	1.25
LSD score *†‡	3.3 ± 1.06	1.5 ± 1.03	2.24 (1.79 to 2.7)	2.8 ±.9	2.5 ±.9	.61

Indicates a significant interaction ($p<0.05$), † Indicates a significant time main effect ($p<0.05$), ‡ Indicates a significant group main effect ($p<0.05$).

MDC: minimum detectable change.

Table 2: Summary of experimental group results for each assessment with considering total FMS scores ≤14 and > 14.

Variable	Experimental ≤14 (N=30)		Change scores	Effect Size	Experimental >14 (N=30)		Change scores	Effect Size
	Pre intervention	post intervention			Pre intervention	Post intervention		
FMS total score *	12.7 ± 1.2	17.1 ± 1.8	4.4 ± 2.3	2.01 (1.39 to 2.63)	16.1 ± .9	18.4 ± 1.4	2.4 ± 1.8	1.36 (.8 to 1.93)
Deep squat score	1.9 ± .7	2.7 ± .5	.8 ± .9	.92 (.39 to 1.45)	2.5 ± .7	2.9 ± .3	.4 ± .7	.52 (0 to 1.03)
Hurdle step score *	2.03 ± .7	2.8 ± .4	.8 ± .8	.94 (.41 to 1.48)	2.6 ± .5	2.9 ± .4	.3 ± .6	.46 (-.05 to .98)
In-line lunge score	1.6 ± .6	2.5 ± .5	.9 ± .7	1.14 (.59 to 1.68)	2.2 ± .5	2.8 ± .4	.6 ± .6	.92 (.39 to 1.46)
Shoulder mobility score	1.9 ± .8	2.3 ± .7	.4 ± 1.1	.37 (-.14 to .88)	2.4 ± .7	2.3 ± .7	- .07 ± 1.04	.1 (-.41 to .61)
Active leg raise score	1.7 ± .8	2.2 ± .8	.5 ± 1.1	.44 (-.08 to .95)	2.4 ± .6	2.4 ± .7	.07 ± .9	0 (-.51 to .51)
Push-up score	1.9 ± .6	2.6 ± .5	.7 ± .9	.88 (.35 to 1.41)	2.3 ± .5	2.6 ± .5	.3 ± .7	.42 (-.09 to .93)
Rotary stability score	1.4 ± .5	2.3 ± .4	.9 ± .7	1.39 (.82 to 1.95)	1.9 ± .4	2.5 ± .5	.6 ± .6	.92 (.39 to 1.46)
Anterior reach (%)	68.8 ± 4.5	73.4 ± 4.3	4.6 ± 2.7	.73 (21 to 1.25)	69.4 ± 4.8	73.8 ± 5.7	4.4 ± 3.6	.58 (.07 to 1.1)
Posteromedial reach (%)	75.6 ± 8.6	81.1 ± 8.2	5.6 ± 5.9	.46 (-.06 to .97)	75.1 ± 8.8	80.9 ± 9.1	5.8 ± 4.1	.45 (-.06 to .96)
Posteriolateral reach (%)	83.8 ± 9.7	88.3 ± 9.3	4.5 ± 5.7	.33 (-.18 to .84)	82.1 ± 8.1	88.7 ± 7.6	6.6 ± 3.5	.59 (.07 to 1.1)
LSD score	3.6 ± 1.07	1.8 ± 1.03	1.8 ± 1.0	1.20 (.65 to 1.75)	3.03 ± .9	1.1 ± .9	1.9 ± .9	1.5 (.92 to 2.07)

* Indicates a significant difference between ≤14 and >14 Change scores ($p<0.05$).

"The Effect of Core Stability Training on Functional Movement Patterns in Collegiate Athletes"
by Bagherian S, Ghasempoor K, Rahnama N, Wikstrom EA et al.
Journal of Sport Rehabilitation

Supplemental File: The core stability training program.

Week 1,2	**Instruction**	**Volume**
Sit-up-1	Standard sit-up	30 s × 3 sets
Sit-up-2	Standard sit-up with trunk rotation	30 s × 3 sets
Back extention-1	Raising the upper body and legs	30 s × 3 sets
Back extention-2	Raising the arm and contralateral leg	30 s × 3 sets
Quadruped	Raising the arm and contralateral leg	Hold each side for 10s×3 set
Front Plank	Supporting with 4 points	30s × 3 sets
Back bridge	Supporting with both feet	30s × 3 sets
Side bridge	On right and left side lying	Hold each side for 30s× 3 set
Week 3,4	**Instruction**	**Volume**
Sit-up-1	Standard sit-up	40 s × 3 sets
Sit-up-2	Standard sit-up with trunk rotation	40 s × 3 sets
Back extention-1	Raising the upper body and legs	40 s × 3 sets
Back extention-2	Raising the arm and contralateral leg	40 s × 3 sets
Quadruped	Raising the arm and contralateral leg	Hold each side for 15s× 3 set
Front Plank	Supporting with 4 points	40 s × 3 sets
Back bridge	Supporting with both feet	40 s × 3 sets
Side bridge	On right and left side lying	Hold each side for 40s× 3 set
Week 5,6	**Instruction**	**Volume**
Sit-up-1	Standard sit-up	50 s × 3 sets
Sit-up-2	Standard sit-up with trunk rotation	50 s × 3 sets
Back extention-1	Raising the upper body and legs	50 s × 3 sets
Back extention-2	Raising the arm and contralateral leg	50 s × 3 sets

Quadruped	Raising the arm and contralateral leg	Hold each side for 20s×3 set
Front Plank	Supporting with 4 points	50s ×3 sets
Back bridge	Supporting with both feet	50s ×3 sets
Side bridge	On right and left side lying	Hold each side for 50s× 3 set
Week 7,8	**Instruction**	**Volume**
Sit-up-1	Standard sit-up	60 s × 3 sets
Sit-up-2	Standard sit-up with trunk rotation	60 s × 3 sets
Back extention-1	Raising the upper body and legs	60 s × 3 sets
Back extention-2	Raising the arm and contralateral leg	60 s × 3 sets
Quadruped	Raising the arm and contralateral leg	Hold each side for 30s×3 set
Front Plank	Supporting with 4 points	60s ×3 sets
Back bridge	Supporting with both feet	60s ×3 sets
Side bridge	On right and left side lying	Hold each side for 60s× 3 set

General Exercise Descriptions

-**Sit–up–1** was a standard sit–up starting with knees bent at 90° and hands folded across the chest.

-**Sit–up–2** was a sit-up with trunk rotation. Participants were instructed to raise, bend, rotate the upper body to the left or right until the elbow touched the opposite thigh before returning to the starting position. Rotation direction alternated between repletion's within a et.

-**Back extension–1** required participants to raise the upper body and lower extremities off the floor simultaneously from a prone position before returning to the starting prone position.

-**Back extension–2** required participants to raise one arm and opposite leg simultaneously from the prone position before returning to the starting position. The arm and leg raised was alternated for each repetition within a set.

-Front plank required participants to maintain a prone position that supported the body by the forearms and toes.

-Quadruped exercise was performed in the quadruped position, while participants raised the right arm and left leg or left arm and right leg during alternating repetitions.

-Side bridge was performed in a side lying position by supporting the body with the elbow and foot.

-Back bridge required participants to lay supine with their feet flat on the ground, knees bent at 90°, hands folded across the chest as they raised their pelvis to achieve and to maintain a neutral hip flexion angle.