Relationship Between Core Stability, Functional Movement, and Performance

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Abstract

Okada, T, Huxel, KC, and Nesser, TW. Relationship between core stability, functional movement, and performance. *J Strength Cond Res* 25(1): 252–261, 2011—The purpose of this study was to determine the relationship between core stability, functional movement, and performance. Twenty-eight healthy individuals (age = 24.4 ± 3.9 yr, height = 168.8 ± 12.5 cm, mass = 70.2 ± 14.9 kg) performed several tests in 3 categories: core stability (flexion [FLEX], extension [EXT], right and left lateral [LATr/LATl]), functional movement screen (FMS) (deep squat [DS], trunk-stability push-up [PU], right and left hurdle step [HSr/HSl], in-line lunge [ILLr/ILLl], shoulder mobility [SMr/SMl], active straight leg raise [ASLRr/ASLRl], and rotary stability [RSr/RSl]), and performance tests (backward medicine ball throw [BOMB], T-run [TR], and single leg squat [SLS]). Statistical significance was set at $p \leq 0.05$. There were significant correlations between SLS and FLEX ($r = 0.500$), LATr ($r = 0.495$), and LATl ($r = 0.498$). The TR correlated significantly with both LATr ($r = 0.383$) and LATl ($r = 0.448$). Of the FMS, BOMB was significantly correlated with HSr ($r = 0.415$), SMr ($r = 0.388$), PU ($r = 0.407$), and RSr ($r = 0.391$). The TR was significantly related with HSr ($r = 0.518$), ILLl ($r = 0.462$) and SMr ($r = 0.392$). The SLS only correlated significantly with SMr ($r = 0.446$). There were no significant correlations between core stability and FMS. Moderate to weak correlations identified suggest core stability and FMS are not strong predictors of performance. In addition, existent assessments do not satisfactorily confirm the importance of core stability on functional movement. Despite the emphasis fitness professionals have placed on functional movement and core training for increased performance, our results suggest otherwise. Although training for core and functional movement are important to include in a fitness program, especially for injury prevention, they should not be the primary emphasis of any training program.

Key Words power, agility, muscle endurance

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Introduction

Core stability is achieved through stabilization of one's torso, thus allowing optimal production, transfer, and control of force and motion to the terminal segment during an integrated kinetic chain activity (8,14,15,23). Research has demonstrated the importance and contributions of core stability in human movement (12) in producing efficient trunk and limb actions for the generation, transfer, and control of forces or energy during integrated kinetic chain activities (3,6,8,14,18). For example, Hodges and Richardson (12) examined the sequence of muscle activation during whole-body movements and found that some of the core stabilizers (i.e., transversus abdominis, multifidus, rectus abdominis, 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 cephalo-caudal progression (head-to-toe) (8).

Functional movement is the ability to produce and maintain a balance between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency (20). Muscular strength, flexibility, endurance, coordination, balance, and movement efficiency are components necessary to achieve functional movement, which is integral to performance and sport-related skills (8,20). Direct and quantitative measures of functional movement are limited; however, Cook (9) proposes qualitative assessment to gain insight about whether abnormal movements are present, which purportedly translate to one's level of core stability and how it impacts performance or injury. To determine whether relationships truly exist between core stability and performance, functional movement and individual components of performance, including power, strength, and balance, must be assessed. However, relationships between these variables have not been established. One explanation for the lack of evidence may be a result of the fact that universal definitions and testing methods do not exist (1,2,20,25,26,28). We hypothesized that there would be a significant relationship between core stability and functional movement and between functional movement and performance. Also, a positive relationship would exist between core stability and functional movement.

Table 1. Scoring system for functional movement screen (5,6).

Tests	3 points	2 points	1 point	0 points
Deep squat	Upper torso is parallel with tibia or toward vertical.	Meet criteria of 3 points with 2 × 6 board under heels.	Tibia and upper torso are not parallel.	If pain is associated with any portion of this test.
	Femur is below horizontal.	Knees are not aligned over feet.	Femur is not below horizontal.	
	Knees are aligned over feet.		Knees are not aligned over feet.	
	Dowel is aligned over feet.		Lumbar flexion is noted.	
Hurdle step	Hips, knees, and ankles remain aligned in sagittal plane.	Alignment lost between hips, knees, and ankles.	Contact between foot and hurdle occurs.	If pain is associated with any portion of this test.
	Minimal to no movement is noted in lumbar spine.	Movement is noted in lumbar spine.	Loss of balance is noted.	
	Dowel and hurdle remain parallel.	Dowel and hurdle do not remain parallel.		
In-line lunge	Minimal to no torso movement is noted.	Movement is noted in torso.	Loss of balance is noted.	If pain is associated with any portion of this test.
	Feet remain in sagittal plane on 2 × 6 board.	Feet do not remain in sagittal plane.		
	Knee touches 2 × 6 board behind heel of front foot.	Knee does not touch behind heel of front foot.		
Shoulder mobility	Fists are within 1 hand length.	Fists are within 1.5 hand length.	Fists are not within 1.5 hand lengths.	If pain is associated with any portion of this test and/or during shoulder stability screen.
Active straight-leg-raise	Dowel resides between mid-thigh and anterior superior iliac spine.	Dowel resides between mid-thigh and jointline of knee.	Dowel resides below jointline.	If pain is associated with any portion of this test.
Trunk-stability push-up	Males perform 1 repetition with thumbs aligned with top of head.	Subjects perform 1 repetition in modified position.	Subjects are unable to perform 1 repetition in modified position.	If any pain is associated with any portion of this test.
	Females perform 1 repetition with thumbs aligned with chin.	Male-thumbs aligned with chin.		If pain is noted during lumbar extension.
		Female-thumbs aligned with chest.		
Rotary stability	Subjects perform 1 correct repetition while keeping torso parallel to board and elbow and knee in line with board.	Subjects perform 1 correct diagonal flexion and extension lift while maintaining torso parallel to board and floor.	Subjects are unable to perform diagonal repetition.	If pain is associated with any portion of this test. If pain is noted during lumbar flexion.

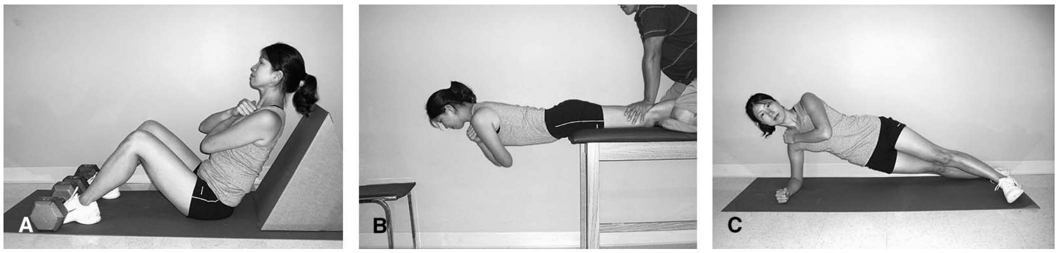

Figure 1. Core stability tests. A) Flexor endurance test from lateral view. B) Back extensor test from lateral view. C) Lateral musculature test from anterior view.

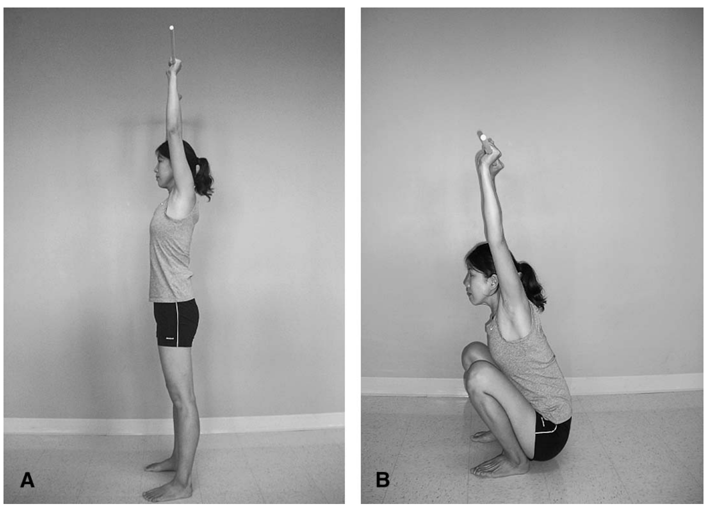

Figure 2. Functional movement screen deep squat from lateral view. A) Start position. B) End position.

Therefore, the primary purpose of this study was to determine the relationships between core stability, functional movement, and performance. A secondary purpose of this study was to establish which assessment tests best represent, or correspond, with performance.

Methods

Experimental Approach to the Problem

To date, relationships have not been verified between core stability, functional movement, and performance. The present study attempted to examine whether there is a relationship among these 3 variables in healthy individuals. A multivariate

Figure 3. Functional movement screen core stability push-up from lateral view. A) Start position. B) End position. C) Trunk extensor test, a part of core stability push-up test.

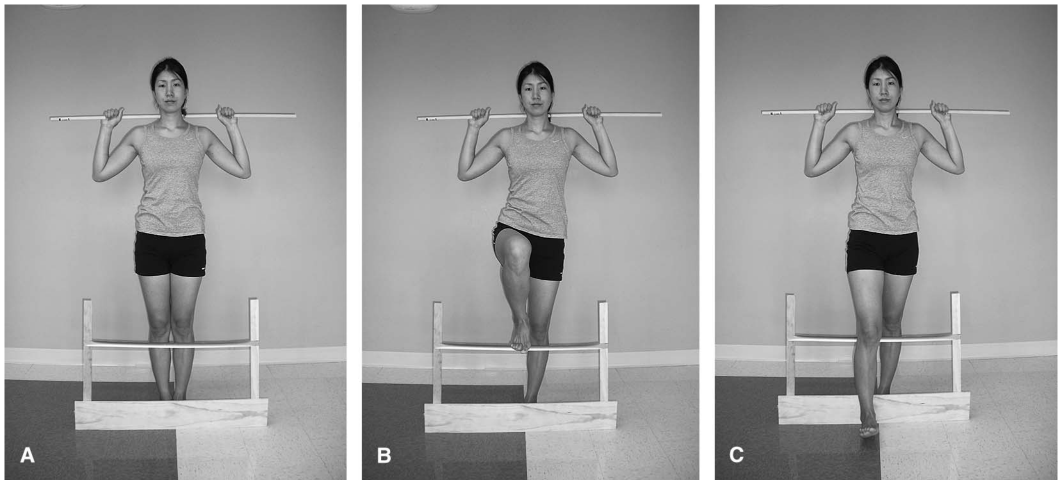

Figure 4. Functional movement screen hurdle step from anterior view. A) Start position. B) Mid position. C) End position.

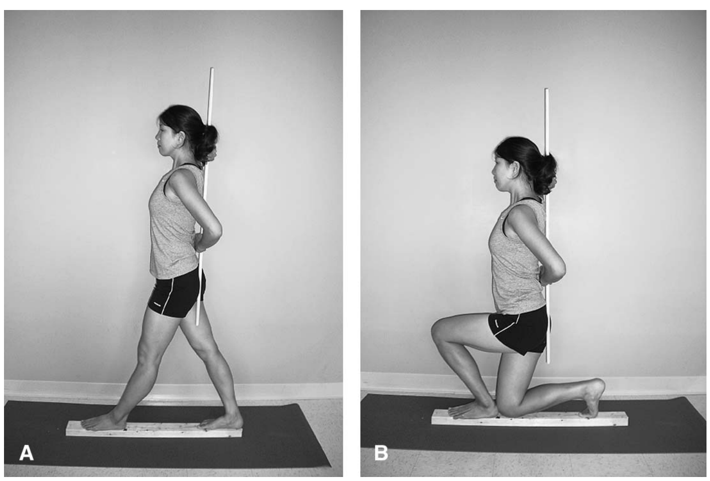

Figure 5. Functional movement screen inline-lunge from lateral view. A) Start position. B) End position.

correlational design was used to answer these study questions. Variables were categorized as core stability, functional movement, and performance. A standard regression analysis was used to determine whether core stability and functional movement screen (FMS) assessments could predict performance. The independent variables were 4 core stability tests and 12 FMS tests. The dependent variable was a total score from all performance variables. Age, height, and body mass were used for descriptive purposes.

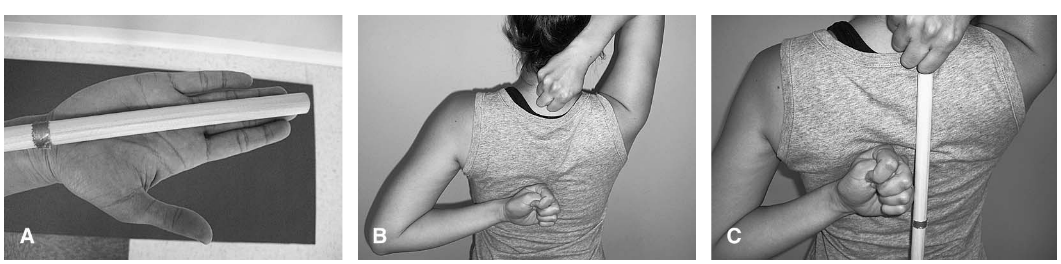

Figure 6. Functional movement screen shoulder mobility from posterior view. A) Measurement of length of hand with dowel. B) Performing right shoulder mobility. C) Measurement of distance between hands with dowel.

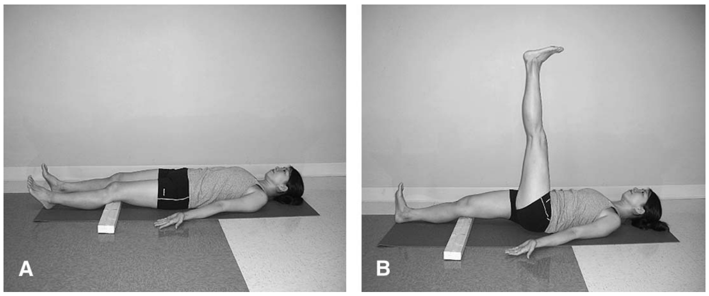

Figure 7. Functional movement screen active straight leg raise from lateral view. A) Start position. B) End position.

Subjects

Twenty-eight healthy men and women (age 24.4 ± 3.9 yr, height 168.8 ± 12.5 cm, mass 70.2 ± 14.9 kg) were tested. Subjects were recreational athletes from varied backgrounds in no particular sport season. All subjects were informed of the experimental risks and signed an informed consent document before the investigation in addition to completing a health history questionnaire. An individual was excluded if he/she reported any a) somatosensory disorder that affects balance, b) ankle instability, c) low back pain, d) lower- and upper-extremity injuries or surgeries that resulted in time loss of physical activity within the past year, e) current taking of medication that affects one's ability to maintain balance, or f) pregnancy. This study was approved by the University Institutional Review Board for Use of Human Subjects.

Procedures

A stopwatch (Accusplit 705X, Accusplit, Inc., Pleasanton, CA, USA; 0.01 s precision) was used to measure time in seconds during core stability tests. A tape measure (Komelon Measuring Tape 30 m Fibreglass Closed Frame, Komelon Corporation, Waukesha, WI, USA; 2 mm precision) was used to measure distance in meters during backward overhead medicine ball throw (BOMB). A 2.72 kg medicine ball (Power Med-ball, Power Systems, Knoxville, TN, USA) was used to assess total body power measured with BOMB. Speedtrap II wireless timing system (Brower Timing Systems, Drape, UT, USA; 0.01 s precision) was used to measure time in seconds during the T-run agility test. Core muscle endurance tests developed by McGill (17,18) was used to assess core stability. These are composed of trunk flexor, back extensor, and right and left lateral trunk musculature tests. The FMS developed by Cook (8,9) was used to assess functional movement. It consists of 7 basic human movements: deep squat (DS), trunk-stability push-up (PU), bilateral hurdle steps (HS), in-line lunges (ILL), shoulder mobility (SM), active straight-leg raises (ASLR), and rotary stabilities (RS). Quality of body movements was quantified as 0 to 3 points on the basis of how the tasks were accomplished. The scoring system of the each test is described in Table 1.

Subjects reported for 1 test session that lasted approximately 2 hours. The session was composed of screening, familiarization, and data collection. Screening consisted of informed consent, health history questionnaire, and anthropometric measurements including height and body mass. The dominant/stance leg was determined as the leg used to complete or recover from 2 of the 3 tests: a balance recovery after posterior push, a step up onto a 20-cm step, and kicking a ball with maximum accuracy through a goal 10 m from the subjects (13).

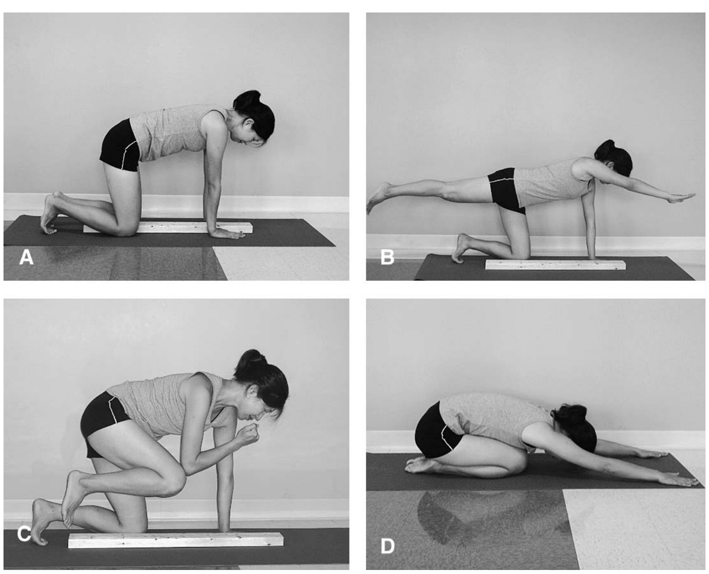

Figure 8. Functional movement screen rotary stability from lateral view. A) Start position. B) Mid position. C) End position. D) Trunk flexion test, a part of rotary stability test.

After screening, subjects completed a warm-up that included a light jog and both static and dynamic stretch for a minimum of 15 minutes or

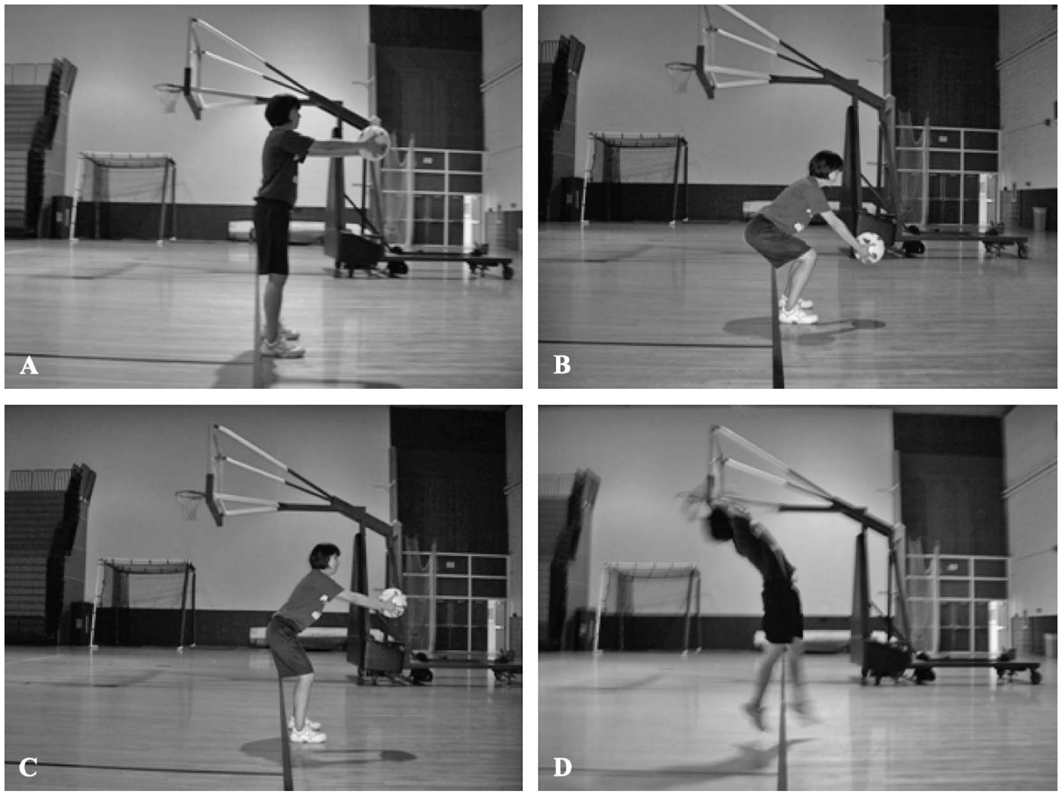

Figure 9. Backward overhead medicine ball throw from lateral view. A) Preparatory phase. B) Countermovement phase. C) Upward acceleration phase. D) Deceleration phase.

until they felt comfortable to perform the tests. Testing immediately followed the warm-up. The order of the tests was randomized among subjects to prevent fatigue and possible test-order effects. Each test was demonstrated first and then subjects practiced it twice to minimize learning effects during data collection. The exception to this was BOMB, which was familiarized with 5 practice trials, as supported by a previous study (11).

Measurements

Core Stability Assessment. McGill's trunk muscle endurance tests were used to assess core stability (17,19,22,28). Results from previous studies show that the 4 trunk isometric muscle endurance tests have excellent reliability coefficients: trunk flexor (FLEX), intraclass correlation coefficient (ICC) = 0.97, back extensor (EXT), ICC = 0.97, and right and left lateral trunk musculature (LATr/LATl), ICC = 0.99 (19). Subjects practiced each of the body positions for a maximum of 5 seconds to avoid fatigue effects. Subjects were encouraged to maintain the isometric postures for each test position as long as possible (Figure 1) (17,19,22,28). The length of time subjects could maintain the correct position was recorded. The longest time of 2 trials, to the nearest 0.1 second, was used for data analysis.

Functional Movement Screen. Subjects performed the FMS by Cook (8,9). FMS tests include DS, core stability PU, HSr/HSl, ILLr/ILLl, SMr/SMl, ASLRr/ASLRl, and RSr/RSl (Figures 2–8) (8,9). All but DS and PU were tested bilaterally. The FMS was shown to have an excellent reliability coefficient (ICC = 0.98) (5). Also, it has good to excellent intertester reliability for all of the 12 variables: ILLl, w = 0.87; ILLr and ASLRr, w = 0.93; the other 9 variables, w = 1.0, or perfect (21). To ensure consistency, subjects watched a video that explained and demonstrated each of FMS movements before being tested. Subjects performed 2 practice trials followed by 3 test trials. Approximately 5 seconds of rest were given between each trial and 1 minute of rest between each test. The subjects were instructed to return to the initial position between each trial. Performance of each FMS was scored according to Cook's guidelines. The best score in each test was used for data analysis. The order of the tests was randomized among subjects.

Table 2. Summary of correlations between core stability, functional movement screen, and performance tests ($n = 28$).*

	BOMB			TR			SLS		
	r	r^2	p	r	r^2	p	r	r^2	p
CS									
FLEX	0.092	0.01	0.643	−0.292	0.09	0.131	0.500†	0.00	0.007
EXT	0.052	0.00	0.794	−0.188	0.04	0.337	−0.063	0.00	0.748
LATr	0.152	0.02	0.441	−0.383‡	0.15	0.045	0.495†	0.25	0.007
LATl	0.167	0.03	0.397	−0.448‡	0.20	0.017	0.498†	0.25	0.007
DS	−0.229	0.05	0.241	0.108	0.01	0.585	−0.225	0.05	0.249
PU	0.407‡	0.17	0.032	−0.331	0.11	0.085	0.355	0.13	0.064
HSr	0.415‡	0.17	0.028	−0.518†	0.27	0.005	0.356	0.13	0.063
HSl	0.336	0.11	0.080	−0.290	0.08	0.135	0.199	0.04	0.310
ILLr	0.045	0.00	0.822	−0.159	0.03	0.419	0.014	0.00	0.944
FMS									
ILLl	0.361	0.13	0.059	−0.462‡	0.21	0.013	0.175	0.03	0.374
SMr	−0.388‡	0.15	0.042	0.392‡	0.15	0.039	−0.446‡	0.20	0.017
SMl	−0.055	0.00	0.781	−0.099	0.01	0.616	−0.246	0.06	0.207
ASLRr	0.093	0.01	0.639	−0.009	0.00	0.964	0.027	0.00	0.893
ASLRl	0.083	0.01	0.674	−0.038	0.00	0.848	0.073	0.01	0.710
RSr	0.391‡	0.15	0.040	−0.293	0.09	0.130	0.327	0.11	0.089
RSl	0.255	0.07	0.191	−0.221	0.05	0.260	0.246	0.06	0.327

*CS = core stability; FMS = functional movement screen; BOMB = backward overhead medicine ball throw; TR = T-run; SLS = single leg squat; FLEX = flexion; EXT = extension; LATr = right lateral; LATl = left lateral; DS = deep squat; PU = core stability push-up; HSr = right hurdle step; HSl = left hurdle step; ILLr = right in-line lunge; ILLl = left in-line lunge; SMr = right shoulder mobility; SMl = left shoulder mobility; ASLRr = right active straight leg raise; ASLRl = left active straight leg raise; RSr = right rotary stability; RSl = left rotary stability.

†$p \leq 0.01$.

‡$p \leq 0.05$.

Performance Assessments

Backward Overhead Medicine Ball Throw. The BOMB was performed to assess total-body power (11,28). Stockbrugger and Haennel (27) examined validity and reliability of the BOMB explosive power test. They found that there was a strong correlation between the distance of the medicine ball throw and the power index for the countermovement vertical jump ($r = 0.906$, $p < 0.01$), and the test-retest reliability of this test was 0.996 ($p < 0.01$). A 2.72 kg medicine ball was used in this study. The test consisted of 4 phases: preparatory, countermovement, upward acceleration, and deceleration phases (Figure 9). Each subject was given 5 practice trials for familiarization (11) followed by 3 test trials. The distance of the medicine ball throw was recorded (m), and the best throw was used for the statistical analysis.

T-Run Agility Test (TR). The TR was used to assess agility and speed (24). Previous research showed that the interclass reliability of the TR was 0.98 when performing 3 trials (24). Subjects ran straight forward and shuffled from left to right and right to left and then ran straight backward on a "T"-shaped configuration (Figure 10). Subjects completed 2 practice trials followed by 3 test trials. Automatic sensor

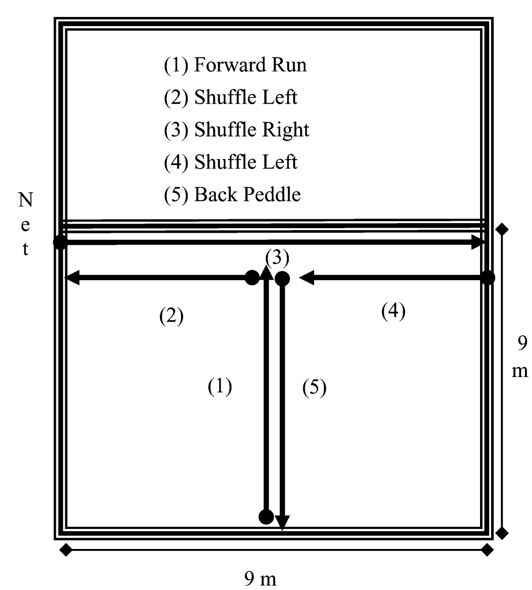

Figure 10. T-run agility test.

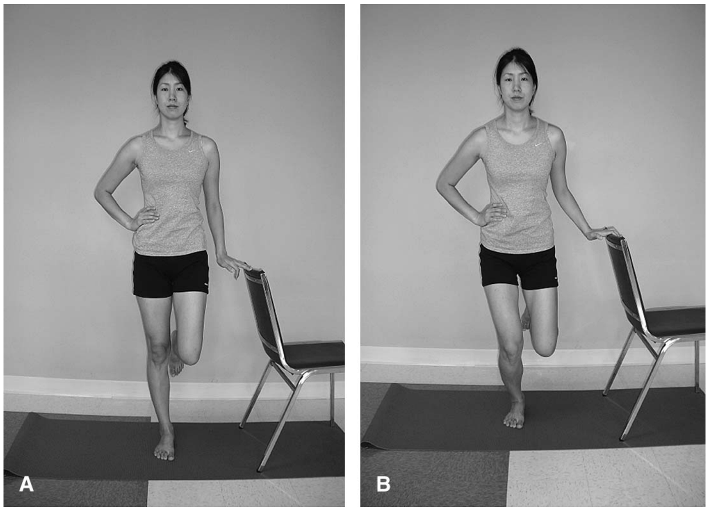

Figure 11. Single leg squat. A) Start position. B) End position.

timers were placed on the start/finish line. The best time, to the nearest 0.1 second, was used for data analysis. A trial was disqualified if the subject failed to touch either of the cones placed right and left of the "T" configuration, failed to face forward for the entire test, or failed to shuffle his or her feet (7).

Single-Leg Squat (SLS). The SLS was performed to assess muscle endurance of the lower body. The SLS dynamic Trendelenburg test, established by Livengood et al. (16), was used in this study and was repeated as many times as possible (Figure 11). This test was shown to have inter-rater reliability with low to moderate agreement ($\kappa = 0.016$–0.28) (10). Only the dominant leg was tested for this test to reduce any fatigue effect on the other tests. The subjects stood upright on their dominant leg without shoes with their same-side hand on their hip and the other hand resting on a bar for balance only. From this position, the subjects performed a squat to approximately 60° of knee flexion and returned to the initial position and repeated it as many times as possible. One squat must have been performed within 6 seconds, and the subjects were instructed to maintain a hip position of 65° flexion, 10° abduction/adduction, and the knee within 10° of valgus/varus throughout the test (16). The test was terminated when the subjects could not complete a squat within 6 seconds or could not maintain proper body position. The subjects were given 2 test trials to perform this test with approximately 5 minutes of rest between attempts. The greater number of repetitions of the 2 trials was used for the analysis.

Statistical Analyses

Descriptive and inferential statistics were performed. Pearson's product-moment correlations (r) were used to evaluate relationships between test variables: a) core stability and performance, b) core stability and functional movement, and c) functional movement and performance. A standard multiple regression analysis was conducted to determine which independent variables in core stability and FMS were significant predictors of total performance. The total performance score was calculated by adding the SLS and BOMB scores and subtracting the TR score. The α-level was set at $p \leq 0.05$.

Results

There were significant correlations between core stability and performance tests (Table 2). The SLS was positively correlated with FLEX, LATr, and LATl. The TR was negatively correlated with LATr and LATl. Significant correlations between FMS and performance tests were found (Table 2). The BOMB was positively correlated with HSr, PU, and RSr but was negatively correlated with SMr. The TR was positively related with SMr and negatively related with HSr and SMr. The SLS was negatively related with SMr. No significant correlations were found between any of the core stability and FMS variables.

The multiple regression analysis included all independent variables and indentified FLEX, LATr (core stability), and SMr (FMS) as significant predictors of total performance. These variables accounted for 86% of the variability in total performance.

Discussion

The primary purpose of this study was to determine the relationships between core stability, functional movement, and performance, and the secondary purpose was to identify assessment tests that best predict, or represent, performance. We assessed core stability through tests that elicited isometric muscle contractions of the trunk musculature (17,19). Functional movement was assessed with Cook's FMS (8,9). The performance tests were selected on the basis of their required movements and muscle groups involved. The BOMB was used to measure total-body power through the transfer of ground forces through the legs and torso to the upper body. The SLS was used to measure muscle endurance of the lower body. The TR was used to measure lower-body agility and speed.

Several significant positive (SLS vs. FLEX, LATr, and LATl) and negative (TR vs. LATr and LATl) correlations were identified between core stability and performance variables.

The SLS had significant correlations with all of the core stability tests except EXT. Even though SLS was used to examine muscle endurance of the lower extremity, subjects had to use their trunk muscles to stabilize their upper body in an upright position. This means that the core muscles were contracted isometrically throughout the test despite dynamic movement of the lower extremity. Because the core stability tests targeted isometric muscle endurance of the core, these similarities in muscle contraction and activation types may have resulted in their significant correlations. Next, significant negative correlations were identified between TR and both LATr and LATl. The LATr and LATl were established to challenge the quadratus lumborum muscle with minimum spine loading (19). The quadratus lumborum muscle functions to stabilize frontal flexion and extension and resist shearing of the spine through activation in extension, flexion, and lateral bending (19). A good performance (i.e., faster time) on the TR required the ability to quickly change directions. To perform well, core stability is necessary to withstand shear forces on the spine that occur in a multidirectional task (4,7). Thus, both TR and LAT could demand quadratus lumborum activity during the tests. Interestingly, BOMB did not have significant correlations with any of the core stability variables. This may be caused by the different components tested. The core stability is used to measure muscle endurance, whereas BOMB is used to assess explosive power. During BOMB, the core muscles quickly contracted to produce explosive power, so muscle endurance does not appear to impact the task. Interestingly, EXT did not significantly relate to the any of the performance variables. This appears odd because the back extensors are necessary to help stabilize the upper body during the SLS and TR, and the back extensors are primary movers for the BOMB.

Significant positive (BOMB vs. HSr, PU, and RSr; TR vs. SMr) and negative (BOMB vs. SMr; TR vs. HSr and ILLl; SLS vs. SMr) correlations were found between FMS and performance. Possible reasons for these results may be body coordination patterns or body movements. For example, BOMB recruited similar body coordination and movement patterns as HSr, RSr, and PU. The HSr was used to assess bilateral functional mobility and stability of the hips, knees, and ankle (8,9). Also, RSr was used to examine trunk stability during a combined upper- and lower-extremity motion in multiple planes (8,9). This indicates that both tests required great total-body coordination and integration. Similarly, stability and mobility combined with body coordination and integration were important for better throwing distance; they contribute to efficiently transfer the kinetic energy through a kinetic chain and prevent an "energy leak" while performing the task (27). In addition, both BOMB and PU occurred in the sagittal plane while maintaining a symmetrical body motion. The TR also contained similar body coordination and movement patterns as HSr and ILLl. For instance, HSr involved a single-leg phase, and the lower-extremity movements occurred in a sagittal plane while maintaining the upper body in the upright posture. Also, ILLl demanded mobility of the lower extremities and stability of the upper body (8,9). Because TR consisted of running and shuffling motions, it included single-leg stance phases and needed mobility of the lower extremity and stability of the upper body to accomplish the task. These similarities in body coordination and movement patterns may have resulted in their significant correlations. Interestingly, SMr had significant relationships with all of the performance variables. However, the relationships are difficult to explain. All but DS and PU were measured bilaterally. The results indicate that significant relationships were not found bilaterally for the majority of these variables; all except ILLl were found significant only on the right side. This may be explained by the dominant arms and legs of the subjects; 27 were right-hand dominant, and 23 were right-leg dominant. This may indicate that the majority of the subjects may have been dominant on the right side of their bodies when performing the tasks.

No significant relationships were found between any of the core stability and FMS variables. Although dynamic, the FMS requires stabilization of the core to complete the tasks for each screen. One would believe a strong core would be necessary to achieve each endeavor. Therefore, the lack of significant correlations appearing between the core stability tests and the FMS is odd. Components of the FMS, such as mobility and coordination, may have influenced the results. This suggests that, if a subject has poor mobility or coordination, success in the FMS would not be attained despite strong core musculature. Or, perhaps, minimum core strength is all that is necessary to successfully complete the FMS. Overall, the correlations between core stability and FMS and the performance variables are difficult to explain. Similar body movements, muscle activation, and body coordination patterns are likely responsible for the results of this study.

Of the 16 variables entered into the regression model, 3 variables (FLEX, LATr, and SMr) were demonstrated as best predictors and accounted for 86% of the variability in total performance. The FLEX and LATr were from the core stability category. In this study, FLEX recorded the highest value of the 4 core stability tests. These high values are similar to those of Tse et al. (28), who examined the improvement of core strength in college-age rowers by using McGill's tests. In addition, although SMr was the only predictor from the FMS category, it is hard to explain its prediction on performance because no research has investigated the relationships between SMr and total performance. However, a possible explanation of this may be arm dominance because the majority of the subjects were right-hand dominant. Further study in SMr and total performance is warranted.

Although FLEX, LATr, and SMr were best predictors in total performance, reliance on these variables (in light of the poor correlations identified in the current study) is not recommended. These findings are most likely caused by different purposes of McGill's tests and FMS with performance. The McGill's tests were developed to assess muscle endurance of the trunk musculature in patients with low back pain (17,19). Furthermore, FMS is used to evaluate quality of human movements and to find deficits in the body during dynamic movements that possibly cause injuries (8,9). Therefore, this may suggest that low scores in the core stability tests or FMS do not influence performance. Further investigation is warranted to develop core stability and functional movement assessments that correspond with performance.

Practical Applications

The results of this study support specificity of training. As mentioned above, the core assessment was an isometric, muscle endurance test, whereas the performance tests involved dynamic movement. Therefore, it is safe to say that isometric training of the core provided little if any benefit to dynamic performance. Likewise, the FMS was designed to identify potential injury in individuals, and thus it too is ineffective in predicting performance.

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