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Relationship between Functional Movement Screening and Skill-Related Fitness in College Students

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Abstract The purpose of this study was to examine the association between Functional Movement Screen (FMS) and skill-related fitness in young, active college students. A total of 56 male (n=48) and female (n=8) participants (age = 20.63 ± 2.06 years) were recruited from a college in the northeast region of the United States. Participants performed both the FMS and skill-related tests in a field house. The FMS tests included deep squat, hurdle step, inline lunge, shoulder mobility, leg raise, trunk stability, and rotary stability (score ranging from 0 to 3 per test; maximum total score of 21) and the skill-related fitness tests consisted of agility T-test, stork stand balance, 50-yard dash, vertical jump, jump mat reaction time test, and Dance Dance Revolution (DDR) coordination test. Pearson Product Moment Correlation analyses revealed no significant correlation between the total FMS score and total skill-related fitness test scores. Spearman Rank Order Rho found some significant correlations between individual FMS test and skill-related fitness test scores (stork balance test and inline-lunge score: r =.362, p = .006; stork balance test and trunk stability push-up = .362, p = .006; DDR score and shoulder mobility: r = .318, p = .017; DDR score and rotary stability: r = .264, p = .049; vertical jump test and deep squat score: r = .264; p = .049). Therefore, the limited significant correlations between individual item of the FMS and the skill-related fitness test are not sufficient enough to present a clear pattern of relationship between the FMS and skill-based fitness among active college students. More research studies are needed to investigate the influence of age, gender, and skill level on the relationship between the FMS and skill-related fitness performances.

Keywords FMS, Skill-related fitness, Relationship, and college students

1. Introduction

Skill-related fitness is defined as the type of physical fitness that have a relationship with enhanced athletic performance, including agility, power, speed, balance, coordination, and reaction time [12]. The President's Council on Physical Fitness and Sports states, that individuals demonstrating skill-related fitness would decrease the risk of pathology caused by functional degeneration. It has also been found that individuals demonstrating skill-related fitness are more likely to participate in fitness-enhancing physical activity [12]. Information collected from skill-related fitness tests is useful for coaches, as a diagnostic tool, to customize training programs for athletes, or for exercise professionals to train nonathletic individuals in specific areas [34].

The Functional Movement Screen (FMS) is a recently recognized instrument designed to assess the quality of fundamental movement patterns and presumably identify an individual's functional limitations or asymmetries [6, 9-11, 46]. With the exception of three clearing tests (impingement clearing test, press-up clearing test, and posterior rocking clearing test), the FMS has seven tasks, including the deep squat (DS), hurdle step (HS), inline lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TSPU) and rotary stability (RS) [9, 10]. A 4-point scale (ranging from 0 to 3) is designed to quantify the quality of the movement patterns for each task of the FMS [9, 10]. Researchers have often applied the final scores of the FMS obtained from a total of 21 scores [5, 6, 13, 23, 25, 27, 28, 30, 35, 50, 51] and the number of bilateral asymmetry from the FMS tasks [5, 25, 51] to predict future musculoskeletal injury incidence. Researchers stated, that there are different cut-point scores of the FMS to predict the musculoskeletal injuries, namely, 11 for men and 14 for women [27]. Other studies had focused on a general score of the FMS for the general population, which indicated that the value of 14 [2, 5, 6, 22-25, 30, 39, 50, 51], and 17 was another predictive score [30].

Intervention program may be beneficial to improve the functional mobility and stability which strengthens body awareness and motor learning and positively affects athletic performance [4, 8–10]. Investigators have also studied the effect of varied intervention program on functional movement screen task scores in mixed martial arts athletes

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[2], sixty firefighters [17], and professional American football players [24].

There are a variety of variables that may contribute to change in the functional movement screen scores, including gender [33, 44], history of injury [1, 44], level of experience [1, 16, 42], age [33, 42], body mass index [42], performance of balance [42], and performers' knowledge in the specific grading criteria of the FMS [17]. Previous studies investigated the change in the functional movement patterns over a competitive season in college athletes [49] and between pre- and post-exercise [7]. Lockie et al. [32] (2015) categorized participants into groups based on the deep squat score. The findings of the study indicated that high performers demonstrated a 13% greater stand-long-jump than intermediate performers which was the only significant result.

Evaluating the lower-body tasks of the FMS for identifying movement deficiencies could affect multidirectional speed and jump performance, which is critical in players participating in team sports [32]. Similarly, investigators have studied the association of the functional movement screen scores with motor capabilities, including balance, speed, and power tests [7, 20], weight status [14, 15, 42], exercise participation [14, 42], performance tests (backward medicine ball throw, T-run, single leg squat, squat jump, reactive strength index protocol, and reactive agility cut) [31, 36], age [42], and cardio and arm endurance [30]. In order to determine the theoretical basis of the functional movement screen contributing to predict athletic performance abilities, Parchmann and McBride [38] (2011) investigated the association of the functional movement screen tasks with sprint times, vertical jump height, agility T-test times, and club head velocity in Division I golfers. Additionally, improper breathing is considered as a variable to weaken muscle balance, motor control, and physical adaptations, which may alter the movement pattern, Bradley and Esformes therefore [3] (2014) investigated the relationship between breathing pattern disorders and functional movement.

Both skill-related fitness and FMS play an important role in assessing physical performance. Until now, limited research has been done to examine the association between the FMS and skill-related fitness. In the present study, the research purpose aim was to investigate association between FMS and skill-related fitness in college students.

2. Methods

Participants

A total of 56 male (n=48) and female (n=8) participants (age = 20.63 ± 2.06 years) were recruited from a college in the northeast region of the United States. An informed consent form was obtained from each participant prior to the beginning of the experiment. Any student athlete who had a recent injury or is currently experiencing pain in the knee or ankle joint was excluded from the study. The participant characteristics is presented in Table 1.

Table 1. Descriptive statistics for participant characteristics on age, year of sport experience, gender, sport type (individual and team sport), and level of sport participation (high school and college varsity) (N = 56)

Variable		*M/%*	*SD/N*
Age		20.63	2.06
Year of sport experience		12.16	3.60
Gender	Male	85.72	
	Female	14.28	
Sport Type	Individual	32	
	Team	68	
Sport Level	High School	36	
	College Varsity	64	

*Data presented at mean, standard deviation, and percentage.

Testing Instruments and Tools

Skill-related Fitness Tests

The present study consists of six tests for skill-related fitness, including Agility T-Test [41, 43, 45], Vertical Jump Test [40], 50-yd dash run [21, 26], Stork Balance Stand Test [21, 26], Just Jump System Reaction Time Test, and Dance Dance Revolution (DDR) [48] Coordination Test. The six components (agility, power, speed, balance, coordination, and reaction time) of skill-related fitness were assessed with the use of two stopwatches, a ruler, and erase marks.

Agility T- test

T-Test was used to measure agility. The participant starts at cone A, sprints forward 10 yards (9.14 m), and touches cone B. He or she then shuffles 5 yards (4.57 m) and touches cone C. After that, he or she shuffles 10 yards (9.14 m) and touches D and then shuffles back to cone B. Upon touching cone B, the participant runs backward 10 yards (9.14 m) and passes the finish line at cone A. Time duration (seconds) for completing the T-test was recorded.

Vertical jump and reaction time tests

A Just Jump Mat (Probotics, Inc., Huntsville, US) was used for the power test and reaction time test. The Just Jump Handled Computer port connects with the jump mat placed on a level surface. For the power test, the participant was asked to stand with both feet shoulder width apart on the mat. He or she jumped straight up as high as he or she can without tucking his legs and land with both feet on the mat. Air time and vertical jump height in inches were read on the display. For the reaction time test, the participant was asked to respond by touching the center of the mat with his or her single foot once the tester signaled "go" on the audio receiver of the Just Jump handle. Timer on the Just Jump hand stopped once he or she touched the center of the mat with his or her single foot.

50-yard dash run and Stork stand test

The standardized 50-yd dash run was used for measuring speed. The participant ran from cone A to cone B in the

50-yd dash distance. Time duration was recorded by stopwatch. Stork stand test was used for measuring balance. The participant was asked to remove the shoes and place the hands on the hips, then position the non-supporting foot against the inside knee of the supporting leg. The participant raised the heel to balance on the ball of the foot. The stopwatch was started as the heel was raised from the floor. The stopwatch was stopped if any of the follow occur: 1) the hand (s) come off the hips, 2) the supporting foot swivels or move (hops) in any direction, 3) the non-supporting foot loses contact with the knee, 4) the heel of the supporting foot touches the floor. The total time in seconds was recorded.

Dance Dance Revolution test for coordination

Dance Dance Revolution was used for measuring coordination. In DDR games, the participant was required to respond to a sequence of step instructions that was presented as drifting arrows that rise slowly from the bottom to the top of the screen. As each arrow drifts upward, it intersected the location of one of four corresponding target arrows arranged in a linear configuration at the top of the presentation screen. When the drifting arrow crosses a target arrow, the participant must coordinate an appropriate step onto the corresponding dance mat target.

Functional Movement Screening

The FMS includes seven tests: overhead squat, hurdle step, in-line lunge, active hamstrings, shoulder mobility, trunk stability, and rotary stability. Each test was scored from 0 to 3, and the maximum total score is 21 (Table 2). Each test has specific score standard for the rater to determine among 0, 1, 2, and 3. Any pain existed while performing the movement in each test automatically resulted in a score of 0. The participant received a score of 3 if the performance meet all the standards delineated in the manual. Two high-quality digital video cameras were respectively positioned in the sagittal and frontal planes to record each participant's movement. The cameras were positioned on tripods in the same location and height for all tests. Dartfish Software was used to perform motion analysis by viewing the movement frame by frame or in slow motion at a de-interlaced 60 frames per second.

Table 2. Description of FMS and Scoring system

Tests	3 points	2 points	1 point	0 point
Deep squat	Upper torso is parallel with tibia or toward vertical. Femur is below horizontal. Knees are aligned over feet. Dowel is aligned over feet.	Meet criteria of 3 points with 2 x 6 board under heels Knees are not aligned over feet.	Tibia and upper torso are not parallel	If pain is associated with any portion of this test
Hurdle step	Hips, knees, and ankles remain aligned in sagittal plane Minimal to no movement is noted in lumbar spine Dowel and hurdle remain parallel	Alignment lost between hips, knees, and ankles Movement is noted in lumbar spine Dowel and hurdle do not remain parallel	Femur is not below horizontal. Knees are not aligned over feet. Lumbar flexion is noted. Contact between foot and hurdle occurs Loss of balance is noted	If pain is associated with any portion of this test
In-line lunge	Minimal to no torso movement is noted Feet remain in sagittal plane on 2 x 6 board Knee touches 2 x 6 board behind heel of front foot	Movement is noted in torso Feet do not remain in sagittal plane Knee does not touch behind heel of front foot	Loss of balance is noted.	If pain is associated with any portion of this test
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	Fists are not within 1.5 hand lengths	f pain is associated with any portion of this test
Trunk-stability push-up	Males perform 1 repetition with thumbs aligned with top of head. Females perform 1 repetition with thumbs aligned with chin.	Subjects perform 1 repetition in modified position Male-thumbs aligned with chin Female-thumbs aligned with chest	Subjects are unable to perform 1 repetition in modified position	If any pain is associated with any portion of this test If pain is noted during lumbar extension
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.

A number of studies have focused on examining the reliability of the FMS in a variety of situations within diverse populations. Li, Wang, Chen and Dai [29] (2014) used exploratory factor analysis to examine the internal consistency and factor structure of the functional movement screening tasks among elite athletes. Researchers have studied the reliability of scoring the FMS tasks in relation to live-versus-video session in US Division I college athletes [46]. The groups that were studied involving three healthy college students between week one and week two [18], 19 volunteer civilians during inter-session and intra-session [37], young professional hockey athletes [39], and a combined group of healthy professional athletes, firefighters, and military service members [50]. Schneiders, Davidsson, Horman, and Sullivan [44] (2011) investigated, inter-rater reliability of both the composite scores and individual tasks of the FMS in order to determine normative values for the FMS in a young, healthy population. Several researchers have studied the intra-rater and inter-rater reliability of the scoring of the FMS in a variety of experiences, including clinical experience [13], experience of using the FMS [13, 19], and educational background and experience [47]. Additionally, Teyhen et al. [50] (2012) investigated the intra-rater test-retest and inter-rater reliability of the same level of novice raters scoring the FMS tasks in a mixed group of active elite athletes, firefighters, and military service members.

Procedure

A letter explaining the purpose and procedures of the study was sent to their instructors of all participants and ask for their support. All participants volunteered to participate in the study and submitted the informed consent form before the tests were administered. All tests were conducted indoors at a field house. Each participant was asked to engage in a 10-minute individual warm-up which included light jogging and stretching exercises followed by specific instructions and demonstration of the tests. Two trials for both FMS and skill-related fitness tests were administered to each participant by a FMS certificated exercise professional and one trained graduate student. A 3-minute break between the trials was implemented to ensure adequate recovery. The best result of the two trials was used for data analysis.

Statistical Analysis

The FMS sum score was analyzed with descriptive statistics (mean ± SD). Each individual value from skill-related fitness tests was first standardized and converted into T score for a sum score of the skill-related fitness tests. Taking into account shorter time in speed, agility, reaction time indicating better performance, the T score for the three components were respectively reversed by subtracting the original value of each T score from 100. Pearson Product Moment Correlation analyses was performed to determine relationship between total FMS and skill-related fitness tests; whereas Spearman Rank Order Rho was used to determine the relationships between individual test items of both the FMS and skill-related fitness tests. All statistical analyses were performed using SPSS Version 21.0 (SPSS InC., Chicago, IL, USA). The alpha level for the present study was set at .05.

Table 3. Descriptive statistics for sum score on functional movement screening and skill-related fitness (N = 56)

	TFMS	TS	ATT	VJ	YDR	SST	RT	DDR
M	16.46	300	11.11	22.74	6.08	5.92	.29	460378
SD	2.89	25.04	1.14	4.27	1.22	4.84	.07	125610.7

Note. TFMS: Total Functional Movement Screening score; TS: Total skill-related fitness standard score; ATT: agility T-test; VJ: vertical jump test; YDR: 50-yard dash run; SST: stork stand test; RT: reaction time; DDR: Dance Dance Revolution coordination test.

Table 4. Correlation between functional movement screening and skill-related fitness (N = 56)

	TFMS	TSF	ATT	RT	YDR	VJ	SST	DDR
TFMS	1	.23	.13	-.082	.196	-.001	.103	.241
OV			-.05	-.09	-.04	.26*	.14	-.007
HS			.16	.09	.13	-.14	-.25	.16
ASLR			-.02	-.11	-.09	.15	-.04	.15
ILL			.20	.07	.178	.18	.36**	.08
SM			.125	-.14	.095	-.21	-.04	.318*
TR			-.17	.188	.13	.23	.362**	.06
RS			.03	-.206	.058	-.08	-.037	.264*

Note. TFMS: Total Functional Movement Screening score; OV: overhead squat; HS: hurdle step; ASLR: active-straight leg raise; ILL: in-line lunge; SM: shoulder mobility; TS: trunk stability; RS: rotary stability. Additionally, TSF: Total skill-related fitness standard score; ATT: agility T-test; VJ: vertical jump test; YDR: 50-yard dash run; SST: stork stand test; RT: reaction time test; DDR: Dance Dance Revolution coordination test. *$p < .05$, **$p < .01$

3. Results

Mean and standard deviation for the total FMS score, total skill-related fitness score, agility T- test time, vertical jump height, and 50-yard dash run time, stork stand balance time, reaction time, and DDR score are displayed in Table 3.

The results of the analyses revealed no significant correlation between the total FMS test score and total skill-related fitness test score. With regard to correlations between individual items of the two tests, the results of analyses indicated that the stork balance test score was significantly correlated with the inline-lunge score (p = .006, r =.362) and the trunk stability push-up (p = .006, r = .362), respectively. The DDR score was significantly correlated with the shoulder mobility (p = .017, r = .318) and the rotary stability (p = .049, r = .264), respectively. The vertical jump test score was significantly correlated with the deep squat score (p = .049, r = .264).

4. Discussion

The primary finding indicated that the sum FMS score was not correlated with the skill-related fitness and its individual items. With respect to correlations between individual items of the two tests, the results of the study indicated that the stork balance test was moderately associated with the inline-lunge score and the trunk stability push-up; the DDR score was moderately associated with the shoulder mobility but weakly associated with the rotary stability; the vertical jump test score was weakly associated with the deep squat score.

The current findings are similar to previous studies investigating the relationship between the sum FMS score and various types of athletic capabilities [30, 32, 36, 38]. Okada et al. [36] (2011) used a sample size of twenty-eight healthy individuals in relation to the same age level to investigate a relationship of functional movement to athletic performance (backward medicine ball throw, T-run agility, and single leg squat) and core stability (trunk flexor, back extensor, and right and left lateral trunk musculature tests). Researchers revealed that no significant association between core stability and FMS was observed. However, from the individual component perspective, backward medicine ball throws had associations with right hurdle step (r = 0.415), right shoulder mobility (r = 0.388), push-up (r = 0.407), and right rotary stability (r = 0.391) within the FMS. In addition, T-run had associations with right hurdle step (r = 0.518), inline-lunge (r = 0.462), and right shoulder mobility (r = 0.392). Researchers emphasized that strength and conditioning coaches should not consider core and functional movement training as the primary program because both FMS and core stability have limited capacities to predict physical performance.

Parchmann and McBride [38] (2011) recruited twenty-five National Collegiate Athletic Association Division I golfers (15 men, age = 20.0 ± 1.2 years; 10 women, age = 20.5 ± 0.8 years) to identify relationship between functional movement screen and athletic performance. Researchers reported that FMS was not correlated with 10-m sprint time (r = - 0.136), 20 – m sprint time (r = -0.107), vertical jump height (r = 0.249), agility T-test time (r = - 0.146), and club head velocity as sport skill (r = - 0.064), suggesting that FMS is not an effective instrument for field test and not associated with any athletic capabilities. For individual task of the FMS, Lyoyd et al. [31] (2015) investigated 31 young male soccer players, ranging from 11 to 16 years old, for identifying relationships between functional movement screen scores and an aged-related variable and physical performance. Findings indicated that the deep squat, inline-lunge, active straight leg raise and rotary stability test were associated with all performance tests, including squat jump, reactive strength index protocol and reactive agility cut. Inline-lunge performance accounted for the maximum variance in reactive strength index with 47% and reactive agility cut 38%. In addition, it was observed that older players had better performance in FMS than their younger counterparts that was supported by previous study [50]; investigators therefore suggested that a combination of both functional movement screen scores and age-related variable could be effective predictors for varying physical performance. The findings were supported by previous studies [22, 29] emphasized that interpreting the score of each task is more acceptable, although some of the FMS tasks have a commonality in assessment.

Considering strong lower limbs are critical for individuals to complete a wide range of efficient functional movements in various types of sports. Researchers investigated relationships between lower-body focused tests of the FMS and physical qualities [20, 32]. Hartigan et al. [20] (2014) enrolled thirty-seven healthy individuals (age 18 to 40) to perform three tasks of the FMS (deep squat, hurdle step, and in-line lunge), unilateral drop jump, center of pressure (balance), and 36.6-meter sprints. It was observed that no relationships existed between in-line lunge performance and balance, power, or speed. Lockie et al. [32] (2015) recruited twenty-two male recreational team sport athlete (age = 24.23 ± 3.82 years) to investigate lower-body focused screens and overall FMS performance and multidirectional speed and jumping abilities. It was also observed that no significant correlation existed in this study, although the deep squat had moderate relationship with between 505 difference (r = - 0.423), and bilateral vertical jump (r = -0.428) and standing long jump (r = - 0.457). Additionally, when categorized into groups based on the deep squat score, the only significant difference was observed that higher performers had a 13% greater standing long jump than their intermediate counterparts. In fact, the FMS is a process-based assessment, but skill-related fitness tests are outcome-based assessments. Each assessment seems to examine different timeframes of a movement, therefore no relationships between the FMS and skill-related fitness were found in the present study.

5. Conclusions

The current investigation indicates that the FMS is not a sufficient predictor for skill-related fitness. In particular, the FMS lacks the capability to predict athletic performance among young, active college students with a total score ≥ 14. With increasing popularity of using FMS, strength and conditioning coaches, physical educators, personal trainers, or physical therapists should consider that the FMS is a more reliable tool in predicting musculoskeletal injuries, rather than a strong predictor for athletic performance. Furthermore, the limited significant correlations between individual item of the FMS and the skill-related fitness test are not sufficient enough to present a clear pattern of relationship between the performances of the two tests. More research studies are needed to investigate the influence of age, gender, and skill level on the relationship between the FMS and skill-related fitness performances, as well whether difference between left and right limb usage on the individual task from the FMS could contribute to varying athletic performance.

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