A preliminary investigation into the relationship between functional movement screen scores and athletic physical performance in female team sport athletes

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ABSTRACT: There is little research investigating relationships between the Functional Movement Screen (FMS) and athletic performance in female athletes. This study analyzed the relationships between FMS (deep squat; hurdle step [HS]; in-line lunge [ILL]; shoulder mobility; active straight-leg raise [ASLR]; trunk stability push-up; rotary stability) scores, and performance tests (bilateral and unilateral sit-and-reach [flexibility]; 20-m sprint [linear speed]; 505 with turns from each leg; modified T-test with movement to left and right [change-of-direction speed]; bilateral and unilateral vertical and standing broad jumps; lateral jumps [leg power]). Nine healthy female recreational team sport athletes (age = 22.67 ± 5.12 years; height = 1.66 ± 0.05 m; body mass = 64.22 ± 4.44 kilograms) were screened in the FMS and completed the afore-mentioned tests. Percentage between-leg differences in unilateral sit-and-reach, 505 turns and the jumps, and difference between the T-test conditions, were also calculated. Spearman's correlations ($p \leq 0.05$) examined relationships between the FMS and performance tests. Stepwise multiple regressions ($p \leq 0.05$) were conducted for the performance tests to determine FMS predictors. Unilateral sit-and-reach positive correlated with the left-leg ASLR (r = 0.704-0.725). However, higher-scoring HS, ILL, and ASLR related to poorer 505 and T-test performance (r = 0.722-0.829). A higher-scored left-leg ASLR related to a poorer unilateral vertical and standing broad jump, which were the only significant relationships for jump performance. Predictive data tended to confirm the correlations. The results suggest limitations in using the FMS to identify movement deficiencies that could negatively impact athletic performance in female team sport athletes.

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INTRODUCTION

A range of assessments are used to monitor the physical capacity of team sport athletes. This can include tests of linear speed (e.g. sprints over varying distances) [1-3]; change-of-direction speed (e.g. 505 and T-test) [1, 4]; lower-body power (e.g. maximal jumps) [1, 2]; and flexibility (e.g. sit-and-reach) [5, 6]. In recent times, anecdotal information suggests that strength and conditioning coaches have used movement screens as an assessment of functional ability in athletes [7]. Cook et al. states [8] that functional movement is the ability to perform locomotor, manipulative, and stabilizing actions, while maintaining control along the kinetic chain. Effective screening exercises should place individuals in positions where particular muscle or joint limitations can be identified if the appropriate stability and mobility is not present [8].

The Functional Movement Screen (FMS) was developed to evaluate these capacities [8, 9], and is composed of the: deep squat; hurdle step; in-line lunge; shoulder mobility; active straight-leg raise; trunk stability push-up; and rotary stability. The FMS has been used with a view to identifying deficiencies that could lead to an increased risk of injury [8-10]. Movement deficiencies that increase injury risk could also theoretically influence sports performance [7]. This relationship could have great value for athletes, as correction of movement inefficiencies identified by screens (e.g. restricted hip flexion in the hurdle step) could lead to improvements in sport-specific movements (e.g. multidirectional sprinting). However, the current links between athletic performance and the FMS have been contentious. Okada et al. [11] found moderate relationships between FMS scores and performance in the backwards overhead medicine ball throw and T-test in recreationally-active individuals (correlation coefficient [r] = -0.383 to -0.462), and no relationships between the FMS and core stability. Parchmann and McBride [12] found that FMS scores did not relate to 20-meter (m) sprint (r = -0.107), vertical jump (r = 0.249), or T-test (r = -0.146) performance in collegiate golfers.

However, both Okada et al. [11] and Parchmann and McBride [12] combined genders within their analysis. This is an issue, as research has demonstrated differences in between-gender movement technique. For example, females display greater knee valgus and flexion during a cutting movement when compared to males [13], and tend to be quadriceps-dominant during cutting and landing tasks [13, 14]. Due to these variations in mechanics, the links between screening scores and athletic performance in female athletes may differ, and there has not been a specific analysis of this population. Additionally, gender can be a contributing factor to the level of correlation between two physical performance variables [1]. This is pertinent when considering whether the FMS could be used to identify specific deficiencies within the body that could impact sport-specific performance in females. Indeed, there is a lack of research investigating the hypothesized relationship between the FMS and athletic performance [7].

Therefore, this study analyzed relationships between the FMS and athletic performance, as measured by typical team sport assessments in females. Tests included the sit-and-reach to assess low back and hamstring flexibility [6, 15]; 20-m sprint [4, 16]; 505 as it can isolate unilateral cutting [1, 17]; modified T-test as it incorporates specific change-of-direction movements [4, 18]; and jump tests [19-21]. The jump tests used in this study provided indirect measurements of power in three planes – vertical, horizontal, and lateral [22]. Due to the need for effective movement patterns during athletic performance, it was hypothesized that higher scores in the FMS would relate to better performance in the sport-specific tests. Furthermore, there would be screens that would predict performance in the athletic tests. This study will provide a preliminary investigation of whether there is value for coaches to use the FMS to monitor functional deficiencies in healthy females with a view towards enhancing athletic performance.

MATERIALS AND METHODS

Subjects. Nine females (age = 22.67 ± 5.12 years; height = 1.66 ± 0.05 m; body mass = 64.22 ± 4.44 kilograms) volunteered for this study. Subjects were recruited if they: were 18 years of age or older; currently participated in a team sport (i.e. soccer, netball, basketball, softball); had a training history (≥two times per week) extending over the previous year; and were currently training for a team sport (≥three times per week). To ensure pre-existing injuries would not affect FMS performance, inclusion criteria were adapted from previous research [10]. Subjects were included if they had not sustained an injury in the previous 30 days that prohibited full participation in regular training and competition, or had not had a recent surgery that limited sports participation. The procedures were approved by the institutional ethics committee, and conformed to the policy statement with respect to the Declaration of Helsinki. All subjects received an explanation of the research, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

Procedures

Testing was conducted in a biomechanics laboratory, which featured a 50-m textured concrete running track, over three sessions separated by one week. The first session incorporated the FMS. The second session included the bilateral sit-and-reach; 20-m sprint; and jump tests. The third session involved the unilateral sit-and-reach; 505; and modified T-test. Each testing session lasted for 30-60 minutes (min), and was performed in the afore-mentioned order due to time and equipment restrictions in the laboratory. Subjects refrained from intensive exercise and stimulants in the 24-hour period prior to testing, and wore their own running shoes with textured soles for all tests, except the sit-and-reach. At the start of the first session, the subject's age, height, and body mass were recorded, before the FMS assessment. For the other testing sessions, a standardized warm-up was completed, consisting of 10 min of jogging at a self-selected pace on a treadmill, before the sit-and-reach assessments were conducted. As static stretching can affect power-based activities [23], the investigators attempted to reduce any detrimental effects of the sit-and-reach by splitting the test over the two sessions, and completing this test prior to dynamic stretching. Following the sit-and-reach, subjects completed 10 min of dynamic stretching, and progressive speed runs over the test distances. In the third session, the warm-up included familiarization to the movements in the 505 and modified T-test. Subjects were tested in the same order across each session at the same time of day. For each unilateral jump test, between-leg differences were expressed as a percentage through the formula: (powerful leg - weaker leg)/powerful leg x 100. The more powerful leg was defined as the leg with the better (i.e. further or higher) jump.

Functional Movement Screen (FMS)

The FMS used seven tests and three clearing examinations [8, 9, 11, 24-26], the reliability of which has been established [24, 26]. The tests were: (1) deep squat: a dowel was held overhead with arms extended, and the subject squatted as low as possible; (2) hurdle step: a dowel was held across the shoulders, and the subject stepped over a hurdle in front of them level with their tibial tuberosity; (3) in-line lunge: with a dowel held vertically behind the subject so it contacted the head, back and sacrum, and with the feet aligned, the subject performed a split squat; (4) shoulder mobility: the subject attempted to touch their fists together behind their back; (5) active straight-leg raise: lying supine on the ground, the subject raised one leg as high as possible; (6) trunk stability push-up: the subject performed a push-up with their hands shoulder-width apart; and (7) rotary stability: the subject assumed a quadruped position and attempted to touch their knee and elbow, ipsilaterally and contralaterally [25]. Clearing tests were used for the shoulder mobility, trunk stability push-up, and rotary stability [8, 9]. The shoulder mobility clearing test involved the subject placing their hand on the

TABLE 1. Scoring procedures for the Functional Movement Screen [4, 5, 7, 24]

Functional Movement	Screening Criteria	Score		
		3	2	1
Deep Squat	Performed without board	X		
Dowel is held overhead with arms extended. Feet shoulder-width apart. Subject squats as low as possible. If score of 3 not attained, subject attempts deep squat with 2x6 inch board placed under heels.	Hips break parallel	X	X	
	Tibia/Torso Parallel	X	X	
	Knees aligned over toes	X	X	
	Symmetrical and weight bearing	X	X	
	Dowel behind toes	X	X	
	No lumbar flexion		X	
	Feet do not externally rotate	X	X	
	Heels do not come off floor	X		
	Performs without pain	X	X	X
	Score			
Hurdle Step	Clears hurdle	X	X	
Subject starts by facing hurdle. Hurdle adjusted to height of subject's tibial tuberosity. A dowel is held across shoulders. Subject steps over hurdle, touches heel on ground in front of hurdle, while keeping stance leg extended. Moving leg then returned to start position. Moving leg is side being scored.	Hip/knee/ankle aligned	X		
	No lumbar flexion	X		
	Dowel stays parallel to ground	X		
	Ankle remains dorsi flexed	X		
	No contact between foot and hurdle	X	X	
	Balance maintained	X	X	
	Performs without pain	X	X	X
	Score	R:	L:	
In-line Lunge	Dowel contacts head/back/sacrum	X		
Measure subject's tibia length (floor to tibial tuberosity). Subject stands with toes at zero-point of tape measure, and mark placed at distance equivalent to tibia length. Subject holds dowel vertically behind body so it contacts head, back and sacrum. Opposite hand to front foot should grasp dowel at cervical spine; other hand grasps at lumbar spine. With feet aligned, the subject performs a lunge placing heel at mark; back knee should touch ground behind front foot. Front leg is side being scored.	Dowel remains in sagittal plane	X		
	No torso movement	X		
	Knee contacts ground behind heel	X		
	Rear foot does not externally rotate	X		
	Lumbar spine remains neutral	X		
	No forward lean	X		
	Balance maintained	X	X	
	Places hands appropriately	X	X	
	Front heel remains on ground	X		
	Performs without pain	X	X	X
	Score	R:	L:	
Shoulder Mobility	Fists are within 1 hand length	X		
Measure hand length of subject (distance from distal wrist crease to tip of third digit). Subject makes fists, tucking thumbs inside. Subject attempts to touch fists together behind their back in one smooth motion. Tester measures distance between two closest boney prominences. Flexed shoulder is side being scored.	Fists are within 1.5 hand lengths		X	
	Fists are not within 1.5 hand lengths			X
	Performs without pain	X	X	X
	No pain with impingement test	X	X	X
	Score	R:	L:	
Active Straight-Leg Raise	Malleolus between midthigh and ASIS	X		
Subject lies supine with head on ground; board placed under knees. Tester identifies midpoint between superior anterior iliac spine (ASIS) and midpoint of patella; dowel placed here ^ to ground. Subject actively raises test leg (ankle dorsi flexed and knee extended) as high as possible. Opposite leg, head, should remain in contact with ground. Leg with flexed hip is side being scored.	Malleolus between midthigh and knee		X	
	Malleolus below knee			X
	Opposite hip remains neutral	X	X	
	Toes remain pointed up	X	X	
	Knee maintains contact with board	X	X	
	Performs without pain	X	X	X
	Score	R:	L:	
Trunk Stability Push-up	Performs with thumbs aligned at chin	X		
Subject assumes prone position with hands shoulder-width apart, positioned per criteria. Subject performs a push-up with knees extended and ankles dorsi flexed; body lifted as one unit.	Performs with thumbs aligned at clavicle		X	
	Body lifted as one unit	X	X	
	Ankles remain dorsi flexed	X	X	
	Performs without pain	X	X	X
	No pain with extension test	X	X	X
	Score			
Rotary Stability	Balanced ipsilateral	X		
Subject assumes a four-point, quadruped position; shoulders and hips at 90°. Subject then flexes one shoulder and extends ipsilateral hip; shoulder then extends and knees flexes to touch elbow and knee. If score of 3 not attained, subject performs diagonal pattern with shoulder and contralateral hip. The shoulder that moves is side of body being scored.	Balanced contralateral		X	
	Spine parallel	X	X	
	Knee/elbow in line	X	X	
	Knee and elbow touch	X	X	
	Minimal trunk flexion		X	
	Performs without pain	X	X	X
	No pain with flexion test	X	X	X
	Score	R:	L:	
		OVERALL:		(21)

opposite shoulder and attempting to point the elbow up. A spinal extension clearing test was used for the trunk stability push-up. A press-up was performed from the push-up start position, and contact was maintained between the hips and ground. The rotary stability clearing test involved spinal flexion. From the quadruped position, subjects kept their hands in contact with the ground in front of the body and rocked back to touch the buttocks to the heels and chest to the thighs.

The scoring checklist is shown in Table 1. Three repetitions of each screen were completed, and the best performed repetition was scored [8, 9]. Five seconds (s) of rest were provided between trials, and one min between tests. Subjects returned to the starting position between each attempt [11]. Two camcorders (Sony Electronics Inc., Tokyo, Japan), positioned anteriorly and laterally filmed the subjects [24, 25]. Two exercise scientists, experienced with the FMS, analyzed subjects live and later reviewed the video footage, and scored each subject independently from 0-3 for each movement (Table 1). Scores of 3, 2, 1, and 0, represented, according to the relevant criteria: 'performed without compensation', 'performed with compensation', 'could not perform', and 'pain', respectively [8, 9, 25]. A movement completed with a single compensation scored 2; more than one compensation scored 1 [25]. If there was a discrepancy in scores between the investigators, they reviewed the video footage, and discussed the result until a resolution was reached. Except for the deep squat and trunk stability push-up, each side of the body was assessed unilaterally. An overall score of 21 was the highest a subject could attain. For tasks that required assessments of both sides of the body, the lowest score contributed to the overall score. For this study, individual scores for each side of the body were also considered.

Sit-and-Reach

The sit-and-reach is a field test used to assess lower-body flexibility [6, 15]. Depending on the session, immediately following the 10 min of treadmill jogging subjects completed either the standard [15] or unilateral [6, 15] sit-and-reach. A sit-and-reach box (Novel Products, Inc., Rockton, USA) with a scale marked on the upper side, was placed against a wall. Subjects removed their shoes and with their legs extended, placed the soles of both feet inside the box. Zero intersected the point where the feet pressed against the box. A positive score measured in centimeters (cm) indicated the subject reached past their toes; a negative score indicated that they did not. The subject positioned their hands on top of each other (tips of the middle fingers aligned), with the palms down. The subject then reached slowly forward and touched as far along the scale as possible, and held this position for 5 s. The point where the tip of the middle fingers touched the scale was the distance measured, and the best trial was used. The researcher monitored each subject's effort to ensure the knees did not flex.

For the unilateral sit-and-reach, the subjects sat at the sit-and-reach box and fully extended one leg so that the foot was flat against the end of the box. Subjects then bent the other leg so that the foot was flat on the floor with the knee and hip flexed at approximately 90º and 45º, respectively. Subjects positioned their hands on top of each other with the palms down, reached forward and touched as far along the scale as possible while not flexing at the extended knee, and held this position for 5 s. Both legs were assessed, and the best trials were used. Percentage reach differences between the legs were calculated via the formula: (*further reach – lesser reach)/further reach x 100*.

20-meter Sprint

20-m sprint time was recorded by a timing lights system (Fusion Sports, Coopers Plains, Australia). 1.2-m high gates were positioned at 0 m, 5 m, 10 m, and 20 m, to measure the 0-5 m, 0-10 m, and 0-20 m intervals. Sprints over 5 m [21], 10 m [1, 21], and 20 m [4, 16] have been used in the assessment of team sport athletes. Subjects began the sprint from a standing start 30 cm behind the start line to trigger the first gate, and were instructed to start in their own time and sprint through all gates. Subjects completed three trials, with three min recovery between each trial, and the fastest trial was used for analysis. Time was recorded to the nearest 0.001 s.

Bilateral and Unilateral Vertical Jump

The vertical jump provided an indirect measure of vertical plane leg power. A Yardstick device (Swift Performance Equipment, Wacol, Australia) measured jump performance [19]. The subject stood side-on to the Vertec (on the subjects' dominant side), and while keeping their heels on the floor, reached upward to displace as many vanes as possible. The last vane moved was recorded as the standing reach height. The bilateral jump involved the subject jumping as high as possible using a two-foot take-off with no preparatory step, with no restrictions placed on countermovement range of motion. Height was recorded in cm from the highest vane moved, and vertical jump height was calculated by subtracting the standing reach height from the jump height. Following the bilateral jumps, subjects completed unilateral jumps in the same manner for both legs, the order of which was randomized between subjects. Subjects took off from one leg, and landed on both feet. Each subject completed three trials for each condition, with two min recovery between trials. The best trial from each condition was analyzed.

Bilateral and Unilateral Standing Broad Jump

The standing broad jump indirectly measured horizontal power. The subject placed the toes of both feet on the back of the start line. With a simultaneous, unrestricted arm swing and crouch, the subject leapt as far forward as possible, ensuring a two-footed landing. Subjects had to 'stick' the landing; if not, the trial was disregarded and another completed. Distance was measured perpendicularly from the front of the start line to the posterior surface of the heel at the landing [19], to the nearest 0.01 m using a tape measure (HART Sport, Aspley, Australia). Following the bilateral jumps, subjects completed unilateral jumps in the same manner [20]. Subjects took off from one leg, and then landed on both feet. The distance jumped was measured in the same manner as the bilateral standing broad jump. The order of which leg was tested first was randomized amongst the subjects. Three trials were completed for each condition. Two min between-trial recovery was allocated, and the best trial for each condition was used.

Lateral Jump

Lateral jump performance was used as an indirect measure of lateral power for each leg [22]. The subject started by standing on the testing leg with the medial border of the foot at the start line [20, 22]; for example, for a left-leg jump, the medial border of the left foot was placed on the start line. The subject jumped laterally to the inside as far as possible and landed on two feet. No restrictions were placed on the arm swing or countermovement of the take-off leg during the preparatory crouch. Jump distance was measured to the nearest 0.01 m, perpendicularly from the start line to the lateral margin of the take-off leg with a tape measure [20, 22]. If subjects over-balanced upon landing, the trial was disregarded and reattempted. Which leg was tested first was randomized amongst the subjects. Each subject completed three trials for each leg, two min recovery was allocated between trials, and the best trial for each leg was used for analysis.

505 Change-of-Direction Speed Test

The 505 is an assessment often used for team sport athletes, as it isolates the change-of-direction ability for each leg [1, 17]. Established methods [1, 17], with one 1.2-m timing gate, (Figure 1) were used. Subjects utilized a standing start with their front foot 30 cm behind the start line, before they sprinted through the timing gate to the turning line, indicated by a line marked on the floor and markers. Subjects placed either the left or right foot (depending on the trial) on the line, turned 180°, and sprinted back through the gate. Three trials were recorded for turns off the left and right foot, the order of which was randomized. Time was recorded to the nearest 0.001 s. Three min recovery was allocated between trials. If the subject changed direction before the turning point, or turned off the incorrect foot, the trial was disregarded and reattempted. The fastest trial for each leg was analyzed. Percentage differences between the left- and right-foot turns were calculated through the formula: (*slower time – faster time)/slower time x 100*.

Modified T-Test

The T-test incorporates team sport-specific movements such as sprint accelerations, decelerations, lateral shuffling, and back pedaling [4, 18]. A modified T-test with shorter distances was used [18]. Markers were positioned as shown in Figure 2, with a start line identified by tape on the floor, and one, 1.2-m high timing gate. Subjects sprinted forwards 5 m to touch the top of the middle marker. They then side-shuffled 2.5 m to the left or right, depending on the trial, to touch the next marker, side-shuffled 5 m in the opposite direction to touch the next marker, side-shuffled 2.5 m back to touch the middle marker again, before back-pedaling past the start line to finish. The hand that was on the same side as the shuffle direction (left hand when shuffling to the left, right hand when shuffling to the right) was used to touch the marker. Six trials were completed; three with movement initiation at the middle marker to the left, and three to the right. The order of trials was randomized, three min rest was allocated between trials, and the best trial from each condition was used.

Statistical Analysis

All statistical analyses were computed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA). Descriptive statistics (mean ± standard deviation; 95% confidence

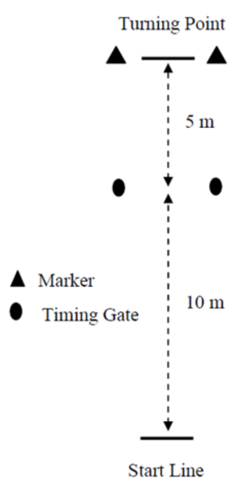

FIG. 1. 505 change-of-direction Speer test design.

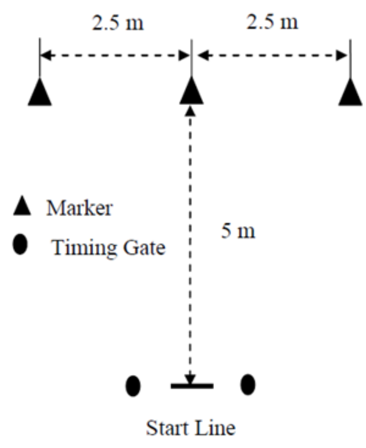

FIG. 2. Modified T-test design.

intervals) provided a profile for each parameter. Due to the sample size, performance test data distribution was checked with Q-Q plots [27] and the Shapiro-Wilk test. Spearman's correlation analysis computed relationships between the FMS and performance tests ($p \leq 0.05$). The correlation coefficient strength was designated as per Hopkins [28]. A rho (ρ) value between 0 to 0.3, or 0 to -0.3, was small; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.5 to 0.69, or -0.5 to -0.69, large; 0.7 to 0.89, or -0.7 to -0.89, very large; and 0.9 to 1, or -0.9 to -1, near perfect for predicting relationships. Stepwise multiple regression analyses ($p \leq 0.05$) were conducted for the sit-and-reach, 20-m sprint, 505, modified T-test, and jump tests (each acted as a dependent variable), with the FMS screens, to determine which could best predict performance in the particular test. Scatter plots were produced for selected screening and test relationships to ascertain if there was a threshold for a performance difference.

RESULTS

Figure 3 displays the mean individual FMS scores. There were no differences in the rotary stability for either side of the body, so one score is shown. The mean overall score for the sample was 13.44 ± 2.88. Performance test data is shown in Table 2. The Q-Q plots and Shapiro-Wilk test ($p = 0.065$-0.988) indicated that this data was normally distributed, even with the different athletic backgrounds of the subjects. Table 3 displays the correlations between the FMS and the sit-and-reach, 20-m sprint, 505, and modified T-test. There were positive correlations between the unilateral sit-and-reach for both legs, and the left-leg in-line lunge ($p = 0.034$) and active straight-leg raise ($p = 0.027$), and overall score ($p = 0.037$). As the reach distances for both legs were similar (Table 3), the ρ and *p* values for both legs were the same. The between-leg sit-and-reach difference had negative correlations with the deep squat ($p = 0.024$), left- ($p = 0.002$) and right-leg ($p = 0.020$) hurdle step, and left-leg active straight-leg raise ($p = 0.045$).

The left-leg 505 correlated with the left-leg in-line lunge ($p = 0.028$) and right-leg active straight-leg raise ($p = 0.018$). The right-leg 505 correlated with the left-leg in-line lunge ($p = 0.006$), left- ($p = 0.027$) and right-leg ($p = 0.045$) active straight-leg raise, rotary stability ($p = 0.025$), and overall score ($p = 0.018$). The difference between the 505 conditions correlated with the left-leg hurdle step ($p = 0.039$) and active straight-leg raise ($p = 0.026$),

TABLE 2. Descriptive data (mean ± standard deviation; 90% confidence intervals [CI]) for bilateral and unilateral sit-and-reach, 20-meter (m) sprint (0-5 m, 0-10 m, and 0-20 m intervals), 505 and modified T-test with turns towards the left and right and percentage differences between the turns, and bilateral and unilateral vertical jump, standing broad jump, and lateral jump, and between-leg differences in jump performance, in healthy, recreational female team sport athletes.

Tests	Subject Mean (n = 9)	95% CI
Sit-and-Reach (cm)	35.94 ± 9.75	28.45-43.44
Sit-and-Reach Left (cm)	35.61 ± 9.81	28.07-43.15
Sit-and-Reach Right (cm)	35.56 ± 9.46	28.29-42.83
Sit-and-Reach Difference (%)	2.57 ± 2.07	0.98-4.16
0-5 m Interval (s)	1.156 ± 0.043	1.123-1.188
0-10 m Interval (s)	1.986 ± 0.165	1.936-2.036
0-20 m Interval (s)	3.453 ± 0.120	3.360-3.545
505 Left (s)	2.626 ± 0.096	2.553-2.700
505 Right (s)	2.636 ± 0.069	2.583-2.688
505 Difference (%)	1.52 ± 1.28	0.54-2.51
Modified T-Test Left (s)	6.890 ± 0.323	6.641-7.138
Modified T-Test Right (s)	7.025 ± 0.287	6.805-7.246
Modified T-Test Difference (%)	2.69 ± 1.88	1.25-4.13
Bilateral Vertical Jump (cm)	43.44 ± 3.43	40.81-46.08
Vertical Jump Left (cm)	29.22 ± 5.56	24.95-33.50
Vertical Jump Right (cm)	30.00 ± 3.46	27.34-32.66
Vertical Jump Difference (%)	7.59 ± 6.02	2.96-12.22
Bilateral Standing Broad Jump (m)	1.79 ± 0.17	1.67-1.92
Standing Broad Jump Left (m)	1.64 ± 0.16	1.51-1.76
Standing Broad Jump Right (m)	1.64 ± 0.13	1.54-1.75
Standing Broad Jump Difference (%)	2.70 ± 1.26	1.73-3.67
Lateral Jump Left (m)	1.56 ± 0.14	1.45-1.67
Lateral Jump Right (m)	1.55 ± 0.10	1.47-1.62
Lateral Jump Difference (%)	4.48 ± 3.61	1.70-7.26

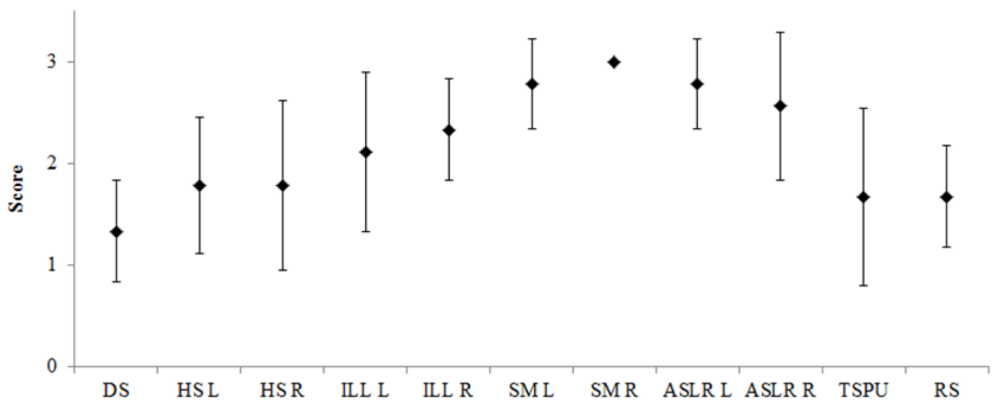

FIG. 3. Scores (mean ± standard deviation) for the Functional Movement Screen assessments (DS = deep squat, HS = hurdle step, ILL = in-line lung, SM = shoulder mobility, ASLR = active straight-leg rise, TSPU = trunk stability push-up, RS = rotary stability, OS = overall score) for the left and right of the body in healthy, recreational female team sport athletes (n=9).

TABLE 3. Spearman's correlations between Functional Movement Screen assessments for the left (L) and right (R) sides of the body, and bilateral, unilateral, and between-leg differences in sit-and-reach, 20-meter (m) sprint (0-5 m, 0-10 m, and 0-20 m intervals), 505 and modified T-test with turns towards the left and right, and percentage differences in turns to each side, in healthy, recreational female team sport athletes (n = 9).

	DS	HS L	HS R	ILL L	ILL R	SM L	ASLR L	ASLR R	TSPU	RS	OS
SAR	0.183	0.543	0.335	0.613	0.413	0.468	0.624	0.520	0.116	0.275	0.587
SAR L	0.274	0.652	0.383	0.704*	0.456	0.518	0.725*	0.598	0.231	0.456	0.698*
SAR R	0.274	0.652	0.383	0.704*	0.456	0.518	0.725*	0.598	0.231	0.456	0.698*
SAR Diff	-0.736*	-0.874*	-0.750*	-0.027	-0.322	-0.522	-0.678*	-0.316	-0.549	-0.414	-0.593
0-5 m	-0.548	-0.391	-0.205	0.107	-0.183	-0.104	0.000	0.299	-0.498	-0.365	-0.227
0-10 m	-0.274	-0.391	-0.481	0.392	0.091	-0.414	0.000	0.209	-0.304	-0.183	-0.176
0-20 m	-0.274	-0.317	-0.419	0.454	0.183	-0.311	0.104	0.319	-0.203	-0.091	-0.050
505 L	-0.274	0.130	-0.009	0.722*	0.183	0.311	0.518	0.757*	0.000	0.456	0.437
505 R	0.183	0.447	0.080	0.829*	0.639	0.311	0.725*	0.677*	0.433	0.730*	0.756*
505 Diff	0.321	0.692*	0.599	0.327	0.229	0.312	0.728*	0.410	0.440	0.779*	0.654
T-test L	-0.274	-0.149	-0.205	0.374	-0.183	0.000	0.414	0.727*	-0.138	0.548	-0.274
T-test R	0.091	-0.149	-0.241	0.071	-0.274	-0.104	0.518	0.807*	-0.184	0.456	0.091
T-test Diff	0.822*	0.708*	0.383	0.125	0.365	0.518	0.725*	0.518	0.452	0.548	0.555

Note: DS = deep squat; HS = hurdle step; ILL = in-line lunge; SM = shoulder mobility; ASLR = active straight-leg raise; TSPU = trunk stability push-up; RS = rotary stability; OS = overall score

TABLE 4. Spearman's correlations between Functional Movement Screen assessments for the left (L) and right (R) sides of the body, and bilateral (2), unilateral (L and R), and between-leg differences, in vertical (VJ), standing broad (SBJ) and lateral (LJ) jump in healthy, recreational female team sport athletes (n = 9).

	DS	HS L	HS R	ILL L	ILL R	SM L	ASLR L	ASLR R	TSPU	RS	OS
VJ 2	0.046	-0.009	0.089	-0.313	-0.046	0.000	-0.468	-0.520	0.255	-0.229	-0.139
VJ L	0.046	-0.263	-0.193	-0.521	-0.046	-0.052	-0.731*	-0.683*	0.135	-0.506	-0.360
VJ R	-0.192	-0.381	-0.150	-0.481	-0.335	-0.163	-0.597	-0.376	-0.073	-0.527	-0.494
VJ Diff	-0.506	-0.460	-0.198	-0.180	-0.644	-0.052	-0.209	0.151	-0.846*	-0.552	-0.542
SBJ 2	-0.091	-0.037	0.116	-0.267	-0.183	0.207	-0.311	-0.139	0.166	-0.183	-0.118
SBJ L	-0.504	-0.412	-0.134	-0.335	-0.367	0.000	-0.728*	-0.490	-0.227	-0.550	-0.426
SBJ R	-0.456	-0.354	-0.178	-0.214	-0.365	0.000	-0.621	-0.458	-0.258	-0.274	-0.328
SBJ Diff	-0.229	-0.309	-0.510	0.465	-0.138	-0.312	-0.104	0.010	-0.523	0.046	-0.186
LJ L	-0.091	-0.130	0.053	-0.499	-0.274	0.207	-0.414	-0.269	0.101	-0.183	-0.210
LJ R	-0.229	0.271	0.322	0.224	0.229	0.416	-0.156	-0.240	0.301	0.046	0.359
LJ Diff	0.639	0.261	0.107	-0.561	-0.091	0.518	-0.104	-0.179	0.120	0.000	-0.025

Note: DS = deep squat; HS = hurdle step; ILL = in-line lunge; SM = shoulder mobility; ASLR = active straight-leg raise; TSPU = trunk stability push-up; RS = rotary stability; OS = overall score

and rotary stability ($p = 0.013$). The modified T-test with movement initiation to the left ($p = 0.026$) and right ($p = 0.009$) correlated with the right-leg active straight-leg raise. The difference between the T-test conditions correlated with the deep squat ($p = 0.007$), left-leg hurdle step ($p = 0.033$), and left-leg active straight-leg raise ($p = 0.027$). All relationships indicated a higher screening score related to slower speed test times, or a greater difference between the test conditions.

The FMS and jump test correlations are shown in Table 4. The left-leg vertical ($p = 0.025$) and standing broad jump ($p = 0.026$) had negative correlations with the left-leg active straight-leg raise. The left-leg vertical jump also had a negative correlation with the right-leg active straight-leg raise ($p = 0.043$). Each relationship indicated a higher-scored active straight-leg raise related to a poorer jump. The trunk stability push-up had a negative correlation with the between-leg difference in the vertical jump ($p = 0.004$), which implied a higher-scored screen related to a smaller difference. Only the left- and right- leg sit-and-reach, between-leg sit-and-reach difference, 505, between-condition difference for the modified T-test, left-leg vertical jump, and vertical jump difference, produced significant predictive relationships (Table 5).

On the basis of these results, scatter plots investigated the performance test relationships with the left- (right-turn 505, left-leg vertical jump, and left-leg standing broad jump) and right-leg (left-turn 505, right-turn 505, left-turn modified T-test, right-turn modified T-test, and left-leg vertical jump) active straight leg raise (Figure 4). In each case, subjects scoring 3 in the active straight-leg raise assessment were generally the poorer performers. Subjects who scored 2 tended to perform better.

DISCUSSION

Although the relationship between the FMS and athletic performance has been discussed in recent literature [11, 12], this is the first study to analyze the relationship between FMS scores and athletic performance in healthy female team sport athletes. A limitation of this study was that the sample size is small (n = 9), which could limit the generalizability of the investigation. Furthermore, although the study approach mirrored that of previous research [11, 12], FMS scores provide ordinal results (i.e. 1-3), and different movement compensations could achieve the same score in certain screens (Table 1). This could affect the strength of any relationships with performance tests. Multidirectional sprinting and leg power is also influenced by factors such as strength and technique, and thus may not be easily predicted by basic actions such as those from the FMS. Nevertheless, the range of motion required within the FMS actions do bear resemblance to those required in team sport movements [24],

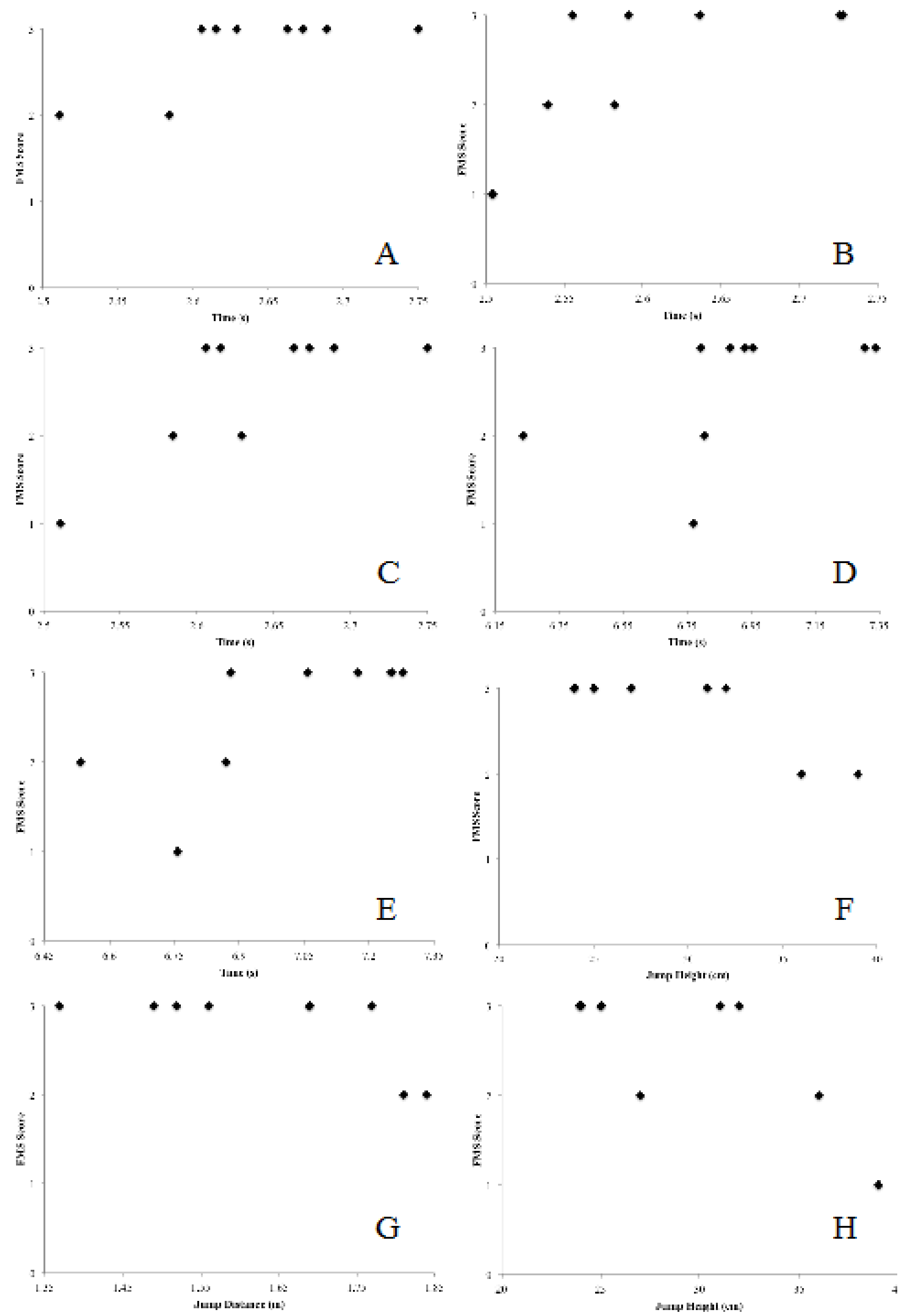

FIG. 4. Scatter plots (n=9) for scores comparisons between (A) left active straight-leg rise (ALSR) and right-turn 505; (B) right-leg ASLR and left-turn 505; (C) right-leg ASLR and right-turn 505; (D) right-leg ASLR and left-turn modified T-test; (E) right-leg ASLR and right-turn modified T-test; (F) left-leg ASLR and left-leg vertical jump; (G) left-leg ASLR and left-leg standing broad jump; and (H) right-leg ASLR and left-leg vertical jump in healthy, recreational female team sport athletes.

TABLE 5. Stepwise linear regression between deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility, active straight-leg raise (ASLR), trunk stability push-up (TSPU), and rotary stability, and selected performance tests (505 time with left- and right-leg turns, between-leg difference 505 times, modified T-test with movement initiation to the right, difference in modified T-test test with movement initiation to left or right, left- and right-leg sit-and-reach, between-leg sit-and-reach differences, left-leg vertical jump, and between-leg vertical jump differences).

Best Predictors of the Test	r	r^2	p
Left-Leg Sit-and-Reach			
Left-Leg ASLR	0.76	0.57	0.018
Right-Leg Sit-and-Reach			
Left-Leg ASLR	0.71	0.50	0.033
Sit-and-Reach Difference			
Left-Leg HS	0.88	0.78	0.002
505 Left			
Left-Leg ILL	0.78	0.61	0.014
Left-Leg ILL, Right-Leg ASLR	0.90	0.81	0.007
Left-Leg ILL, Right-Leg ASLR, Left-Leg ASLR	0.96	0.92	0.004
505 Right			
Right-Leg ASLR	0.77	0.59	0.015
Right-Leg ASLR, Right-Leg ILL	0.92	0.80	0.004
Right-Leg ASLR, Right-Leg ILL, TSPU	0.97	0.91	0.001
Right-Leg ASLR, Right-Leg ILL, TSPU, RS	1.00	0.99	<0.001
505 Difference			
Left-Leg Hurdle Step	0.74	0.55	0.023
Modified T-Test Right			
Right-Leg ASLR	0.71	0.51	0.032
Right-Leg ASLR, Left-Leg HS	0.89	0.79	0.009
Modified T-Test Difference			
DS	0.84	0.71	0.004
Left-Leg Vertical Jump			
Left-Leg ASLR	0.84	0.71	0.004
Vertical Jump Difference			
TSPU	0.84	0.71	0.004

Note: r = multiple regression correlation coefficient; p = significance

and this study provides a preliminary analysis of whether the FMS could identify deficiencies that may affect sports performance in female athletes. Although this study does not prove cause-and-effect, the findings do indicate limitations for the FMS.

Subjects who exhibited greater flexibility as measured by the unilateral sit-and-reach, also tended to have higher scores in the left-leg in-line lunge and active straight-leg raise, and the overall score (Table 3). The left-leg active straight leg raise also best predicted the left- and right-leg sit-and-reach (Table 5). Additionally, a smaller between-leg difference in the sit-and-reach related to a higher-scored deep squat, hurdle step for both legs, and left-leg active straight leg raise, and was best predicted by the left-leg hurdle step. These results provide an indication that female athletes should be able to demonstrate unilateral flexibility across different tasks. However, as will be discussed, this research also implied that greater flexibility as measured by the FMS did not relate to better athletic performance. Even with the study sample size, strength and conditioning coaches should be cognizant that the flexibility measures attained by the FMS may have limited application to sport-specific performance in females.

The 20-m sprint did not correlate with the FMS, which supports Parchmann and McBride [12]. For both the 505 and modified T-test, higher scores in the hurdle step, in-line lunge, active straight-leg raise, and rotary stability related to slower change-of-direction speed test times (Table 3). The in-line lunge, active straight-leg raise, and rotary stability were predictors of the 505 for turns off each leg (Table 5). Additionally, a higher-scored left-leg hurdle step and active straight-leg raise (as well as the deep squat for the modified T-test) related to greater differences between the 505 and T-test conditions, which infer a greater imbalance in change-of-direction speed performance. This somewhat contrasts Parchmann and McBride [12], who found no relationship between the FMS and T-test performance in golfers. However, the results from the current study signified that those females who performed better in the FMS also performed poorer in the change-of-direction speed tests. Cook et al. [8] stated that the in-line lunge and hurdle step require flexibility of the hip muscles. The active straight-leg raise assesses the flexibility of the hamstring, gastrocnemius, and soleus [9]. However, each of these screens is performed slowly, from positions atypical to team sports. In addition, greater flexibility, and by extension greater musculotendinous compliance, may compromise power-based activities such as sprinting. As an example, greater musculotendinous compliance has been linked to increased 20-m sprint time in track sprinters [23]. These findings were further emphasized by data showing subjects who scored 3 in the active straight-leg raise tended to be slower in the change-of-direction speed tests (Figure 4), and higher flexibility could be a contributing factor.

The only screen that had a significant relationship with jumping was the active straight-leg raise for both legs with the left-leg vertical jump, and the left-leg active straight leg raise with the left-leg standing broad jump (Table 4). A higher-scored active straight-leg raise related to a poorer jump performance, which can be also seen in Figure 4 for subjects scoring 3 in this screen. This further emphasizes the potential influence of greater muscle compliance negatively affecting a power-based activity such as a jump [23]. Interestingly, a higher-scored trunk stability push up related to a smaller between-leg vertical jump difference (Table 4), which was also predicted by this screen (Table 5). The trunk stability push-up involves the maintenance of a stable trunk, which should allow for force transition through the body into the upper extremities [9]. A vertical jump requires a strong core, to allow the force generated by the legs to travel into the upper body [29], which is important for team sport athletes who need to use their arms when airborne [30]. The trunk stability push-up may provide an indication of core stability that could assist with between-leg balance in vertical jumping for females. This relationship could be confirmed with the analysis of a greater sample of female athletes. Nonetheless, within the limitations of this study, the FMS appears limited in identifying deficiencies that could adversely affect jump performance in female athletes.

CONCLUSIONS

This study suggested that the FMS was limited in its ability to detect movement compensations that could impact athletic performance in female athletes. The FMS provides an indication of flexibility as measured by a unilateral sit-and-reach. However, greater flexibility as measured by the hurdle step, in-line lunge, and the active straight-leg raise, related to slower change-of-direction speed, and poorer unilateral jump performance. Strength and conditioning coaches may find more value in using other methods for the assessment of movement weaknesses in females. For example, Nimphius et al. [1] established strong relationships between relative strength as measured by a one-repetition maximum squat and 10 m, 17.9 m, and 35.8 m sprint times, and the 505 (r = -0.73--0.85), in female softball players. Nonetheless, given the relatively small sample from this study, future research should incorporate a greater range of female athletes to prove or disprove any suggested limitations for the FMS in predicting team sport performance. Future studies should also determine the effects of specific movement compensations as defined by the FMS on athletic performance, and whether training to correct these compensations can translate to sports performance.

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