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Research-Grade Scoring for the Functional Movement Screen and Relationships with Athletic Performance Tests in Team Sport Athletes

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Abstract

Study background: There are limitations in using the traditional Functional Movement Screen (FMS) to identify deficiencies affecting athletic performance. Despite this, no research has analyzed the research-grade FMS scoring system with regards to athletic performance, where screens are weighted to increase their sensitivity. This research investigated relationships between the research-grade FMS and selected screens, with multidirectional speed and jump tests typically used to assess team sport athletes.

Methods: Thirty-two male recreational team sport athletes were assessed in the FMS using research-grade scoring, and multidirectional speed (20-meter sprint; 505 change-of-direction speed test) and jump (bilateral and unilateral vertical, standing broad, and lateral) tests. Participants were dichotomized into higher-, intermediate-, and lower-performing groups according to overall research-grade FMS score to ascertain whether participants who scored better in the screens also performed better in the athletic tests. A one-way analysis of variance determined any significant ($p<0.05$) between-group differences for sprinting and jumping performance. Correlations (r; $p<0.05$), scatter plots and regression equations were calculated for selected individual research-grade scored screens (deep squat, hurdle step, and in-line lunge) and the performance tests. These screens were selected due to movement pattern similarities (i.e., lower-body triple extension) with sprinting and jumping.

Results: There were no significant between-group differences in any of the multidirectional sprint or jumps tests. The deep squat positively correlated with the bilateral vertical and standing broad jump, and left-leg standing broad and lateral jump (r=0.37-0.52), although the explained variability from the regression equations were low (14-27%). The left-leg in-line lunge correlated with the bilateral and left-leg standing broad jump, and lateral jumps for both legs (r=0.38-0.50), with low explained variability (15-25%).

Conclusion: Despite the increased scoring sensitivity, the research-grade FMS, and individual screens, have a similarly limited capacity to identify any movement deficiencies that relate to multidirectional sprinting and jumping in team sport athletes.

Keywords: Functional screening; Multidirectional speed; Leg power; Standing broad jump; Lateral jump

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Introduction

The Functional Movement Screen (FMS) is a composite testing protocol that was developed in order to identify deficient movement patterns, using exercises that are said to challenge the ability to facilitate movement in a proximal-to-distal fashion [1,2]. These exercises (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability) have traditionally been scored from 0-3. Scores of 0, 1, 2, and 3 represent, according to relevant criteria for each screen: 'pain'; 'could not perform' or 'performed with more than one compensation'; 'performed with a single compensation'; and 'performed without compensation', respectively [1-3]. Recognition of movement compensations specific to a particular screen has been suggested as a method for strength and conditioning coaches to define a movement limitation that could lead to an increased risk of injury [1,2]. There is research that has suggested value in using the FMS as an injury prevention measure [4-6]. There has also been an implied link to athletic performance [7], because the movements completed within the FMS can be conceptualized in running and jumping actions [8].

However, there is little evidence that suggests the FMS scored by traditional methods relates to athletic performance [9-13]. For example, FMS performance has been found to have no significant relationships with core stability in healthy individuals [9], multidirectional speed and leg strength in collegiate golfers [10], and multidirectional speed and power in recreational male athletes [11]. Moreover, the 0-3 scoring system appears to be limited in its ability to identify specific compensations that could directly affect athletic performance (e.g. multidirectional speed and jumping). This reduces the ability of strength and conditioning coaches to use the FMS as a screening tool for weaknesses that could be targeted to enhance an athlete's movement abilities. Indeed, Lockie et al. [11] found that for the one screen that did relate to multidirectional speed and power (the deep squat), the differences between the participants who scored 1, 2, or 3, were not significant when comparing performance in a 20-meter (m) sprint, 505 and modified T-test, or vertical, standing broad, and lateral jumps. However, Lockie et al. [11] did find that better performing participants in the deep squat tended to perform better in these athletic performance tests. A more sensitive scoring system could potentially identify those deficiencies that could influence multidirectional speed and power in athletes.

Frost et al. [3] developed a research-grade scoring system for the FMS, which weights specific compensations made by an individual during a test, as well as ensuring scores attained in particular tests from both sides of the body contribute to a final score out of 100. The weightings mean that particular movements within a screen contribute differently to the final score. For example, in the deep squat, a parallel torso and tibia contribute six points. Alignment of the knees over the toes, a symmetrical squat, and a dowel position held behind the head, each contribute four points to the total for the deep squat, for a possible score out of 18 [3]. As a result, a certain score for a screen could provide an indication of the movement compensation that was made. This reduced the ability of the screen to have different compensations produce the same score [3]. If it can be shown that the ability to perform a particular screening test relates to athletic

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performance, then this screen could be used as a monitoring tool to aid in improving a certain physical capacity, such as multidirectional sprinting and jumping. The research-grade scoring system, with its expanded weighting of the component movements within a screen, may make results derived from the FMS more sensitive to comparisons with sport-specific assessments and athletic performance.

Therefore, this study analyzed the relationship between the research-grade FMS and athletic performance. Athletic performance was defined by tests that are commonly used to measure the physical characteristics of athletes, in particular team sport athletes. This included the 20-m sprint [14-17]; 505 change-of-direction speed test [18-21]; and bilateral and unilateral vertical, standing broad and lateral jumps [22-24]. It was hypothesized that due to a more sensitive scoring system, those participants who scored higher in the research-grade FMS would also perform better in multidirectional speed and jump tests. Furthermore, research-grade scores from individual screens that emphasize lower-body triple extension movements (deep squat, hurdle step, and in-line lunge) would have an association with multidirectional speed and jump tests, as they comprise similar movement patterns (e.g. lower-body triple extension [1,3]) to those required in sprinting [25,26] and jumping [27,28]. This research will provide beneficial information for strength and conditioning coaches in that it will demonstrate whether there is benefit to using the research-grade FMS to screen for deficiencies that could influence athletic performance in team sport athletes.

Methods

Experimental approach

This study analyzed the relationship between FMS scores derived from the research-grade scale, and those attained from tests that are used in team sport athlete assessment. The screens that were the focus of the study were the deep squat, hurdle step, and in-line lunge. The athletic performance test battery included 20-m sprint and 505 change-of-direction speed tests, and bilateral and unilateral vertical, standing broad and lateral jump tests. Participants were stratified into higher-, intermediate-, and lower-performing groups as defined by the research-grade FMS overall score. This delineated between the athletic performance characteristics of team sport athletes that performed better or worse at the FMS as scored by the research-grade scale. Relationships between research-grade scored screens and the speed and jump tests were investigated by Pearson's correlations and scatter plots. The dependent variables were: research-grade FMS scores; 0-5 m, 0-10 m, and 0-20 m times; 505 times with 180° turns off each leg; bilateral and unilateral vertical jump height; bilateral and unilateral standing broad jump distance; and unilateral lateral jump distance.

Participants

Thirty-two male recreational team sport athletes (age=22.84 ± 3.90 years; height=1.79 ± 0.07 m; body mass=79.37 ± 12.49 kilograms (kg)), volunteered to participate in this study. Participants were recruited if they: were 18 years of age or older; were currently participating in a team sport (e.g. soccer, rugby, Australian football, basketball, baseball); had a training history (≥ two times per week), including strength training, extending over the previous year; were currently training (≥ three times per week on the field or in the gym); did not have any medical conditions compromising study participation; and had not sustained an injury in the previous 30 days that prohibited them from full participation in regular training and sports competition [6]. Although there may be certain differences in traits between different sport participants, the analysis of performance with regards to physical characteristics common to athletes from assorted team sports has been consistently conducted within the literature, due to similarities in movement demands between sports (i.e. all of these sports require multidirectional speed and leg power) [17,24,25,29,30]. Participants maintained their normal physical activity for the duration of the study, which occurred within the competition season for all participants. The procedures used in this study were approved by the institutional ethics committee. All participants received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

Procedures

Testing was conducted in the university biomechanics laboratory, on a textured concrete floor, over three sessions each separated by one week. The first testing session involved the FMS. The second testing session incorporated the 20-m sprint; and the bilateral and unilateral vertical, standing broad, and lateral jump tests. The 505 was assessed in the last session. Each session lasted for approximately 30 min in duration, and was performed in the afore-mentioned order. Testing was conducted in this order for all participants due to laboratory and equipment availabilities. Participants refrained from intensive exercise and any form of stimulant (i.e. caffeine) in the 24-hour period prior to testing, and wore their own athletic trainers for all tests.

At the start of the first session, the participant's age, height, and body mass were recorded. Height was measured barefoot using a stadiometer (Ecomed Trading, Seven Hills, Australia); body mass was recorded by electronic digital scales (Tanita Corporation, Tokyo, Japan). Participants then completed the FMS. For the second and third sessions, participants completed a standardized warm-up, consisting of 10 minutes of jogging at a self-selected pace on a treadmill, 10 minutes of dynamic stretching, and progressive speed runs over the test distances. Participants were tested in the same order across each session at the same time of day. Three minutes recovery was allocated between sprint trials, and two minutes between jump trials.

Research-grade functional movement screen

The FMS used seven functional movements and three clearing examinations [1-3]. As stated, the deep squat, hurdle step for both legs, and in-line lunge for both legs as individual screens were a focus of this research. However, participants completed all screens so that an overall research-grade score could be attained. The screening tests, as designated by Frost et al. [3], were completed in the following order for each participant: (1) deep squat: a dowel was held overhead with arms extended, and the participant squatted as low as possible; (2) hurdle step: a dowel was held across the shoulders, and the participant stepped over a hurdle in front of them level with their tibial tuberosity; (3) in-line lunge: with a dowel held vertically behind the participant so it contacted the head, back and sacrum, and with the feet aligned, the participant performed a split squat; (4) shoulder mobility: the participant attempted to touch their fists together behind their back; (5) active straight-leg raise: lying supine, the participant actively raised one leg as high as possible; (6) trunk stability push-up: the participant performed a push-up with their hands shoulder-width apart; and (7) rotary stability: the participant assumed a quadruped position and attempted to touch their knee and elbow, ipsilaterally and contralaterally. Clearing tests were used for shoulder mobility, trunk stability push-up, and rotary stability [1,2]. The shoulder mobility clearing test involved the participant placing their hand on the opposite shoulder and attempting to point the elbow upward. The trunk stability push-up involved spinal extension, where the participant performed a press-up from the push-up start position, while maintaining contact between the hips and the ground. The rotary stability clearing test involved spinal flexion from the quadruped position. Participants slowly rocked back and attempted to touch the buttocks to the heels and chest to the thighs, with the hands remaining as far in front of the body as possible.

The research-grade FMS scoring checklists used in this study were documented by Frost et al. [3]. Frost et al. [3] stated this scoring system was based upon the work of Hickey et al. [31], who demonstrated the reliability of this scoring system. Three repetitions of each task were completed, and the best performed repetition was graded [1,2]. Approximately 5 seconds (s) of rest were provided between trials, one minute between tests, and participants were instructed to return to the starting position between each trial [9]. Participants were filmed by two video camcorders (Sony Electronics Inc., Tokyo, Japan), positioned anteriorly and laterally [3,8]. Two exercise scientists, trained and experienced with the FMS, scored participants live individually, before later reviewing the video footage to confirm their scores. Each movement was rated according to the criteria detailed by Frost et al. [3]. If there was any discrepancy between the investigators, they reviewed the video footage and discussed the score until a resolution was reached. With the exception of the deep squat and trunk stability push-up, each side of the body was assessed independently within the screens. Scores for each side of the body contributed to the overall score [3]. An overall cumulative score of 100 was the highest a participant could attain.

20-meter Sprint

20-m sprint time was recorded by a timing lights system (Fusion Sports, Coopers Plains, Australia). Gates were positioned at 0 m, 5 m, 10 m, and 20 m, at a height of 1.2 m, to measure the 0-5 m, 0-10 m, and 0-20 m intervals. Sprints over 5 m [16,25], 10 m [16,17,21,25], and 20 m [14-17] have been used to assess athletes from team sports. Participants began the sprint from a standing start 30 centimeters behind the start line to trigger the first gate. Once ready, participants started in their own time, and ran maximally once they initiated their sprint. Participants completed three trials, and the fastest trial was used for analysis. If the participant rocked backwards or forwards prior to starting, the trial was disregarded and repeated. Time for each interval was recorded to the nearest 0.001 s.

Bilateral and unilateral vertical jump

The vertical jump was used as an indirect measure of vertical plane leg power. A Yardstick apparatus (Swift Performance Equipment, Wacol, Australia) was utilized to measure each jump [11,22,24]. The participant firstly stood side-on to the Yardstick on their dominant side, and while keeping their heels on the floor, reached upward as high as possible to displace as many vanes as possible. The last vane moved was recorded as the standing reach height, and was the zero reference for the jump assessment. The bilateral vertical jump involved the participant jumping as high as possible using a two-foot take-off with no preparatory step. No restrictions were placed on body range of motion during the countermovement. Vertical jump height was calculated by subtracting the standing reach height from the jump height in meters. Following the bilateral jumps, participants completed unilateral jumps in the same manner for both the left and right legs, the order of which was randomized between participants [11,24]. Participants initiated the vertical jumps from one leg, and landed on both feet. Each participant completed three trials for each jump condition, and the best trial was analyzed.

Bilateral and unilateral standing broad jump

The standing broad jump provided an indirect measure of horizontal plane leg power. The participant placed the front of both feet on the back of the start line. The participant leaped forward as far possible, ensuring a two-footed take-off and landing, and had to ‘stick’ the landing for a successful trial. If this was not done, the trial was disregarded and reattempted. No restrictions were placed on range of motion during the preparatory phase of the jump, or the arm swing used. Using established protocols [11,22,24], jump distance was measured to the nearest 0.01 m using a standard metric tape measure (HART Sport, Aspley, Australia), perpendicularly from the front of the start line to the most posterior surface of the heels at the landing. Following the bilateral jumps, participants completed unilateral jumps in the same manner for both legs [11,23,24]. Participants initiated the horizontal jumps from one leg, and then landed on both feet. The distance jumped was measured in the same manner as the bilateral standing broad jump, and the order of which leg was tested first was randomized amongst the participants. Each participant completed three trials for each condition, and the best trial was used.

Lateral jump

Lateral jump performance was used as an indirect measure of lateral leg power. The participant started by standing on the testing leg with the medial border of the foot at the start line [11,23]; for example, for a right-leg jump, the medial border of the right foot was placed on the line. The participant self-selected the range of motion of the preparatory crouch before jumping laterally to the inside (i.e. jumping to the left for a right-leg trial, and jumping to the right for a left-leg trial) as far as possible and landing on two feet. No restrictions were placed on range of motion of the arm swing or take-off leg during the preparatory crouch. The distance jumped was measured to the nearest 0.01 m using established methods, perpendicularly from the front of the start line to the most lateral margin of the take-off leg with a standard tape measure [11,23]. If participants over-balanced upon landing, the trial was disregarded and reattempted. The order of which leg was tested first was randomized. Each participant completed three trials for each leg, and the best trial for each leg was analyzed.

505 Change-of-Direction Speed Test

The 505 was included in this study as it is a common assessment for team sport athletes [18-21], and it isolates change-of-direction ability for each leg [32]. The test was structured according to established methods [32], with one, 1.2-m high timing gate. Figure 1 displays the structure of the 505. During the warm-up, participants familiarized themselves with the required movement patterns. Participants used a standing start as per the 20-m sprint, with their front foot 30 centimeters behind the start line. The participants sprinted through the timing gate to the turning line, indicated by a line marked on the laboratory floor and markers. Participants placed either the left or right foot, depending on the trial, on the line and turned 180°, before sprinting back through the gate. Three trials were recorded for turns off the left and right foot, the order of which was randomized amongst the participant group, and time was recorded to the nearest 0.001 s. If the participant changed direction before hitting the turning

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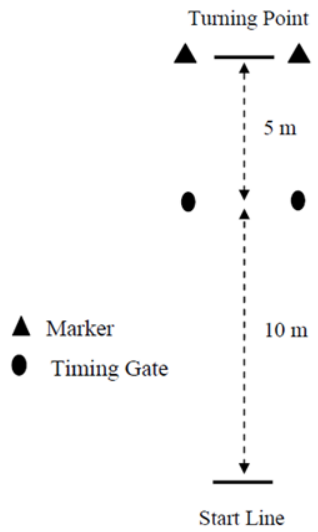

Figure 1: 505 change-of-direction speed test design. m: meters

point, or turned off the incorrect foot, the trial was disregarded and reattempted. The fastest trial for each of the 505 conditions was used.

Statistical analysis

Descriptive statistics (mean ± standard deviation) were calculated for each variable. The Levene statistic calculated the homogeneity of variance of the data. The data analysis for this study was modeled on previously research [25,30,33,34]. In order to ensure that the groups were comprised of participants who scored differently in the research-grade FMS, cut-off points were established through the formula *mean + (0.2 x standard deviation of the mean)* and *mean - (0.2 x standard deviation of the mean)* [24,35]. Multiplying the between-participants standard deviation by 0.2 provides the smallest worthwhile change in the mean for this sample [36], either above or below the sample mean. Thus, participants above the smallest worthwhile change greater than mean were placed in the higher-performing research-grade FMS group. Participants below the smallest worthwhile change less than the mean were placed in the lower-performing group, while participants in between the cut-off points were placed in the intermediate group. According to these groups, a one-way analysis of variance (ANOVA) computed any significant ($p<0.05$) differences between the individual screening exercises, and multidirectional speed and jump tests. Post hoc analysis was conducted for between-group pairwise comparisons using a Bonferroni adjustment for multiple comparisons.

Pearson's correlation analysis ($p<0.05$) was used to compare relationships between the research-grade FMS scores from the selected screens (deep squat, right and left leg hurdle step, right and left leg in-line lunge,), and the athletic performance tests. This kept the focus of the correlation analysis on the most relevant screens as it pertains to multidirectional, lower-body movement [37]. The strength of the correlation coefficient (r) was designated as per Hopkins [38]. An r value between 0 to 0.30, or 0 to -0.30, was considered small; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.50 to 0.69, or -0.50 to -0.69, large; 0.70 to 0.89, or -0.70 to -0.89, very large; and 0.90 to 1, or -0.90 to -1, near perfect for predicting relationships. The one-way ANOVA and correlations were computed using the Statistics Package for Social Sciences (Version 22.0; IBM Corporation, New York, USA). Depending on the results of the correlation analysis, scatter plots were derived between a screen and athletic test in Microsoft Excel (Microsoft Corporation™, Redmond, Washington, USA), and regression equations were produced. The explained variability between the screen and athletic test was provided by the square of the regression coefficient (R^2) expressed as a percentage [39].

Results

When participants were split into groups according to the overall research-grade FMS score, the higher-performing group consisted of 11 participants, the intermediate group 8 participants, and the lower-performing group 13 participants. There was a significant ($p=0.02$) difference in age between the higher-performing group (24.73 ± 2.45 years), when compared to the lower performers (20.54 ± 2.85 years). There were no significant age differences for comparisons with the intermediate group (24.00 ± 5.29 years). There were also no significant between-group differences in height (higher=1.80 ± 0.06 m; intermediate=1.80 ± 0.09 m; lower=1.78 ± 0.07 m) or mass (higher=79.36 ± 13.85 kg; intermediate=82.63 ± 10.39 kg; lower=77.38 ± 12.99 kg).

The mean overall research-grade FMS score for the higher-performing group was 73.00 ± 10.96, and this was significantly ($p<0.01$) greater than both the intermediate-performing group (50.88 ± 2.42) and lower-performing group (32.00 ± 8.10). The intermediate-performing group's mean overall research-grade FMS score was also significantly ($p<0.01$) greater than the lower-performing group. Descriptive athletic performance data for each group is shown in Table 1. There were no significant between-group differences in any of the multidirectional speed or jump tests ($p=0.11$-0.92).

The correlation data is shown in Table 2. There were eight significant correlations in total, and all were positive. The deep squat had moderate correlations with the bilateral vertical ($p=0.04$) and standing broad ($p=0.03$) jump, and left-leg standing broad jump ($p=0.01$), and a large correlation with the left-leg lateral jump ($p<0.01$). The left-leg in-line lunge had moderate relationships with the bilateral ($p=0.02$) and left-leg ($p=0.03$) standing broad jump, and right-leg lateral jump ($p=0.03$), as well as a large relationship with the left-leg lateral jump ($p<0.01$). On the basis of these correlation data, scatter plots and regression equations were produced for the significant relationships displayed for the deep squat (Figure 2) and left-leg in-line lunge (Figure 3). The explained variability between the deep squat and the jump tests ranged from 14-27%, while for the left-leg in-line lunge the explained variability range was 15-25%.

Discussion

This is the first study to analyze the relationships between the FMS scored by the research-grade system established by Frost et al. [3], and athletic performance as measured by tests commonly used for team sport athletes. A key reason for the development of the research-grade FMS was due to the inability of the traditional scoring system to differentiate between a broad range of movement pattern variations, making it difficult for practitioners to define where in the kinetic chain an athlete may have a deficiency [3]. Nonetheless, even with a more sensitive scoring system that weighted specific compensations within the screens, the results from this study tended to support previous research that cite limited relationships between the FMS and sport-specific test performance [9-13]. In addition to this, even

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Table 1: Descriptive data (mean ± standard deviation) for measures of multidirectional speed (20-meter [m] sprint: 0-5 m, 0-10 m, and 0-20 m intervals; 505 change-of-direction speed test with turns off the left and right legs); and jumping (vertical jump [VJ]; standing broad jump [SBJ]; lateral jump [LJ]) bilaterally and unilaterally in higher- (n=11), intermediate (n=8), and lower-performing (n=13) groups as defined by the overall research-grade Functional Movement Screen score in male recreational team sport athletes. s: seconds.

Athletic Performance Tests	Higher	Intermediate	Lower
0-5 m Interval (s)	1.033 ± 0.104	1.005 ± 0.027	1.063 ± 0.068
0-10 m Interval (s)	1.772 ± 0.137	1.718 ± 0.049	1.799 ± 0.101
0-20 m Interval (s)	3.066 ± 0.226	2.967 ± 0.103	3.095 ± 0.172
505 Left (s)	2.430 ± 0.090	2.403 ± 0.091	2.393 ± 0.114
505 Right (s)	2.412 ± 0.086	2.404 ± 0.082	2.393 ± 0.146
Bilateral VJ (m)	0.61 ± 0.09	0.62 ± 0.05	0.59 ± 0.09
VJ Left (m)	0.38 ± 0.06	0.43 ± 0.10	0.37 ± 0.07
VJ Right (m)	0.40 ± 0.10	0.40 ± 0.05	0.38 ± 0.07
Bilateral SBJ (m)	2.47 ± 0.25	2.37 ± 0.11	2.29 ± 0.29
SBJ Left (m)	2.16 ± 0.31	2.05 ± 0.14	1.98 ± 0.19
SBJ Right (m)	2.06 ± 0.21	2.03 ± 0.13	1.97 ± 0.17
LJ Left (m)	1.99 ± 0.31	1.89 ± 0.13	1.77 ± 0.24
LJ Right (m)	1.89 ± 0.25	1.86 ± 0.17	1.76 ± 0.21

Table 2: Correlations between the deep squat, left- and right-leg hurdle step (HS), and left- and right-leg in-line lunge (ILL) as scored by the research-grade Functional Movement Screen scale, with linear speed (0-5 m, 0-10 m, and 0-20 m sprint intervals), change-of-direction speed (505 with turns from the left and right legs), and bilateral and unilateral leg jumping (VJ=vertical jump; SBJ=standing broad jump; LJ=lateral jump) in male recreational team sport athletes (n=32).

	Deep Squat	HS Left	HS Right	ILL Left	ILL Right
0-5 m	-0.16	0.03	0.12	-0.25	-0.14
0-10 m	-0.17	0.06	0.14	-0.25	-0.10
0-20 m	-0.17	0.04	0.11	-0.23	-0.06
505 Left	-0.03	0.21	0.14	-0.02	-0.07
505 Right	-0.13	0.09	0.02	-0.08	0.03
Bilateral VJ	0.37*	0.15	0.04	0.30	0.12
VJ Left	0.04	-0.07	-0.23	0.07	-0.05
VJ Right	-0.04	0.08	-0.02	0.29	0.09
Bilateral SBJ	0.39*	-0.22	0.14	0.42*	0.25
SBJ Left	0.45*	0.29	0.14	0.38*	0.22
SBJ Right	0.14	0.19	0.01	0.29	0.14
LJ Left	0.52*	0.31	0.21	0.50*	0.31
LJ Right	0.27	0.15	0.01	0.38*	0.26

* Significant ($p<0.05$) relationship between variables.

though there were some significant relationships between scores of selected research-grade screens and jump multidirectional jump tests, the explained variance was very low (<27%). The findings from this study have implications for strength and conditioning coaches with regards to how they may use results that are derived from the FMS when using the research-grade scoring system.

When the participants were dichotomized into groups according to the research-grade overall FMS score, the lower-performing group was significantly younger than the high-performing group (20.54 ± 2.85 years vs. 24.73 ± 2.45 years). Athletes who have a greater training age tend to exhibit better athletic characteristics, such as a more balanced leg strength profile [40]. As the high-performing group was significantly older, they would likely have more experience and time spent completing sport-specific conditioning and strength training, which in turn may have benefited their research-grade FMS score. However, this did not translate to the athletic performance tests.

Even with the research-grade scoring system, there were no significant between-group differences in the athletic performance tests (Table 1). With regards to multidirectional sprinting, there were also no significant correlations between the lower-body focused screens (deep squat, hurdle step, in-line lunge) scored by the research-grade system, and the 20-m sprint intervals and 505 (Table 2). Parchmann and McBride [10] also found that multidirectional speed did not relate to FMS performance as scored by the traditional FMS scale in collegiate golfers and this lack of relationship between sprinting and screening tests has also been documented for male [11] and female [13] team sport athletes. The complexity of movements required when sprinting, accelerating, decelerating, cutting, and back pedaling, do not seem to be conceptualized in the screening movements within the FMS, whether they are scored by the traditional method [10,11,13], or the research-grade system used in this study. Indeed, although screens such as the hurdle step and in-line lunge involved stepping actions [1], this type of step does not resemble the gait kinematics produced during sprint acceleration [25,26] or cutting maneuvers [30,41]. Even when using the research-grade scoring system, the FMS does not appear to be able to detect any movement deficiencies that could affect multidirectional sprinting in male team sport athletes.

As stated, there were no significant differences in multidirectional jump performance for participants with higher, intermediate, or lower performance in the research-grade FMS (Table 1). There were, however, some significant correlations between the lower-body focused screens and jumping. The deep squat positively related to the bilateral vertical and standing broad jump, and left-leg standing broad and lateral jump (Table 3). When correctly performed, the deep squat [1,3] and jumping [27,28] all feature a triple extension of the hip, knee, and ankle joint, which provides some explanation as to why there would be selected correlations. The left-leg in-line lunge, which also features a degree of triple extension of the lower limbs, also positively related to the bilateral and left-leg standing broad jump, and both lateral jumps (Table 2). Lockie et al. [11], found relationships between multidirectional jump performance and the traditionally scored FMS in male recreational athletes (r=-0.38-0.46). However, similar to Lockie et al. [11], the significant correlations pertaining to jump performance from the current study were only moderate-to-large (r=0.37-0.52), suggesting the research-grade scored screens may be limited in their ability to infer performance deficiencies in multidirectional jumping.

Further to this, the deep squat and left-leg in-line lunge were investigated via scatter plots (Figures 2 and 3). The explained variability between the deep squat and left-leg in-line lunge with the jump tests were all low, ranging from 14-27%. Given the limited strength of relationships between athletic performance and the research-grade FMS, this study reaffirms research that has documented limitations of the traditional FMS and its application to athletes and sport-specific performance such as multidirectional jumping [10,11,13]. Taken together, these results demonstrate that athletic performance as determined by jump testing is not readily described by FMS performance, whether scored by the traditional or research-grade system.

There were certain limitations with this research that should be acknowledged. The sample size resulted in the higher-, intermediate, and lower-performing groups being unequal in number, and this may have influenced the between-group statistical analysis. A larger sample

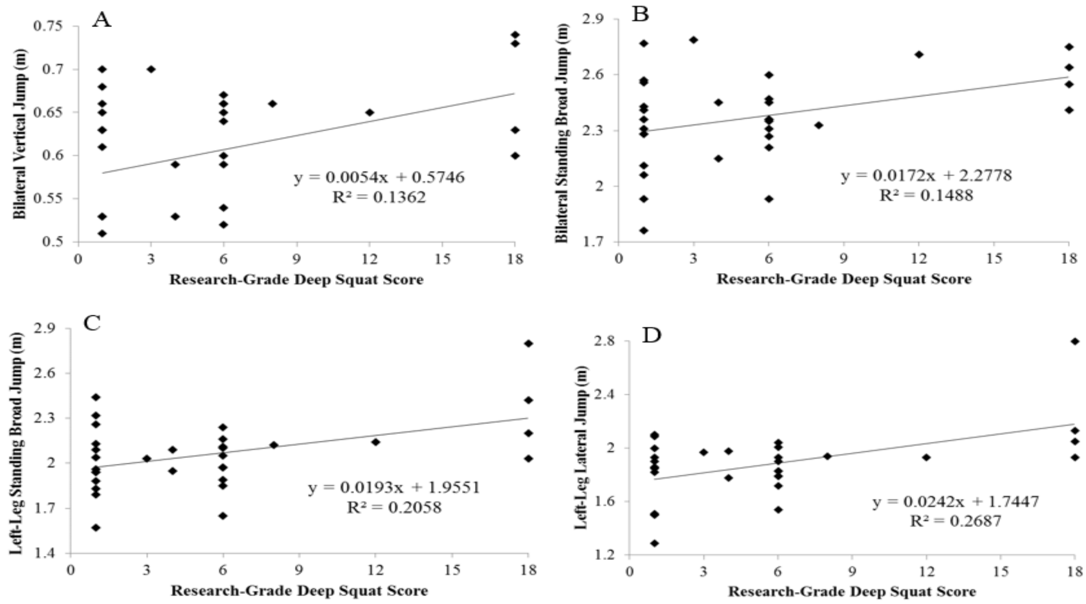

Figure 2: Scatter plots, lines of best fit, and regression equations for relations between the deep squat as scored by the research grade scale with bilateral vertical jump (A), bilateral standing broad jump (B), left-leg standing broad jump (C), and left-leg lateral jump (D) in male recreational team sport athletes (n=32). m: meters. R^2: regression coefficient.

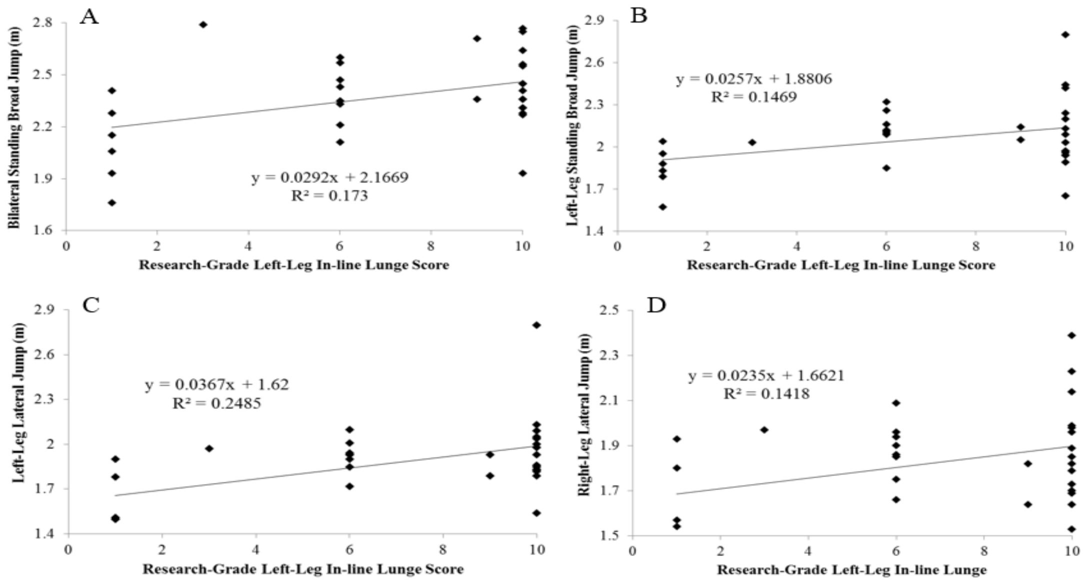

Figure 3: Scatter plots, lines of best fit, and regression equations for relations between the left-leg in-line lunge as scored by the research grade scale with bilateral standing broad jump (A), left-leg standing broad jump (B), left-leg lateral jump (C), and right-leg lateral jump (D) in male recreational team sport athletes (n=32). m: meters. R^2: regression coefficient.

could have alleviated this potential issue. The implications of scoring better or worse on the research-grade FMS still requires further clarification. For example, previous research has suggested that when using the traditional FMS scoring system, a final score below 14 out of 21 (the highest possible score) could assist with identifying injury risk in trained individuals [4-6]. No such thresholds have been set for the research-grade scoring system, and it is outside the scope of this study to speculate on this. Lastly, correlation analyses do not establish cause-and-effect between variables, and factors such as an individual's participants' physical characteristics can influence the statistical data that is calculated [42].

Nevertheless, this research provides valuable information for the strength and conditioning coach, as it highlights the limitations in inferring information from FMS actions scored by the research-grade system about athletic performance. Even with the increased sensitivity of the research-grade scale, the FMS is limited in its ability to identify movement deficiencies that impact multidirectional sprinting and jumping. Strength and conditioning coaches should use other assessments to determine athletic performance capabilities in healthy male athletes. Basic exercises such as a normal lunge [43] or squat [44] may have more value in assessing movement patterns, as they are more specific to actions that could be produced during sports. Furthermore, as suggested by previous research [10,21], traditional strength testing should also serve as a better screening tool for performance in team sport athletes. The findings from this study do not support the use of the research-grade FMS to screen for identifying movement deficiencies influencing athletic performance in male team sport athletes.

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