International Journal of Sports Physical Therapy 2019 Dec; 14(6): 911-919

The association between the functional movement screen™, y-balance test, and physical performance tests in male and female high school athletes

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Abstract

Background

Poor balance, lack of neuromuscular control, and movement ability are predictors of performance and injury risk in sports and physical activity participation. The Functional Movement Screen™ (FMS™) and lower quarter Y-Balance Test (YBT) have been used by clinicians to evaluate balance, functional symmetry, and static and dynamic movement patterns, yet little information exists regarding the relationship between the FMS™, YBT, and physical performance tests (e.g. vertical jump) within the high school population.

Purpose

The purpose of this study was to investigate the relationship between the FMS™, dynamic balance as measured by the YBT and physical performance tests (standing long jump, vertical jump, Pro Agility Test) in male and female high school athletes.

Study Design

Cohort study.

Methods

Fifty-six high school athletes (28 females, 28 males; mean age 16.4 ± 0.1) who participated in organized team sports were tested. Participants performed the FMS™, YBT, and three physical performance tests (standing long jump, vertical jump, Pro Agility Test).

Results

Females outperformed males on the FMS™ and YBT, while males outperformed females on the performance tests. In both sexes, the composite FMS™ score was positively correlated with the left and composite YBT scores. Agility was negatively correlated with composite FMS™ in males ($p < 0.05$) and the left and composite YBT in females ($p < 0.05$).

Conclusions

The FMS™ and YBT may evaluate similar underlying constructs in high school athletes, such as dynamic balance and lower extremity power. The results of this study demonstrate the utility of the FMS and YBT to relate multiple constructs of muscular power to an individual's ability to balance. Furthermore, establishing the need for the utilization and application of multiple field-based tests by sports medicine professionals and strength and conditioning coaches when evaluating an athlete's movement and physical performance capabilities. Utilization of multiple field-based tests may provide the first step for the development of injury prevention strategies and long-term athlete development programs.

Level of Evidence

2b.

Keywords: Functional Movement Screen™, movement system, sport performance, Y-Balance Test

INTRODUCTION

Sport and physical activity require musculoskeletal fitness (e.g. muscular strength and power) and adequate motor coordination and control to produce high levels of force during activity. Inadequate functional strength or movement deficiencies may negatively influence sport performance or lead to an increased risk of injury.[1,2] The Functional Movement Screen (FMS™) and lower quarter Y-Balance Test (YBT) are examples of functional screening tools used by athletic trainers and physical therapists to identify physical dysfunction or functional asymmetries.[3-7] The constructs measured through the FMS™ and YBT tests are indicative of an individual's ability to balance, motor coordination, and control.[8,9] While these tools are used by sports medicine providers for movement evaluation, they may also have implications for an individual's performance in sport and physical activity as decreased balance, lack of neuromuscular control and movement dysfunction have been suggested to be predictors of poor athletic performance.[10-12] Athletes who present with contralateral imbalances are at an increased risk of injury during sport, which results in compensatory movement patterns and muscle inhibition, potentially resulting in lower performance levels.[5]

The FMS™ and YBT tests are examples of field-based measurement tools that can be used quickly and effectively by sports medicine professionals to screen for movement and balance deficiencies in individuals who intend to enter sport performance competition. The FMS™ is a screening tool that was developed to identify functional or physical asymmetry or limitations.[11,12] The FMS™ may evaluate an individual's muscular strength, balance, range of motion, and coordination at some level.[11,12] Current evidence suggests this screening tool may be used to evaluate preparedness for physical activity.[11-14] The YBT is a reliable tool developed as a standardized measure of dynamic balance and neuromuscular control.[15] The YBT measures balance during a single leg stance and requires an individual to possess strength, flexibility, and proprioception to adequately perform the test.[16,17] Performance on the YBT improves with sports training and is also a way to evaluate an athlete's preparedness for sport participation.[16,18-20]

Although the YBT and FMS™ were developed for the purposes of assessing functional movement patterns and balance which may provide insight to inefficacies throughout the kinetic chain that can cause a decrease in performance and increase injury risk, little evidence exists regarding their relationship to field tests of physical performance (e.g. standing long jump, Pro Agility test). Limitations in flexibility,[21-24] strength,[23,25-29] and power[30,31] also may have negative consequences on performance in fundamental movements in sport.[32] Due to the time demand for medical professionals' (e.g. physical therapists and athletic trainers) care towards athletes during rehabilitation and treatment hours, it is not possible to perform multiple screening tests/tools prior to an athletic season to determine if athletes have poor mobility and fundamental movements that may alter sport performance. Understanding associations between movement performance and global screening tools (FMS™ and YBT) could provide a foundation for prevention programs and performance enhancement for athletes.

To date, there is limited research regarding the relationship between the FMS™, YBT, and field tests of physical performance in high school sport athletes. Using the FMS™ or YBT independently or in tandem may aid sports medicine and strength and conditioning professionals in their ability to identify individuals with an increased risk of injury during sport participation through identification of physical or functional movement deficiencies. Thus, the purpose of this study was to investigate the relationship between the FMS™, YBT and physical performance tests (standing long jump, vertical jump, Pro Agility Test) in male and female high school athletes.

METHODS

Participants

Fifty-six participants (28 females, 28 males; mean age = 16.4 ± 0.1) from a rural high school in South Carolina volunteered to participate. The study was approved by the University's Institutional Review Board and parental consent and participant assent were obtained prior to testing. Participants were excluded if they had a current injury that limited their sport participation or if they had any movement related disorders that restrained the participant from performing testing protocols.

Procedures

Demographic and anthropometric data (age, height, weight, BMI) were collected at the start of the first testing session. Participants were randomly assigned to begin testing with either the screening tests (FMS™ and YBT) or the performance tests (e.g. standing long jump, vertical jump, Pro Agility Test).

Functional Movement Screen (FMS™)

The FMS™ was administered using standard equipment (Functional Movement Systems, Lynchburg, VA, USA), procedures, and verbal instructions.[8,9] The seven FMS™ tasks performed included: deep squat, hurdle-step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability test. Participants completed clearing tests to identify pain (active shoulder impingement, trunk flexion, and trunk extension tests). A maximum of three trials of each movement were performed and live coded. A score of 3 was given if the movement was performed as instructed with full range of motion and postural control. A score of 2 was given if the movement was completed in a compensatory position or lacked full range of motion or postural control. A score of 1 was given if the participant could not complete the movement. A score of 0 was given if the participant indicated the presence of pain during the movement. According to FMS™ testing guidelines, the highest score from the trials was recorded.[11,12] For complete bilateral movement (i.e. hurdle step, in-line lunge, shoulder mobility, active straight leg raise and rotary stability) the lower of two scores was utilized in the composite score. The FMS™ was administered by research team members trained in the screen. Rater reliability was established using a weighted kappa statistic (*k*).[33,34] The FMS™ was administered and scored live by a member of the research team certified in FMS™ scoring ($k_w = 0.867$). The strength of agreement between members of the research team ranged from "good" ($k = 0.860$, $p = 0.002$) to "very good" ($k = 0.990$, $p < 0.001$).

Lower Quarter Y-Balance Test

Participants performed the YBT using the Y-Balance Test kit (Move2Perform, Evansville, IN) in three reach directions: anterior, posteromedial, and posterolateral. All testing was conducted using standard procedures and instructions.[35,36] Before screening, the researcher demonstrated how each movement was performed and explained the errors in performance that would void trials: 1) touching the floor, failing to return the moving foot to the center of the apparatus; 2) touching the top of the slider with any part of the foot; 3) kicking the indicator forward; 4) the heel lifts off the platform.[16,36] Participants performed four practice trials in each direction.[36] Feedback was given to the participant if they performed a void trial but no instruction was provided. Each participant's right leg length was measured for data normalization (anterior iliac spine to medial malleolus).[35] Participants performed the assessment on both the right and left extremities while they reached with the contralateral limb. A total of three successful reaches were performed. The maximal reach distance (cm) in each direction was used for data analysis. The YBT aggregate score was calculated for each side (right and left) by summing the maximal reach distance in the three directions, dividing by three times the right leg length, and multiplying by 100.[16] The YBT composite score was calculated by taking the mean of the right and left scores. These scores were representative of reach as a percentage of limb length.

Standing Long Jump

The standing long jump was used to provide a measure of lower extremity horizontal power.[37] The participant was instructed to place the toes of both feet behind a designated starting line and to "jump as far forward as possible, ensuring a two-footed landing". Distance was recorded (cm) by measuring from the starting line to the most posterior surface of the foot at landing.[37] Three trials were performed, and the best trial was used for data analysis.

Vertical Jump

The vertical jump was utilized to measure lower extremity power in the vertical plane.[38] The Vertec (Swift Performance Equipment, Wacol, Australia) is a standardized device, with color coded vanes, used to measure jump height performance. First, each participant stood flat-footed to the side of the Vertec (dominant hand side toward the Vertec). The participant was instructed to "reach upward and displace as many vanes as possible". The highest vane was recorded as the standing reach height. The participant was then instructed to jump as high as possible using a two-foot take off without a preparatory step. Height was recorded (cm) from the highest vane moved and the vertical jump height was calculated by subtracting the standing reach height from jump height.[38] Three trials were completed, and the best trial was used for data analysis.

Pro Agility Test

The Pro Agility Test was used to identify an individual's ability to change direction- a whole body movement that involved the capability to accelerate and decelerate quickly in addition to change of direction in response to a stimulus.[39] Three markers were positioned five yards apart on the floor. Participants started in the middle marker and accelerated five yards to their right, then ten yards to their left, and finally sprinted five yards to their right through the middle marker.[40] All times were recorded to the hundredths of a second using a hand-held stopwatch. Time began upon the individual's movement and ended as he or she crossed the final marker.[40] Three trials were completed, and the best trial was used for data analysis.

Statistical Methods

Participant descriptive statistics (mean and standard deviations) were calculated for the total sample and by sex. Independent t-tests were performed to determine sex differences for all measures. Pearson correlational analyses were conducted on z-transformed measures to examine associations among health-related fitness measures and sex. Statistical analyses were computed using SPSS (Version 24; IBM Corporation, New York, USA), and $p < 0.05$ was utilized for statistical significance.

RESULTS

Descriptive statistics and differences between the sexes are presented in Table 1. Results indicated males were significantly older, taller, heavier, and had a higher BMI compared to females ($p < 0.01$). Females performed significantly better on the FMS™ (female: 14.2 ± 2.1, male:12.7 ± 2.6). There was no difference between males and females for aggregate YBT performance scores; however, when evaluating YBT scores by reach direction, females outperformed males on both the right anterior (female: 63.8; male: 59.0; $p < 0.01$) and left anterior reaches (female: 64.6; male: 58.9; $p < 0.01$). For all physical performance tests, males significantly outperformed females ($p < 0.01$).

Table 1.

Descriptive Statistics.

	Male (n = 28)	Female (n = 28)	p value
Age (years)	16.8 ± 0.9	16.0 ± 0.9	0.00‡
Height (cm)	177.4 ± 8.6	165.2 ± 8.1	0.00‡
Weight (kg)	78.2 ± 18.0	58.7 ± 8.0	0.00‡
BMI	24.7 ± 4.8	21.5 ± 2.3	0.00‡
Composite FMS™	12.7 ± 2.6	14.2 ± 2.2	0.03†
Right YBT*	88.1 ± 11.8	89.5 ± 8.2	0.59
Left YBT*	88.3 ± 8.6	90.7 ± 7.8	0.28
Composite YBT*	88.2 ± 9.7	90.1 ± 7.8	0.42
SLJ (cm)	222.8 ± 33.3	160.0 ± 26.2	0.00‡
Vertical (cm)	63.1 ± 10.8	42.8 ± 7.4	0.00‡
Pro Agility (seconds)	4.9 ± 0.4	5.7 ± 0.5	0.00‡

BMI = body mass index; FMS™ = Functional Movement Screen; YBT = Y-Balance test; SLJ = standing long jump

*reach represented as percentage of leg length; † $p < 0.05$; ‡ $p < 0.01$

Pearson correlations between measures are presented in Tables 2 (males) and and33 (females). For both sexes there were significant positive correlations between the composite FMS™ score and left YBT scores (male: r = .447; moderate, female: r = .446; moderate) and the composite FMS™ score and composite YBT scores (male: r = 0.424; moderate, female r = .408; moderate). For both sexes there was also a significant positive association between vertical jump height and SLJ distance (male: r = .850; strong, female: .647; moderate). For males, there were significant inverse associations between agility (time) and the composite FMS™ score (r = -.436; moderate), vertical jump height (r = -.683; moderate), and SLJ distance (r = -.712; strong). For females, there were significant inverse associations between agility (time) and the left YBT scores (r = -.504; moderate), composite YBT scores (r = -.446; moderate), and SLJ distance (r = -.693; moderate).

Table 2.

Correlations between tests in Males.

	Composite FMS™	Left YBT*	Right YBT*	Composite YBT*	SLJ	Vertical
Composite FMS™						
Left YBT*	0.447‡					
Right YBT*	0.373	0.813‡				
Composite YBT*	0.424†	0.935‡	0.967‡			
SLJ	0.254	0.091	-0.064	0.001		
Vertical	0.259	0.176	0.1	0.138	0.850‡	
Pro Agility	-0.436†	-0.206	-0.017	-0.101	-0.712‡	-0.683‡

FMS™ = Functional Movement Screen; YBT = Y-Balance test; SLJ = standing long jump

*reach represented as percentage of leg length; † $p < 0.05$; ‡ $p < 0.01$

Table 3.

Correlations between tests in Females.

	Composite FMS™	Left YBT*	Right YBT*	Composite YBT*	SLJ	Vertical
Composite FMS™						
Left YBT*	0.446†					
Right YBT*	0.350	0.899‡				
Composite YBT*	0.408†	0.973‡	0.975‡			
SLJ	-0.228	0.096	0.044	0.071		
Vertical	-0.254	-0.140	-0.233	-0.192	0.647‡	
Pro Agility	-0.084	-0.504‡	-0.367	-0.446†	-0.693‡	-0.258

FMS™ - functional movement screen; YBT – Y-balance test; SLJ – standing long jump

* reach represented as percentage of leg length; † $p < 0.05$; ‡ $p < 0.01$

DISCUSSION

The purpose of this study was to examine associations between movement ability (i.e., FMS™), dynamic balance (i.e., YBT), and physical performance in male and female high school athletes. Males outperformed females on all tests of physical performance (SLJ, vertical jump, Pro Agility Test). Across youth and into adulthood, normative reference data demonstrate that males tend to have greater musculoskeletal strength and power compared to females, therefore the results of the physical performance tests were expected. [41,42]

Females outperformed males on the FMS™ (male = 12.7, female = 14.2). Across the FMS™ literature there has been conflicting evidence regarding sex differences in youth and the composite FMS™ score.[3,43,44] The normative data for youth (ages 10-17) from India demonstrate that males outperform females regarding the composite FMS™ score (male = 14.93, female = 14.17).[43] However, recent studies of youth in the southeastern US revealed that females perform better on the FMS™ when evaluating composite scores (male = 14.67, female = 15.16; male = 12.62; female = 14.40).[3,44] Therefore, this study provides another reference for sex comparison using the composite FMS™ score in young participants, specifically the high school population.

The lack of a significant association between the FMS™ and most performance measures in both males and females may be due in part to the differences in ranges of motion required for maximum performance in the FMS™ and the ballistic movements associated with tests of power. The FMS™ evaluates movement to identify physical and functional asymmetries and requires substantial ranges of motion to achieve maximum scores. Limitations in the performance of the FMS™ may be indicative of increased injury risk and reduced performance outcomes.[45] Due to the FMS™ evaluating the quality of movement, higher scores require substantial neuromuscular coordination & control, while the performance measures are evaluating only the outcome of the movement.[46] However, movement patterns associated with maximum outcomes in performance tests (e.g., SLJ and vertical jump) require substantially less range of motion compared to the FMS™ for maximum outcomes. For example, during the FMS™ deep squat test, a position in which "the femur is below horizontal" is required for a maximum score. In contrast, outcomes in the SLJ and vertical jump tests are not dependent on the use of a full range of motion. Instead, the SLJ and vertical jump rely on exploiting the stretch-shortening cycle, which uses rapid stretching of agonist musculature in an abbreviated squatting motion, followed by a reflexive contraction of lower limb extensors resulting in maximal muscle activation.[48,49]

There was a significant association between FMS™ and the Pro Agility tests found only in males, and on average female performances in the Pro Agility test were slower than males. Differences in Pro Agility performance may be due in part to strength and power differences between the sexes or due to previous familiarization to the test.[50-52] Most males participated in sports (e.g., football, soccer) that utilize the Pro Agility movements for recruiting and may have provided familiarization to the task, while most females were samples from sports that do not typically use the test (e.g., volleyball). The relationship between FMS™ and agility for males may be due to similar coordinative patterns between the tests. During change of direction and accelerating tasks, an individual's core activation and single leg stabilization is tasked which is similar to the core activation and single leg stabilization required during the rotary stability and inline lunge of the FMS™.[53,54] Furthermore, proper core activation is required for foundational movements in sport (e.g., agility change of direction tests) and is essential in the development and transfer of force through the kinetic chain.[54,55]

The results of the current study revealed no significant differences between sexes on the right, left, or composite YBT score. The current literature regarding sex performance on the YBT discloses conflicting findings. While in a different population, Chimera, Smith, and Warren found no differences between the sexes in Division I athletes for the YBT composite score.[15] Another study done within Division I basketball athletes and non-athlete recreational participants, also concluded no difference between sexes in the normalized reach directions and average reach.[56] In high school athletes, Gorman et al. found that males outperformed females on all three normalized reach directions and the composite score.[57] A similar dynamic balance task, the Star Excursion Balance Test (SEBT), also has conflicting results in the literature. Gribble and Hertel found no sex differences on performance after normalizing reach directions.[58] This study supports the findings of Gribble, Robinson, and Hertel who found that overall females outperformed males, contradicting the notion of no difference in performance between sexes.[59] However, those two studies were conducted using college-aged students. Although significant differences were not found between sexes in this study, there are apparent sex differences on the YBT and SEBT performance, which demonstrates the need for further research defining sex-specific normative values for dynamic balance in youth.

In both sexes there were significant positive correlations between FMS™ composite score and YBT left scores and YBT composite scores. The relationship between the FMS™ and YBT composite scores may be due to similar components being utilized within each screening tool. Both tools test an individual's range of motion, mobility, and stability of the lower extremity. The YBT's dynamic balance is similar to three tasks in the FMS™: the in-line lunge, rotary stability, and hurdle step. Each of these tasks involve unilateral movement or a narrow base of support. Furthermore, to perform the tasks of the FMS™ and YBT an individual needs musculoskeletal strength and core stability to maintain single leg balance.[11,12] These results represent the first significant relationship between the FMS™ and YBT composite scores, indicating the two screening tools may evaluate similar underlying constructs.

The negative relationship between agility and the left and composite YBT scores in females may be due to the underlying need for coordination and control of musculature during both static and dynamic balance tasks. Previous research suggests that balance is considered a feature of agility and that improving balance may in fact improve agility.[60,61] Agility hinges on an individual's ability to coordinate and control their center of mass (CoM) and extremities to effectively accelerate and decelerate during athletic movements. Furthermore, individuals must effectively control their CoM while on one leg to promote effective acceleration and deceleration.[62] The YBT examines the coordination and control of an individual's CoM on a unilateral base of support. Muscular strength and stability (i.e. control) are essential for an individual during movement (i.e. during dynamic balance and acceleration/deceleration movements). The lack of stability during unilateral movements may lead to coordinative and performance issues in sport.[62] Thus, to perform well on the YBT, an individual must possess adequate balance, coordination, muscular strength, and neuromuscular control, which is similar to the requirements of agility tests.

The relationship between vertical jump and SLJ in both sexes was anticipated as both tasks are related to the underlying construct of muscular power.[63] The strong relationship (r = 0.70 to 0.91) between these two tests is well established in the literature.[64] The relationships of agility and SLJ for both sexes as well as agility and vertical jump for males was expected as there is crossover with the underlying constructs of lower extremity power between the tasks. The relationship between agility and the SLJ has been previously expressed in first year collegiate athletes for both sexes (male: r = -0.61; moderate, female: r = -0.79; strong).[37] Peterson, Alvar, & Rhea also found a significant relationship between the broad jump and sprint acceleration for both sexes (male r = 0.48; moderate; female r = 0.61; moderate).[37] Furthermore, it has been reported that plyometric training to increase muscular power increases an individual's vertical jump height and decreases an individual's agility times.[65] Thus, the reported negative relationship between agility and vertical jump for males follows suit with the previous relationships that are well established in the literature.[37,65]

CONCLUSION

The FMS™ and YBT are two screening tools used by sports medicine professionals to identify strength, balance, and movement patterns. As a result, imbalances in mobility and stability as well as asymmetries in compensatory movement patterns may be identified. The FMS and YBT may evaluate similar underlying constructs, such as dynamic balance and movement coordination. Results from this study identified moderate relationships between the FMS and YBT screens and tests of physical performance (e.g., SLJ, VJ, and Pro Agility Test) in both males ($p < 0.05$) and females ($p < 0.05$). Females outperformed males on both the FMS™ and YBT tests, while males outperformed females in measures of physical performance. Out of the three physical performance measures (SLJ, VJ, and Pro Agility Test), the Pro Agility Test was the only test that was significantly correlated with the composite FMS™ in males and YBT (left and composite) in females. These results demonstrate the utility of the FMS and YBT to relate multiple constructs of muscular power to an individual's ability to balance. This study's results establish the need for the utilization and application of multiple field-based tests by sports medicine professionals and strength and conditioning coaches when evaluating an athlete's movement and physical performance capabilities. Future research is warranted to determine if the strength of these relationships remain constant with larger samples of males and females across multiple sport disciplines.

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