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ORIGINAL RESEARCH

FUNCTIONAL MOVEMENT SCREEN™ IN YOUTH SPORT PARTICIPANTS: EVALUATING THE PROFICIENCY BARRIER FOR INJURY

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ABSTRACT

Background & Purpose: The number of youth participating in sport increases yearly; however, the evaluation of youths' movement ability and preparedness for sport remains inadequate or neglected. The Functional Movement Screen (FMS™) is an assessment of an individual's movement quality that has been utilized to evaluate risk of injury in collegiate and professional sport; however, there is minimal support regarding the predictive value of the screen in youth sport. The purpose of this study was to evaluate the mean and distribution of FMS™ performance in sport participants age 11-18, and to evaluate the existence of a composite FMS™ score proficiency barrier to predict injury risk.

Study Design: Prospective cohort study.

Methods: One hundred, thirty-six participants (63 male, 73 female) age 11 to 18 years (16.01 $\pm$ 1.35) were recruited from local schools and sport organizations. The FMS™ was administered prior to each participant's competitive season and scored by researchers who demonstrated reliability in assessments derived from the screen (κ_w = 0.70 to 1). Injury data were collected by the participants' Athletic Trainer over one season. An injury was defined as any physical insult or harm resulting from sports participation that required an evaluation from a health professional with time modified or time lost from sport participation.

Results: Females scored significantly higher than males for mean FMS™ composite score (t = 14.40; m = 12.62; $p < 0.001$), and on individual measures including: the hurdle step (t = 1.91; m = 1.65; $p < 0.001$), shoulder mobility (t = 2.68; m = 2.02; $p < 0.001$), active straight leg raise (t = 2.32; m = 1.87; $p < 0.001$), and the rotary stability components (t = 1.91; m = 1.65; $p < 0.05$). Two FMS™ composite scores (score $\leq$14 and $\leq$15) significantly increased the odds of injury (OR = 2.955). When adjusting for sport, there was no score relating to increased odds of injury.

Conclusion: Dysfunctional movement as identified by the FMS™ may be related to increased odds of injury during the competitive season in youth athletes. Consideration of an individual's movement within the context of their sport is necessary, as each sport and individual have unique characteristics. Addressing movement dysfunction may aid in injury reduction and potentially improve sport performance.

Level of Evidence: 1b.

Key Words: Functional movement screen, injury prevention, movement system, movement quality, youth sport

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INTRODUCTION

Sport provides opportunities for millions of youth to be active and healthy,[1] though musculoskeletal injury remains a potential hazard to many participants.[2,3] While pre-participation and physical screenings evaluate an individual's general health status, these assessments do not determine preparedness for sport's intense physical demands, and often do not include an evaluation of functional motor competence (i.e. one's ability to coordinate and control movement to attain a goal). Evaluations of functional motor competence aid in determining an individual's functional and physical capacity, as well as injury potential.[4-10] The Functional Movement Screen (FMS™) is a screen of functional motor competence that evaluates qualitative movement coordination patterns and may be able to identify individuals who may be at risk for injury.[4] The FMS™ consists of the following seven tasks: overhead deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability pushup, and rotary stability. Each task is scored from 0 to 3, 0 indicating pain with movement and 3 indicating optimal function in that task. Summing each task score yields the FMS™ composite score (maximum 21). This assessment has been utilized in collegiate and professional sports to predict injury risk and shows promise to address the same issue for youth sport.[4,11-18] The ability to evaluate the risk for injury based on an individual's functional motor competence and address potential movement limitations prior to participation may be critical to alleviating injury prevalence.

FMS™ and Youth Sport

Although the FMS™ was developed for use in high school athletes, initial research addressed athletes in collegiate and professional sports.[4,11,13,19] For example, two studies found collegiate athletes composite FMS™ scores ranging from 12.53 to 16.07.[13,19] In general, FMS™ data on youth (high school, 18 & under) demonstrates a range of composite FMS™ score means from 12.1 to 16.44.[18,20-24] Bardenett et al.[18] assessed high school sport participants and noted their mean composite FMS™ score 13-13.1.[18] In response to these low scores, the authors called for further evaluation in youth sport.[18] Overall, there are limited data on FMS™ scores in youth sport.

FMS™ and Risk of Injury

In order to determine an individual's risk of injury based on the FMS™, there needs to be a composite FMS™ score that is predictive of future injury. In 1980, Seefeldt proposed the idea of a movement skill "proficiency barrier",[25] which may be viewed as a threshold, above which an individual will be able to successfully transition movement skills into more complex movements (e.g., sport skills). The application of a proficiency barrier for injury risk has also been explored with the FMS™ assessment in adults in sport (collegiate and professional). Data from multiple studies has demonstrated that FMS™ levels have been able to predict injury and these data have identified a potential proficiency barrier level.[11,13,15,18,19]

The proficiency barrier determined from multiple studies has been a composite FMS™ score ≤14.[11,13,15,18,19] This composite score was initially established using the data from professional American football players,[11] and has been used in subsequent studies.[13,15,18,19] Examining the predictive utility of this score in youth sport is important as it may establish the need to address movement deficiencies at a young age, when youth are still physically maturing and have a greater adaptational window for skill development. Thus, using the FMS™ screening to help alleviate future injury potential may be of greater significance if injury risk can be identified in youth sport. Unfortunately, with the varying definitions of injury throughout youth studies (e.g. excluding contact injury), it is difficult to determine if this score is applicable in youth sport.[18,21,23] In the adult sport setting, a composite FMS™ score of 14 or below increased the odds of injury (3.85 to 11.67) compared to those scoring above 14.[11,13,15,19] In collegiate sport, this composite FMS™ score has been strongly correlated with overall injury incidence ($r = 0.761$) and lower extremity injury ($r = 0.952$ without the shoulder score).[13]

While literature on FMS™ and injury in youth is increasing, current studies do not show evidence of a proficiency barrier relating to injury in youth sport.[11,13,15,18,19] The previously established proficiency barrier for a FMS™ composite score of <14 was not significantly associated with an increased risk of injury in youth (ages 8 to 21 years) who participated in multiple sports.[18,21,23,26] A limitation of these studies is that the majority of studies evaluating this proficiency barrier were only evaluating one specific sport or position, with large age ranges.[21,23,26] Furthermore, the one study evaluating a potential barrier across multiple sports had a low injury rate, as they only included injuries which were musculoskeletal in nature.[18] This is important as other types of injuries (i.e. neurological, concussions, etc.) may have an etiology related to an individual's functional motor competence, specifically as it relates to developing athletes with a limited training background (i.e. falling on the playing surface).[27] Thus, studying the FMS™ across multiple youth sports, with an inclusive injury definition, may identify individuals at risk for future injury based on their functional motor competence.[11,19,21,23] The purposes of this study were to a) describe normative data on FMS™ performance in sport participants age 11-18 and b) evaluate if there was a composite FMS™ score proficiency barrier that was predictive of increased odds of injury in this sample.

METHODS

Participants and procedures

A prospective cohort observational design was utilized. A total of 136 participants (63 male, 73 female) age 11-18 (16.01 $\pm$ 1.35) years were recruited from local high schools (public and private) and local sport organizations. Exclusion criteria included: participants with a musculoskeletal injury within the past six months that limited participation or movement capability at the time of testing, or did not have current medical clearance for participation in sport. Individuals completed informed consent and were required to have parental consent before participating. Data were collected prior to the beginning of the individual's respective sport competitive season (fall sport August – September; spring sport January – February). The FMS™ was administered during data collection sessions at each sports setting prior to the competitive season, and injury information was received at the end of each sports respective season.

Measures

The FMS™ consists of seven tasks that are tested in the following order: overhead deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability pushup, and rotary stability. All tasks are completed bilaterally except for the overhead deep squat and the trunk stability push up. Participants were given standardized verbal instruction (per the FMS™ manual).[4] Each task of the FMS™ is ranked on a scale of 0 to 3 relating to an individual's capability to perform each suggested movement.[28,29] Participants who experienced pain during any portion of the FMS™ or during clearing tasks associated with three skills (shoulder mobility, trunk stability pushup, rotary stability) received a score of '0' for the task they were performing. Tasks which are completed bilaterally were scored per side, then received the lower of the two scores as the final score for that task. The final scores of each task were summed for a composite score with a maximum of 21 points. Participants were videotaped or live coded (dependent upon time of enrollment) performing a maximum of three trials of each FMS™ task. If participants met the criteria for a "3" prior to completion of all trials of one task, we moved to the next task as further screening is not needed.[4] The FMS™ was coded by individuals trained in the assessment. Inter/intra-rater coding reliability was established prior to the study and was adequate for all raters for both video (κ_w = 0.73 to 1) and live coding (κ_w = 0.70 to 1).[30]

A Certified Athletic Trainer employed by each site tracked participant injuries using their preferred tracking software. Injury was defined as any physical insult or harm resulting from sports participation that required an evaluation from a health professional and time modified or time lost from sport participation.[13,19,21,31] Due to inconsistencies in the definition of injury in the literature, this definition of injury was utilized to unify the definitions in the literature.[15,18,19,21,23] Individuals who sustained injury from any source outside of the school sport in which they were participating were excluded from injury analyses. Both contact and non-contact injuries were collected. Injury data were collected data on all participants at the end of their respective sport seasons, with six participants injury data lost to follow up.

Statistical analysis

An a priori power analysis was performed, determining that a sample of 129 was needed to achieve adequate power (1-ß = 0.80). An alpha < 0.05 was used to determine significance. Data was double entered and checked for consistency prior to analysis. Independent t-tests were performed to detect differences in male and female height, mass, age, and FMS™ performance. The probability of sustaining injury was modeled as a function of composite FMS™ score via logistic regression.[11,18] Additional, logistic regression analyses were used to assess if there was a certain composite FMS™ value which was associated with an increased odds of injury after controlling for sport participation.

RESULTS

Descriptive statistics (means and standard deviations) for participants (height, mass, age) are shown in Table 1, and FMS™ performance is shown in Table 2. The ethnic breakdown of the sample was: 81.6% white, 16.2% black, and 2.2% other. Participants were recruited based on study site, and individuals in the sample participated in football (40 male), soccer (23 male; 39 female), volleyball (18 female), lacrosse (10 female), and other (6 female).

There were significant differences between the sexes for height and mass, with males having greater mass ($t = 6.56$, $p < 0.001$) and height ($t = 8.810$, $p < 0.001$; Table 1). Youth sport participants demonstrated a mean composite FMS™ score of 13.54 $\pm$ 2.66. The distribution of sport participants FMS™ scores are presented in Tables 2 and 3.

There were two composite FMS™ scores significantly related to increased odds of injury (composite FMS™ $\leq$14, and $\leq$15) without addressing sport (Table 4). A composite FMS™ score of <14 or <15 was associated with an increased risk of sustaining injury (OR = 2.99). As 74% of injuries occurred in football, no significant differences were observed after adjusting for the sport being played. A breakdown of injury by sex and sport is shown in Table 5.

Table 1. *Descriptive Statistics.*

	Sex	n	Mean	Std. Dev	p value
Height (cm)	Male	63	173.72	7.47	**0.00***
	Female	73	163.12	6.56	
Mass (Kg)	Male	63	73.93	16.72	**0.00***
	Female	70	57.38	11.61	
Age	Male	61	15.87	1.44	0.37
	Female	68	15.65	1.26	

*$p < 0.001$ for differences between males and females

DISCUSSION

The first purpose of this study was to provide normative data for FMS™ scores in youth sport. Youth sport participants tested at the beginning of their sport season demonstrated a mean composite FMS™ score of 13.54 $\pm$ 2.66, which is similar to other studies examining youth sport that demonstrated a range of composite FMS™ scores ranging from 12.1 to 16.44.[18,21-24,26] Males from the sample demonstrated a FMS™ composite mean of 12.26, while the females demonstrated a FMS™ composite mean 14.4.

In a previous study, normative findings in youth (males and females, age 10 to 17) demonstrated that males outperformed females regarding the composite FMS™ score;[20] however, the results indicate that females significantly outperformed males ($t =$ -3903, $p < 0.001$; Table 2). Individual task scores from the general population normative youth data from India demonstrated that males outperformed females on the inline lunge, trunk stability pushup, and the rotary stability tasks.[20] Data from the sample demonstrate that females outperformed their male counterparts on tasks relating to their active range of motion (active straight leg raise, shoulder mobility) and core and lower extremity coordination and control (hurdle step, rotary stability). Previous studies on sex differences in more general functional motor competence assessments also reveal conflicting results with reports of higher scores for males,[32] females,[33] or no differences between the sexes.[33-35] The specific differences in FMS™ in the current data set may be due to the differences between males and females joint range of motion (ROM) which has been previously identified in the literature.[36,37] Unfortunately, specific joint ROM was not assessed in this study. Alternatively, the equivocal findings in the literature may be a function of the sport composition represented in the data set. There was a higher proportion of football players in this male sample, with only eight uninjured. However, compared to the normative composite FMS™ values of

Table 2. *Functional Movement Screen™ Scores.*

	Sex	n	Mean	Mode	Std. Dev	Min	Max	p value
Deep Squat	Male	63	1.70	2	0.56	1	3	0.35
	Female	65	1.80	2	0.67	1	3	
Hurdle Step	Male	63	1.65	2	0.54	1	3	**0.00****
	Female	65	1.91	2	0.42	1	3	
Inline Lunge	Male	62	2.13	2	0.66	1	3	0.07
	Female	65	2.32	2	0.53	1	3	
Shoulder Mobility	Male	62	2.02	3	1.00	0	3	**0.00****
	Female	65	2.68	3	0.62	1	3	
Active Straight Leg Raise	Male	63	1.87	2	0.61	1	3	**0.00****
	Female	65	2.32	3	0.75	1	3	
Trunk Stability Pushup	Male	63	1.60	2	0.77	0	3	0.29
	Female	65	1.46	1	0.73	1	3	
Rotary Stability	Male	63	1.65	2	0.60	0	3	**0.01***
	Female	65	1.91	2	0.38	1	3	
Composite FMS™	Male	61	12.62	14	3.06	6	18	**0.00****
	Female	65	14.40	15	1.88	9	18	

*$p < 0.05$; **$p < 0.001$ for differences between males and females

Table 3. *FMS™ Composite Score by Sport.*

Sport	n	Composite FMS™ Mean	Std. Dev
Football	38	12.37	3.08
Male Soccer	23	13.04	3.04
Female Soccer	38	14.18	1.92
Female Lacrosse	9	13.44	1.88
Female Volleyball	15	15.27	1.49
Female Other	3	15.67	1.53

youth (general population), the male football players demonstrated lower composite scores than the established youth male mean (male mean = 14.93, male football mean = 12.37).[20] In addition to being taller and heavier, the males may have been closer to experiencing peak height velocity (i.e. maturation) than females, which may influence flexibility and coordination as growth in long bones precedes development of tendons and ligaments.[38-41] Corroborating this idea, females out performed males on three of the four skills that involve measuring the length of the involved limb (i.e., hurdle step, shoulder mobility, leg raise). Subsequent studies should account for previous injury and perhaps maturational timing to account for other potential factors related to injury risk.

Table 4. *Proficiency Barrier Analysis of Composite FMS™ Score Predicting Injury.*

	Not adjusted for sport				Adjusted for sport			
	OR	LCL	UCL	p-value	OR	LCL	UCL	p-value
Composite ≤13	1.553	0.687	3.511	0.290	0.97	0.313	3.005	0.957
Composite ≤14	2.955	1.249	6.986	0.013*	2.066	0.676	6.316	0.203
Composite ≤15	2.955	1.249	6.986	0.013*	2.066	0.676	6.316	0.203
Composite ≤16	2.452	0.852	7.063	0.096	1.337	0.345	5.181	0.674
Composite ≤17	2.826	0.595	13.422	0.191	3.541	0.491	25.514	0.209

OR= odds ratio; LCL= lower confidence limit; UCL= upper confidence limit*$p < 0.05$

Table 5. *Sample Injury Breakdown.*

		Male	Female
Football	Injured	32	-
	Not injured	8	-
Soccer	Injured	4	4
	Not injured	19	35
Volleyball	Injured	-	0
	Not injured	-	16
Lacrosse	Injured	-	2
	Not injured	-	8
Other	Injured	-	1
	Not injured	-	1

*6 participant's injury data were not reported

Overall, the composite FMS™ scores from youth sport participants represent an individual score of '2' per task. Thus, it is clear these youth participants demonstrate compensated movement patterns as evaluated by the FMS™. Improved functional motor competence may have a protective effect on future injury incidence because motor competence is associated with multiple aspects of physical fitness (e.g., muscular strength, power, endurance and cardiovascular endurance) in youth,[5,42,43] which is linked to injury risk.[10] As FMS™ scores demonstrated by youth sport participants had a similar range to collegiate/adult FMS™, these data speak to the fact that global functional motor competence is developed early in life and may not necessarily improve across age or with sport participation. Furthermore, sport practice early in youth may place too great an emphasis on sport-specific skills (i.e. tactics, game play) and de-emphasize the learning, retention, and growth in foundational and functional movement.[44] Thus, promoting functional motor competence in children before they transition into high-level youth sport is warranted as childhood and early adolescence is a critical time where foundational and functional skill should be developed. Longitudinal testing also would be important to provide stronger evidence relating to changes, or lack thereof, in functional motor competence. As long term declines in functional motor competence have been noted in recent literature,[45] these data provide additional evidence for the importance of learning how to move effectively in childhood, as functional movement is important for performance as well as providing a potentially protective effect against injury.

FMS™ and Injury

The second purpose of this study was to evaluate if there would be a proficiency barrier of a composite FMS™ score, which would be related to increased odds of injury. We evaluated odds of injury across different composite FMS™ scores and found that individuals scoring below 15 had a higher risk of injury (Table 4). When controlling for injury by sport most individuals who sustained injury were males participating in football (74%). Even with the high proportion of injuries in football, our injury rate was comparable to another study evaluating youth (case rate/100 players = 31.6; Powell & Barber-Foss, mean = 26).[46] These injury data may be related to not only to the participants inherent functional movement issues, evidenced by football players demonstrating the lowest mean composite FMS™ scores (composite

FMS™ = 12.37), but also to the nature of the sport; specifically with regard to the frequency of direct collisions that occur during football and the necessary coordination and control to effectively maneuver their body during and after collisions. Previous literature shows the composite FMS™ score may be useful for evaluating injury potential in adults;[11,15,19] however, this study reaffirms previous research in youth sport that demonstrates there may not be an appropriate proficiency barrier in youth.[18,23,26] This finding is consistent with Cook et al., who present the position that the FMS™ alone may not adequate for the prediction of injury, and that the screen should be supplemented with other measures of sport readiness (i.e. power, endurance, etc.).[28,29]

There are limitations that should be addressed. The intent was not to evaluate FMS™ and injury within each sport; therefore, this study was not powered to adequately address a proficiency barrier by sport. The inclusions of few male sports were due to team availability at each site. The authors acknowledge missing data within this sample due to participant and site access, and loss to follow up. Attempts were made to collect missing data; however, protocol did not allow for collection for participants in-season. Additionally, ascertaining mechanisms of injury in future research may be useful in evaluating the effect that movement versus incidental contact may have with injury. As participants in this study may be at varying levels of maturation, the authors recognize that the physiologic processes unique to each individual at their stage of maturation may affect their movement ability or risk of injury.

This study may provide a reference point for FMS™ scores in youth sport participants. These data, along with other FMS™ data across youth and into adulthood also suggest that functional motor competence is developed in childhood, as composite FMS™ data is similar across from childhood into early adulthood (i.e., ages 8-21 years).[18,21-24,26] These data also demonstrate that dysfunctional movement coordination and control is present in many youth, which ultimately may manifest as injury over time (i.e., adulthood). Thus, while using the FMS™ as an acute predictor of injury may not be appropriate in youth, it may be predictive later in an individual's sport career if their functional movement capabilities do not change.

CONCLUSION

Dysfunctional movement as identified by the FMS™ may be related to increased odds of injury in youth athletes during the competitive season. Injury may develop acutely or chronically; however, an individual's functional motor competence within the context of their sport should be considered as each individual and sport has unique characteristics such as anatomical structure and level of contact. Addressing movement dysfunction in youth may aid in reduction of injury and potentially improve sport performance. However, in youth sport, the immediate utility of the FMS™ may be more applicable for the clinical identification of dysfunctional movement rather than its capability to independently predict injury.

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