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Functional Movement Screen™ in High School Basketball Players: Pre- and Post-Season

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ABSTRACT

International Journal of Exercise Science 15(6): 1-14, 2022. Pre-participation screening and tracking of an athlete's functional status during a competitive season is essential to maintaining optimal performance. The sport of basketball had the third highest number of boys and girls participating during the 2018-2019 season (23), which typically occurs October to March each year. The Functional Movement Screen™ (FMS; 10) has been administered to some youth athletes from various sports, however, both males and females from basketball have not been studied extensively. The purposes of this study were: 1) to assess functional movements before and after the natural progression of a high school competitive basketball season; 2) to determine if there were functional movement differences between male and female youth basketball players. Eighteen male (n = 10) and female (n = 8) high school basketball players completed the FMS pre- and post-season. Scores were analyzed using a mixed-model ANOVA. No significant differences were found for Time or Sex for composite FMS scores (*Mean* ± *SD*, Pre-season: 16.2 ± 2.1, Post-season: 17.1 ± 1.4; Males: 16.8 ± 1.8, Females: 16.5 ± 2.0). Specific FMS tests were compared pre- to post-season using Wilcoxon signed-rank tests and were not significantly different after the competitive season or between the sexes. Sex differences relating to overall FMS composite scores or specific test scores were not apparent in this age group or sport. In this small group of high school basketball players, participation in a competitive, high school basketball season did not limit nor enhance functional movement ability.

KEY WORDS: Youth, sports, functional fitness, seasonal changes, sex differences

INTRODUCTION

Functional movement is the ability to perform movements (i.e., deep squat, push-ups, leg lunges) requiring balance, stabilization, and basic coordination without compensation or displaying left-to-right imbalances in muscle activity or flexibility (10). Competent functional movement allows for the proper development of motor control and optimal adaptability to training (10). Functional movement can be influenced by age, sex, and maturation along with intrinsic factors such as muscle activation, neuromuscular control, and mobility (2, 9, 10, 15, 28). When deficiencies in these foundational movement patterns arise, problems can develop such as a decline in movement efficiency, pain during physical activity, and musculoskeletal injuries (10, 13).

The Functional Movement Screen™ (FMS; 10, 13) was developed as "a tool to appraise general whole-body movements based on the notion that individuals should be able to move freely, symmetrically, and without pain" (6, 10, 13). The original FMS is comprised of seven tests which are assessed to rate movement ability, efficiency, and balance by observing basic movement patterns and techniques (10, 28). The FMS can be used with all physically active populations and was initially designed to put individuals in positions where possible muscular weaknesses, mobility limitations, or anatomical and muscular asymmetries were exposed and identified (10, 34). Proficient functional movements are recommended prior to strength and power training, and performance and skill enhancement (13). In addition, since its initial development, the composite (total score out of 21) of the FMS as well as specific movement scores (scored 0-3) have been studied for purposes other than identifying movement limitations or asymmetries (22). These include using FMS cut-off scores to predict the risk of injuries and as gauges of potential athletic performance (5, 15, 22, 26). The validity of using a specific FMS cut-off score to predict injury across various sports remains controversial and has not been consistently verified for healthy, active adults (8, 15, 22) or for high school-age youth (5, 27, 32, 36). More research about norms and interpreting FMS scores for athletes participating in youth sports is needed.

Although the FMS has been used to study some youth athletes and nonathletes, the results have varied, and more data are needed. Bardenett et al. (5) evaluated high school athletes in six different sports and reported a mean FMS composite score of approximately 13.0 for males and 13.1 for females. Lee et al. (18) also used the FMS to assess functional movement ability in male high school baseball players and recorded a preseason FMS composite score of 15.9. For elite youth basketball players, Garbenytė-Apolinskienė et al. (14) reported a pre-training mean FMS composite score for both male and female athletes of 15.9. And finally, Smith et al. (31) reported a median FMS score of 16 (range 9-21 yrs) in high school male athletes from football, soccer, and baseball. Extensive results have not been reported for all high school sports and there remains a wide range of values for FMS composite scores for high school athletes.

Only a few previous investigations have studied whether the FMS composite scores change during the time period of a competitive season (3,16,18,33,35). During the competition phase, the purpose of training is to optimize skill development and to maximize strength and power through increases in training intensity and decreases in training volume (4). Peak performance may be achieved for a short period of time, and therefore, training maintenance generally occurs during longer term competitive periods of time (e.g., ≥ 3 months)(4). This focus on skill development and maximized performance may contribute to the common problem of overuse injuries in youth participating in team sports (19). Lee et al. (18) noted a decrease in the mean FMS composite score after a 12 weeks of baseball games/competitions (Mean 15.9 to 14.3). Waldron et al. (35) reported no change in FMS scores for elite youth players after an 8-month rugby season even though performance measurements improved. No change in FMS composite scores was reported also by Avery et al. (3) after an 8-month competitive season of ice hockey, however, they did report an increased score for one of the FMS tests. When seasonal changes were tracked in college soccer and volleyball athletes there were no changes in composite FMS scores, however four FMS tests did change with two improving and two decreasing (33). In addition, seasonal changes reported for college athletes in other sports have also been contradictory (16, 33).

FMS scores for high school athletes have been reported most often for youth participating in American football and soccer (5, 31). However, of the team sports in the U.S., the sport of basketball was reported to have the most high schools sponsoring competitive teams for this sport during the 2018-2019 season (23). Basketball was the third most popular sport for total participation of high school male and female basketball players (23). Because there are different physiological and skill demands for various sports, FMS scores may vary among players on different sports teams.

Male and female high school basketball players were assessed by Sorenson (32) using the FMS during a high school basketball season. Although Sorenson (32) confirmed for high school female and male basketball players that the FMS score, specific test scores, and sex were not significant predictors of injury, he also reported FMS means of 14.5 and 14.7 for these 112 male and female basketball players, respectively (32). Subsequently, Wieczorkowski (36) who had the same goal of using the FMS to predict seasonal injuries, reported a pre-season high school basketball mean FMS score for non-injured girls and boys basketball players of 15.6. Garbenytė-Apolinskienė et al. (14) reported that the FMS results increased after an integrated training program for Lithuanian elite female basketball players from 15.9 to 17 with no changes after training for the male basketball players (FMS = 15.9 to 16.9). Thus, previous scores for basketball players have varied.

When FMS composite scores are compared between males and females below the age of 18 years, conflicting results have been reported. Abraham et al. (1) reported a significant difference between a general population of boys and girls 10-17 years of age for mean FMS composite scores. These differences were supported by Anderson et al. (2) for secondary school athletes when they reported that girls' FMS composite scores were less than boys' scores, and also for the FMS test scores of in-line lunge, and the trunk stability push-up. Conversely, Chimera et al. (9) found that FMS composite scores did not differ by sex, but that females performed better than men for in-line lunge, shoulder mobility, and straight-leg raise. However, women performed more poorly for the trunk stability and rotary stability (9). When comparing younger populations by sex, differences have been apparent (2, 21). However, when comparing composite FMS scores between sexes in adults, differences were not observed (28). The idea that young female athletes consistently perform better or worse in certain tasks than males, may have important implications on how different groups of athletes are able to move, play, or adapt to a training stimulus. Furthermore, Lin et al. (20) in a literature review of common sport injury differences by sex, stated that there was a higher incidence of bone stress injuries, ACL injury, and concussions in female athletes compared to males at both the high school and collegiate level. This information may indicate a need to approach sport training differently between sexes in youth athletics, wherein this may not be the case after athletes reach maturity.

Therefore based on previous research with inconsistent results, the purposes of this study were: 1) to assess functional movements before and after the natural progression of a high school competitive basketball season; 2) determine if there were functional movement differences between male and female youth basketball players. Thus, the specific hypotheses for the study were: Hypothesis 1 - There will be no significant differences in mean FMS composite scores assessed before and after a competitive, high school basketball season or between the players grouped by sex; Hypothesis 2 – There will be no significant differences in specific FMS test scores before and after a competitive, high school basketball season or between the players grouped by sex.

METHODS

A quasi-experimental design was used to collect FMS data in a natural setting (i.e., before and after a competitive season for male and female basketball players) (29). This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science* (24).

Participants

Recruitment: Participants were recruited from a rural high school in northwest Ohio. Prior approval for the study was obtained from the Institutional Review Board at Bowling Green State University. During the initial contact with potential participants, the purpose of the study was explained in detail including each test in the FMS. All participants were also provided with participant assent and parental consent forms. Potential participants were instructed to take both forms home and discuss their participation with their parents. They were also provided with information on how to sign-up for testing times if they wished to participate. Participants were informed that participation was completely voluntary and parental permission was required to be involved in the study. Completed consent and assent forms were collected at an orientation session. Volunteers were members of their high school boys or girls varsity and junior varsity basketball teams for the 2019-2020 season which took place from late October 2019 to mid-March of 2020. The athletes were cleared for physical activity by a physician after a pre-participation physical exam which was a requirement to be a member of any team.

Protocol

Measures: The FMS is a tool to determine functional movement ability and is comprised of seven functional tests and three clearing tests (10, 13). The order for administering the tests is as follows: 1) Deep Squat; 2) Hurdle Step; 3) In-Line Lunge; 4) Shoulder Mobility; 5) Shoulder Clearing Test; 6) Active Straight Leg Raise; 7) Trunk Stability Push-Up; 8) Spinal Extension Clearing Test; 9) Rotary Stability; 10) Spinal Flexion Clearing Test. Scripted instructions, depictions, and scoring of each of the 10 movements are described by Cook (10). Scoring for the FMS is shown in Table 1. Each of the seven functional tests and three clearing tests were scored from 0 to 3 according to FMS instructions (10). Both the left and right side of the body are scored separately and the lower score from the two sides was recorded (10). In addition, the three clearing tests are scored as either pain was present (positive) or if pain was not present (negative) (10). All seven test scores are added together to determine an FMS composite score with a possible range of scores from 0 to 21 (2, 10). A greater composite score signifies greater functional movement ability, whereas a lower score indicates impaired ability and possible increased risk of injury (2, 9, 15).

Table 1. Scoring[1] for the FMS (10)

FMS Test	Left side (L)	Right Side (R)	Final score
Deep Squat	NA	NA	0-3[1]
Hurdle Step	0-3	0-3	Lowest score[2]
In-line Lunge	0-3	0-3	Lowest score[2]
Shoulder Mobility[3]	0-3	0-3	Lowest score[2]
Active Straight Leg Raise	0-3	0-3	Lowest score[2]
Trunk Stability Push-Up[4]	NA	NA	0-3
Rotary Stability[5]	0-3	0-3	Lowest score[2]
FMS Composite (Total) Score			Sum of 7 scores

[1] Scoring: 0 = pain present; 1 = client unable to perform the movement; 2 = exercise is performed with compensation; 3 = movement was completed correctly without loss of balance or movement compensations; [2] Lowest score from the left or right side; [3] Impingement clearing test, [4] Press up clearing test; [5] Posterior rocking clearing test; Clearing tests are administered after the FMS test to assess active scapular stability, spinal extension, and spinal flexion; if a 0 is assigned for any FMS test then a score of 0 is assigned for the test (10).

Interrater reliability of the FMS administrator: Interrater reliability was assessed using three FMS Level I certified examiners in real time. A convenience sample of 12 subjects who were not athletes were evaluated by all three raters for all seven tests and for the three clearing tests. IBM SPSS Statistics 24 software was used to calculate the Intraclass Correlation Coefficient (*ICC*), and Krippendorff's alpha (*KALPHA*) (17) to determine the interrater reliability between the three raters for each test. Results from these analyses are shown in Table 2. The *ICC* was 0.952 (95% *CI* = 0.879, 0.985) indicating high reliability among the three raters for composite FMS scores. In addition, in previous literature the FMS composite score has been shown to have moderate to good interrater and intrarater reliability with an *ICC* of 0.843 (95% *CI* = 0.640, 0.936) (11) and an *ICC* of 0.869 (95% *CI* = 0.785, 0.921) (11), respectively. Moreover, the FMS has been shown to have high interrater (*ICC*, *SEM* = 0.98, 0.25) and intersession (*ICC*, *SEM* = 0.92, 0.51) reliability (25).

KALPHA was also calculated for each of the FMS test scores because these were ordinal data from three raters (17). A *KALPHA* score of 0.8 or above indicates acceptable reliability (30) where 1.00 represents perfect reliability and 0.00 indicates the absence of reliability (17). Most importantly, the *q* value (a probability) indicates the percent chance that *KALPHA* would be below 0.67 if the entire population was tested. For these analyses, the entire population was set at 10,000. All tests met this criterion except for the right leg and left leg in-line lunge (*KALPHA* = .55 and .44, respectively), left hurdle (*KALPHA* = .78), and the deep squat (*KALPHA* = .78), with *q* values at .67 = .8241, .9793, .0942, and .0942, respectively. The right and left in-line lunge values did not meet the *KAPLPHA* of 0.8, thus indicating poorer reliability for these tests. The *q* value at 0.67 indicated that there would be a 82% and 98% chance that *KALPHA* would be below 0.67 if the entire population 10,000 was tested in the right and left in-line lunge tests. In addition, the *KALPHA* for the squat (.78) and the left hurdle step (.78) both suggested moderate interrater reliability in these tests. At 0.67, the deep squat had a *q* value of .094 and the left hurdle step had a *q* value of .094, thus having only a nine percent chance of alpha being below 0.67 if a whole population of 10,000 were tested. Therefore, it was concluded that there was lower reliability among the three raters for the left and right in-line lunge, and moderate reliability for the deep squat and left hurdle step. These findings are similar to the findings of Teyhen et al. (34) who performed reliability for FMS testing and reported the lowest levels of interrater agreement for the in-line lunge and rotary stability tests between novice raters.

Table 2. FMS inter-rater reliability among three raters.

FMS Test	*KALPHA* [a]	95% *CI* [b]	*q* at 0.67 [c]
Right Rotary Stability	0.90	(0.74, 1.00)	
Left Rotary Stability	1.00	(1.00, 1.00)	
Trunk Stability Push-Up	0.95	(0.87, 1.00)	
Right Active Straight Leg Raise	0.91	(0.78, 1.00)	
Left Active Straight Leg Raise	1.00	(1.00, 1.00)	
Right Shoulder Mobility	1.00	(1.00, 1.00)	
Left Shoulder Mobility	1.00	(1.00, 1.00)	
Right In-line Lunge	0.55	(0.33, 0.77)	0.82
Left In-line Lunge	0.44	(0.16, 0.67)	0.98
Right Hurdle Step	0.85	(0.73, 0.95)	
Left Hurdle Step	0.78	(0.57, 0.95)	0.094
Deep Squat	0.78	(0.57, 0.95)	0.094
Composite Score	0.96	(0.93, 0.98)	

[a]*KALPHA* is a reliability measure that works well with two or more raters and for ordinal data (17). A *KALPHA* >.8 indicates acceptable reliability; [b]*CI*= Confidence Interval; [c]*q* represents the probability of failure to achieve an alpha of at least 0.67 if the entire population of 10,000 were tested (17). When *q* values (probabilities of achieving an alpha of 0.67 with a hypothetical sample of 10000) were calculated the right and left in-line lunge had an 82% or 99% probability of achieving reliability alpha of 0.67 and thus, were rated as having, moderate reliability. The left hurdle step and deep squat had a low probability (9.4%) or chance of achieving a reliability of 0.67 and thus, were rated as having low reliability.

Orientation session: To minimize the effects of practice on completion of the FMS movements and day-to-day variations in performing the FMS (7, 12), all participants were required to perform an orientation session. This session allowed the participants an opportunity to familiarize themselves with the FMS tests to minimize the practice effect (i.e., results of a test are changed by repeating the test more than once). This was performed at least 24 hours before their pre-season testing session. Each of the seven FMS tests and three clearing tests were explained to athletes at this time and they were given time to practice each test. Participants were permitted to ask questions as needed throughout this session. The orientation also allowed for an opportunity to provide further details on what to expect during subsequent testing sessions.

Testing: Data collection occurred between 7:45 a.m. and 6:00 p.m. All participants completed testing within two weeks prior to the first official day of basketball practice and within two weeks after their basketball season was completed. Before beginning the screening, participants completed a short demographic questionnaire (adapted from Chimera et al.; 9) in which they self-reported years of experience playing basketball and of participating in weight training, and seven additional questions about existing bone or cardiovascular disorders, and any previous injuries or surgeries to the hips, knees, ankles, shoulders, elbows or wrists. Participants also self-reported demographic data for age, height, and body weight.

After completing the required documents, participants performed a warm-up consisting of 5-min of light jogging or walking, similar to the warm-up used by Anderson, Neumann, and Bliven (2). After the warm-up, each participant performed all 10 of the FMS movements in accordance with the specific testing guidelines provided by Cook (10). The participants performed testing in comfortable athletic clothes and footwear which were fitted and tied properly. Any verbal directions or feedback (e.g., you will next complete the hurdle step, etc.) was limited and remained consistent with the FMS directions throughout pre- and post-season testing sessions (10). All testing procedures lasted approximately 15-20 minutes including completion of the questionnaires and performance of the warm-up. All participant information remained confidential and individuals were not identified.

Statistical Analysis

A mixed-design measures ANOVA was performed to examine the main effects of Time (2: Pre, Post- season) and Sex (2: Male, Female), with $p \leq 0.05$ for the dependent variable of FMS composite score. Specific FMS test scores for all participants and then grouped by sex were compared pre- to post-season using Wilcoxon signed-rank tests, $p \leq 0.05$. To compare athletes' FMS composite scores by Injury Occurrence (non-repeated factor) and Time (repeated factor), a two-way, mixed-model ANOVA was calculated. Statistical analyses were calculated using IBM SPSS Statistics 24 software (IBM Corp., Armonk, NY, USA).

RESULTS

Functional movement assessments pre- and post-season were completed for 18 high school varsity and junior varsity basketball players (10 males and 8 females; Age, $M \pm SD$: 15.6 ± 1.6 years). Demographics for the athletes are shown in Table 3. The girls' season started in late October and lasted 18 weeks. The boys' season started at the beginning of November and lasted 17 weeks. Approximately 50% of the participants were members of their high school varsity basketball teams, while the other half were on the junior varsity teams. Eight male athletes were right-hand dominant, and two were left-handed. For the female athletes, seven were right-handed, and one was left-hand dominant. Seventeen of the 18 participants had three or more years of basketball playing experience. Twelve athletes reported having experienced a musculoskeletal injury at some point prior to pre-season testing.

Table 3. Demographics of high school basketball players (N = 18).

	Males (n = 10)		Females (n = 8)		Total	
Variable	*Mean ± SD*	*Range*	*Mean ± SD*	*Range*	*Mean ± SD*	*Range*
Age (years)	15.8 ± 1.7	14-18	15.4 ± 1.5	14-17	15.6 ± 1.6	14-18
Weight (pounds)	158.3 ± 19.9	125-190	141.5 ± 18.6	100-162	150.8 ± 20.6	100-190
Height (inches)	71.1 ± 3.1	66-76	66.0 ± 3.7	61-72	68.6 ± 4.6	61-76

During the competitive season, athletes participated in basketball practices lasting approximately 2-2.5 hours, five days a week with the exception of days on which competitions occurred. Competitions were scheduled 2-3 days a week. The participants also completed weight training at moderate intensity that was planned and supervised by a Certified Strength and Conditioning Specialist (CSCS) two days a week throughout the season. Weight training sessions during the season focused on compound lifts (e.g., deadlift, squat, hang clean, push press) and accessory exercises to strengthen common areas of potential injury such as the shoulder and knee joints. Periodization followed an undulating pattern with repetitions and loads decreasing as the season progressed. Training sessions lasted approximately 30 minutes with the following structure: a dynamic warm-up, core training, compound lifts, accessory exercises focusing on injury prevention, and finished with mobility and flexibility training.

No athletes volunteered initially for the study who had any limitations that would have prevented them from completing the testing or study. If an athlete sustained an injury during the duration of the study but was no longer on participation restrictions at the time of post-testing, he or she was eligible to complete post-testing. Injuries were recorded during the season. Injury was defined as: "a musculoskeletal [damage] that occurred as a result of participation in an organized high school practice or competition setting that required medical attention in which the athlete sought care from an certified athletic trainer, physical therapist, physician, or other health care provider, and was restricted from complete participation for one or more exposures (practice or game)" (5). Only one athlete sustained a season-ending injury during the competitive season and thus, was not included in the final data analyses. Although not a focus of the study, a total of four participants (two males and two females) experienced an injury that resulted in practice or game restrictions between pre-season testing and post-season testing. However, all athletes were recovered and able to complete post-testing. For composite FMS scores there was no interaction or statistically significant difference between the injured and non-injured athletes [$F(1,16) = 1.235$, $p = 0.283$, $\eta_p^2 = .072$, $1\text{-}\beta = 0.182$], or between pre-season or post-season mean scores [$F(1,16) = 3.853$, $p = 0.067$, $\eta_p^2 = .194$, $1\text{-}\beta = 0.454$]

For the mean composite FMS scores there were no significant differences pre- to post-season or between the male and female basketball players (i.e., main effect of Time [$F(1,16) = 2.810$, $p = 0.113$, $\eta_p^2 = .15$, $1\text{-}\beta = 0.351$; *Means* ± *SDs*: Pre-Season, Post-Season = 16.2 ± 2.1, 17.1 ± 1.4]); Sex [$F(1, 16) = 0.180$, $p = 0.677$, $\eta_p^2 = .011$, $1\text{-}\beta = 0.068$; *Means* ± *SDs*: Males, Females = 16.8 ± 1.8, 16.5 ± 2.0]). There was no interaction of Time × Sex [$F(1, 16) = 0.057$, $p = 0.814$, $\eta_p^2 = .004$, $1\text{-}\beta = 0.056$]. Average composite scores pre- and post-season and by sex are shown in Table 4.

Table 4. Means and standard deviations for FMS composite scores by Time and Sex.

	Time[a]	
	Pre-Season	Post-Season
Sex[b]	*Mean* ± *SD*	*Mean* ± *SD*
Males (*n* = 10)	16.3 ± 1.9	17.3 ± 1.5
Females *(n = 8)*	16.1 ± 2.5	16.9 ± 1.4

[a] Main Effect: $p = 0.11$; [b] Main Effect: $p = 0.68$

Results from the Wilcoxon signed-rank tests for each FMS test are shown in Table 5. No significant differences were found between specific FMS test scores pre- to post-season for the group as a whole, or by sex. The number of participants who increased, decreased, or remained the same for specific FMS tests are shown in Table 6.

Table 5. Wilcoxon Signed-Rank test results for pre-season vs. post-season FMS test scores (*N* = 18).

FMS Test	*Z* score	*p* value	Cohen's *d*
Deep Squat			
Males	-0.45	0.66	0.14
Females	-0.58	0.56	0.21
Total	0.00	1.00	0.00
Hurdle Step			
Males	-0.45	0.66	0.14
Females	0.00	1.00	0.00
Total	-0.30	0.76	0.07
In-line Lunge			
Males	-0.82	0.41	0.26
Females	-1.00	0.32	0.35
Total	-0.38	0.71	0.09
Shoulder Mobility			
Males	0.00	1.00	0.00
Females	-0.45	0.66	0.16
Total	-0.41	0.68	0.10
Active Straight Leg Raise			
Males	-1.13	0.26	0.36
Females	-1.00	0.32	0.35
Total	-1.41	0.16	0.33
Trunk Stability Push-Up Males	-1.19	0.23	0.38
Females	-1.00	0.32	0.35
Total	-1.51	0.13	0.36
Rotary Stability			
Males	-1.00	0.32	0.32
Females	-0.58	0.56	0.21
Total	0.00	1.00	0.00

Note. Cohen's *d* effect size interpretation values: < 0.3 small, 0.3-0.5 moderate, > 0.5 large.

Table 6. Number of basketball players who increased, decreased, or remained the same for each FMS test score after the competitive season (*N* = 18).

	Deep Squat			Hurdle Step			In-Line Lunge			Shoulder Mobility			Active Straight Leg Raise			Trunk Stability Push-Up			Rotary Stability		
	+	–	/	+	–	/	+	–	/	+	–	/	+	–	/	+	–	/	+	–	/
Male	3	2	5	3	2	5	2	4	4	1	2	7	5	2	3	4	2	4	1	1	8
Female	1	2	5	3	3	2	1	0	7	1	1	6	1	0	7	3	1	4	2	1	5
Total	4	4	10	6	5	7	3	4	11	2	3	13	6	2	10	7	3	8	3	2	13

Note. (+) represents an increase in score, (–) represents a decrease in score, (/) represents no change in score.

DISCUSSION

FMS composite scores and specific test scores were neither negatively, nor positively influenced by participation in the competitive basketball season. There were also no differences between mean composite FMS scores or specific FMS test scores of the male and female basketball players. Four athletes experienced an injury during the season, but there were no differences between the injured and noninjured athletes.

The first purpose of this study was to assess functional movements using the FMS over the course of the natural progression of a high school competitive basketball season. It was hypothesized that changes in training and practice over the course of the season would focus on repetitive movements, skill development and tapering and thus, would change FMS scores after the season. Using a similar age group (i.e., < 19 yrs of age) of elite rugby league players, Waldron et al. (35) reported no change in mean FMS scores after a season similar to the findings in the present study. Also, no significant change in composite FMS scores pre- to post-season, or between males and females in NCAA Division II volleyball and soccer players (*N* = 57) were found by Sprague, Mokha, and Gatens (33). However, in contrast to the present study, Sprague et al. (33) did report increases in the mean FMS test scores for deep squat and inline lunge, and a decrease in the mean FMS test score for active straight-leg raise after the seasons for all athletes (33). No specific FMS test scores changed after the season in the present study. Bond et al. (8) evaluated NCAA Division II men's and women's basketball players (*N* = 119) pre- and post-season using the FMS and reported small to medium improvements in scores, with small specific FMS test improvements in the deep squat, hurdle step, and in-line lunge. For female collegiate, track and field athletes, Gustafson et al. (16) reported significant increases in mean FMS composite scores after a 7-wk competitive season. It is important to note that this sample of collegiate athletes were older, and therefore, this could point to important differences between high school and collegiate level athletes, maturity levels, and how they may physically respond to training. Furthermore, the lack of change in FMS scores pre- to post-season may have significant implications for high school level athletic participation and for the lifelong beneficial effects to athletes who participate. A decrease in FMS scores might indicate that the competitive season and its demands were detrimental to the athletes' functional movement, and therefore, potentially hinder one's ability to stay active long into adulthood. Conversely, an increase might suggest the opposite. However, since there was no meaningful change in composite FMS scores resulting from participation in a competitive high school basketball season, neither conclusion was supported. While high school sports may not directly enhance functional movement ability, participation did not seem to hinder movement in this sample of basketball athletes.

Mean FMS composite scores for basketball players from the present study of 16.8 for the males and 16.5 of the females combining pre- and post-season test scores were greater than the combined FMS composite mean score for girls and boys basketball players of 15.6 reported by Wieczorkowski (36). When studying elite basketball players in Lithuania, Garbenytė-Apolinskienė et al. (14) reported comparable means for composite FMS scores of 15.9 pre-season for both males and females. However, after an integrated training program that combined flexibility, strength and stability exercises these means improved to 17.0 and 16.9 for the males and females, respectively; means similar to the present study. Mean FMS composite scores reported by Sorenson (32) of 14.5 for male and 14.7 for female basketball players were much lower. Few studies have reported norms for high school basketball athletes.

Moore et al. (22) has indicated that the FMS scores may vary by sport. It is well documented that different sports place varied physiological demands on the body (4). The mean composite FMS scores for all athletes in the present study of 16.2 and 17.1 for pre- and post-season are comparable to the median score of 16 reported by Smith et al. (31) for athletes in football, soccer, and baseball. Similarly, Lee et al (18) for baseball players, and Garbenytė-Apolinskienė et al. (14) for elite youth basketball players reported comparable mean FMS composites scores of 15.9. Conversely, Bardenett et al. (5) reported a mean FMS composite of 13.0 for male and 13.1 for female high school athletes participating in the sports of cross country, football, soccer, swimming, tennis, and volleyball. They did not report FMS composite score means by sport. Therefore, in agreement with the suggestion by Moore et al. (22), it is recommended that more research using the FMS is needed for various sport teams and with much larger sample sizes by sport.

A second purpose of this study was to determine if there were functional movement differences between male and female youth basketball players. While the present study observed no significant difference in scores between males and females, there are conflicting results reported in the literature. On this topic, Anderson et al. (2) found differences in FMS composite scores of youth males and females. When they examined a much larger group (N = 60) of secondary school athletes as compared to the present study, they found females demonstrated a significantly lower FMS composite score (2). Abraham et al. (1) found the same trend in their assessment of 1,005 school-age students (10-17 years of age) who were recreationally or competitively physically active. However, the difference in scores was quite small with the mean score for males being less than one point greater than females (1). It is also important to note that this study took place in India where the culture and emphasis on youth sports could differ from the U.S. for how and when children learn to be physically active. Conversely, Pfeifer et al. (27) assessed 136 youth athletes 11-18 years of age who participated in a variety of fall and spring sports in the U.S., and found females had a higher FMS composite score (14.4) than males (12.3). Whereas, Loudon et al. (21) studied a wide range of adult runners 18-52 years of age (N = 43) and found no differences in composite FMS scores between males and females. In another adult sample 18-40 years of age of recreationally active individuals, Schneiders et al. (28) found no significant differences in composite scores between men and women in New Zealand. Data from youth samples present differences in FMS scores due to sex, whereas studies on adults do not appear to report differences in scores between males and females. This supports the idea that high school athletes may have inherent differences from adults, may be different developmentally for functional movements by sex during youth, and therefore may need to train differently for athletic competitions or sports participation. Further research is warranted in this area.

Limitations: The results of the present study should be interpreted cautiously. Although the sample size was small, the results do provide additional norms for high school boys and girls basketball players which have not been reported previously in many studies. In addition, seasonal changes and comparison of results by sex were reported for high school basketball players. Future recommendations are that this study be replicated with a larger sample size from multiple high schools and across various divisions (i.e., high schools varied by the size of the student population). Future studies for comparisons of FMS composite scores and specific test scores by maturation level and sport are also warranted.

Conclusions: In conclusion, FMS composite scores in this study did not change between the beginning and the end of a high school basketball season. There were also no differences between male and female average composite scores or test scores pre- and post- season based on sex. A review of the results of the present study and the current literature points to differences in functional movement capacity and FMS scores between the population of adolescent athletes and their adult counterparts. Coaches, trainers, parents, and athletes must be aware of these differences when training. The training tactics that work well for collegiate and professional athletes may not be the best practice for these developing young high school athletes. This is also important to consider when using the FMS as a screening tool in high school and adolescent athletes.

A key limitation of the present study was the rather small sample size, so the resulting findings may not directly apply to a larger population. Nevertheless, these data add to the growing body of literature on this younger, high school athletic population which has not been studied extensively in previous research. Further research relating to adolescents' functional movements and the lasting impact youth sports have on individuals is warranted to understand safe and effective training methods in young populations. Research in this area will benefit coaches, trainers, parents, and ultimately the young athletes, to promote safe and healthy development and perhaps, a physically active lifestyle into adulthood.

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