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Movement Ability in High School Basketball Players: Pre- and Post-Season

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Table of Contents

Abstract

Functional movement is the ability to perform movements (e.g., 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 (Cook, 2010). Competent functional movement allows for the proper development of motor control and optimal adaptability to training (Cook, 2010). Participation in structured youth sports is common in American culture, but how this participation effects functional movement ability long into adulthood is yet to be determined. The purpose of this study was to determine how functional movement ability, assessed by the Functional Movement Screen® (FMS), is impacted by participation in a season of high school level basketball. Eighteen total male (n = 10) and female (n = 8) high school basketball players completed the FMS pre- and post- season. Scores were analyzed using a mixed-design repeated measures ANOVA. No significant differences were found for the main effects of Time [$F(1,16) = 2.810$, $p = 0.113$, $1\text{-}\beta = 0.351$] or Sex [$F(1, 16) = 0.180$, $p = 0.677$, $1\text{-}\beta = 0.068$] for composite FMS scores, or for the interaction of Time × Sex [$F(1, 16) = 0.057$, $p = 0.814$, $1\text{-}\beta = 0.056$]. In addition, individual FMS tasks scores were compared pre- to post-season using Wilcoxon signed-rank tests. No significant differences were found between individual FMS task scores pre- to post-season for the group as a whole, or based on sex. Therefore, the results of the present study indicate participation in a high school basketball season does not limit nor enhance functional movement ability. In addition, differences in sex, relating to overall FMS composite scores, individual task scores, or changes in scores were not apparent in this age group or sport.

Key words: Functional Movement Screen, high school basketball players, sex differences, changes over time

Movement Ability in High School Basketball Players: Pre- and Post- Season

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 (Cook, 2010). Competent functional movement allows for the proper development of motor control and optimal adaptability to training (Cook, 2010). In addition, functional movement is the foundation for activities of daily living. For example, a squat is performed when one bends down to pick something up from the ground, trunk extension when reaching for an object from the overhead cupboard, and rotary stability when one switches laundry from the washer to the dryer. Functional movement involves the "principles of proprioceptive neuromuscular facilitation, muscle synergy, and motor learning", and can be influenced by age and maturation along with intrinsic factors such as muscle activation, neuromuscular control, and mobility (Anderson, Neumann, & Bliven, 2015; Cook, Burton, & Hoogenboom, 2006a, p. 62). When deficiencies in these foundational movement patterns arise, it can lead to several concerns, including pain during physical activity, musculoskeletal injuries, a decline in movement efficiency, and ultimately a hindered ability to perform basic activities of daily life.

While impaired functional movement is a concern for all populations, it is especially concerning for athletes who are at a heightened risk of injury who rely on the ability to perform high level skills efficiently and pain free. Lockie et al. (2015) addressed the importance of movement screens for athletes used to assess these foundational movement patterns; these researchers argued that a pre-participation screen can provide valuable information on imbalances that could influence injury risk and affect performance. "The main goal in performing pre-participation or performance screenings is to decrease injuries, enhance performance, and ultimately improve quality of life", according to Cook, Burton, & Hoogenboom (2006a, p. 63). Schneiders, Davidsson, Horman, and Sullivan (2011) pointed out that pre-participation screenings are common in athletics for a number of reasons; for instance, "screening procedures can also be used in injury prevention in order to counsel individuals with sport specific functional deficits, create individual pre-habilitation or rehabilitation programs and to enhance sporting performance" (p. 76). The problem with pre-participation screenings, however, is that these are often sport specific and focused more on athletic ability than underlying movement deficits. Therefore, these assessments are lacking the ability to aid in athlete development, and instead are typically used to determine talent or skill level.

This idea of a comprehensive pre-participation screening that focuses on basic movement patterns led to the development of The Functional Movement Screen® (FMS) which is trademarked by functionalmovement.com (2019). The FMS is "a tool to appraise general whole-body movements based on the notion that individuals should be able to move freely, symmetrically, and without pain" (Beach, Frost, & Callaghan, 2014, p. 488). The popular testing tool gauges movement ability, efficiency, balance, and fluidity. Utilizing this type of screen allows for the identification of underlying biomechanical factors by observing basic movement patterns and techniques (Schneiders et al., 2011). The tool was initially designed to put individuals in positions where possible muscular weaknesses, range of motion and mobility limitations, or anatomical asymmetries are exposed, and is applicable to all active populations (Cook, Burton, & Hoogenboom, 2006a; Teyhen at al., 2012). However, since its development the screen has been researched for other purposes as well, such as an injury risk indicator and as a gauge of potential athletic ability or fitness capacity.

Cook and others (Cook, 2010) who created the FMS had an ultimate goal of designing a tool that would be able to identify movement deficits with the intention of then remedying these deficits through individualized exercise prescription. Teyhen et al. (2012) have supported the validity of using the FMS in this way by noting that scores did in fact improve after individuals routinely performed corrective exercises. This idea has been reinforced by Kiesel, Plisky, and Butler (2011) who studied a group of American professional football players and their ability to increase their FMS scores after following a seven-week intervention plan. They reported improved FMS scores after implementing a stretching routine, trigger point treatment, individualized corrective exercises, and traditional strength and conditioning program for seven weeks (Kiesel, Plisky, & Butler, 2011). These results are important because the deficiencies identified by the FMS can actually be addressed and corrected, potentially enhancing the quality of life and movement patterns during athletic performance.

In addition, Sprague, Mohka, and Gatens (2014) performed FMS testing on 57 NCAA Division II women's volleyball and men's and women's soccer players pre- and post-season. They observed increases in individual task scores for the deep squat and in-line lunge and a decrease in the number of asymmetries and individual task scores of 1, thus supporting that participating in a competitive sport season could in itself result in improve functional movement (Sprague, Mohka, & Gatens, 2014). This was further supported by Gustafson (2019) who also assessed FMS scores pre- and post- season in 24 female indoor track athletes. Again, improvements in FMS scores were observed pre- to post- competitive season, in which composite scores improved significantly (Gustafson, 2019).

When assessing functional movement, it is important to keep in mind that several considerations can influence an individual's capacity for proper movement technique such as age, maturation, physiology, and neuromuscular factors (Anderson, Neumann, & Bliven, 2015). Previous injury can also lead to the development of compensatory movement patterns which ultimately affect movement competency and efficiency. There may even be a correlation between functional movement and fitness capacity. O'Connor, Deuster, Davis, Pappas, and Knapik (2011) studied U.S. Marines and noted that those soldiers with lower FMS scores also had poorer scores on other fitness tests (i.e., pull-ups to exhaustion, 2-minute abdominal crunch, timed 3-mile run). However, this has not been supported in other published research studies. Consideration must be taken for all of these factors (i.e., maturation, physical fitness, etc.) when interpreting one's composite FMS score.

Composite scores on the FMS have been repeatedly shown to be affected by previous injury. Injury has been defined in the literature as "any musculoskeletal complaint from participation in a team organized event that requires evaluation by an [athletic trainer] or any physician" (Bring et al., 2018, p. 360); or, "a musculoskeletal injury that…required medical attention in which the athlete sought care from an [athletic trainer], physical therapist, physician, or other health care provider, and was restricted from complete participation for one or more exposures (practice or game)" (Bardenett et al., 2015, p. 305). Chimera, Smith, and Warren (2015) found an array of FMS score similarities in athletes who had experienced similar injuries. For example, those with a history of hip, hand, elbow, or shoulder injury or surgery resulted in the lowest FMS composite scores as compared to their healthy counterparts (Chimera, Smith, & Warren, 2015). Those with a knee surgery in their history had worse rotary stability than those who were uninjured (Chimera, Smith, & Warren, 2015). And, participants who experienced a hip injury performed more poorly on the deep squat and hurdle step than uninjured participants; those with hip surgery had lower hurdle step and in-line lunge scores (Chimera, Smith, &

Warren, 2015). Oddly, individuals with trunk/back injuries performed better on the deep-squat (Chimera, Smith, & Warren, 2015). Interestingly, participants with a history of ankle injuries actually performed better on the in-line lunge than those who were uninjured, possibly due to effective rehabilitation practices (Chimera, Smith, & Warren, 2015). Finally, as expected, those with shoulder or hand injuries or surgeries had trouble with shoulder mobility (Chimera, Smith, & Warren, 2015).Therefore, previous injury routinely indicates a likely deficit in some aspect of functional movement.

In addition to the aforementioned specific results, Garrison, Westrick, Johnson, and Beneson (2015) along with Chapman, Laymon, and Arnold (2014) determined that an athlete was at a greater risk of injury if they had a composite FMS score at 14 or below, and an even higher risk if they had a history of previous injury. Garrison et al. (2015) also determined that this injury risk rate can be generalized to a wide population including both male and female athletes in contact and non-contact sports. However, Bring et al. (2018) argued against the FMS score as an injury prediction tool in long distance runners as they found no correlation between composite scores and injuries among high school or college distance runners. Although, it should be noted, all of these studies used to determine this injury prediction cut-off score of 14 had populations of healthy, active adults so this may not be generalizable to all populations, especially high school aged adolescents. Therefore, this is an area requiring further investigation.

Aside from previous injuries, specific sex characteristics have had an influence on functional movement as well. In a previously mentioned study, Chimera, Smith, and Warren (2015) compared FMS performance between NCAA Division I male and female athletes who were uninjured and between the ages of 18 and 24 years. Aside from injury data they also found specific differences between males and females. Females had worse performances in the trunk and rotary stability tasks, whereas they performed better on in-line lunge, shoulder mobility, and straight-leg raise than their male counterparts (Chimera, Smith, & Warren, 2015). However, there were no differences in the deep squat, hurdle step, or composite scores between sexes (Chimera, Smith, and Warren, 2015). A similar study by Loudon, Parkerson-Mitchell, Hildebrand, and Teague (2014) comparing FMS scores of long-distance runners based on age and sex also found no difference based on sex in composite scores, while there were differences in independent tests with results suggesting women were more flexible than men overall. The finding that there is no inherent difference in composite scores between sexes was supported again by Schneiders et al. (2011) who studied recreationally active exercisers 18-40 years of age. In contrast, Anderson, Neumann, and Bliven (2015) studied secondary school athletes (31 males and 29 females), ages 14-17 years, and did find differences in composite scores of males and females. The mean female scores were below 14 which was lower than their male peers mean composite scores (Anderson, Neumann, & Bliven, 2015). These conflicting findings could indicate that maturity or the presence or absence of athletic participation plays a role in functional movement ability and effects growing adolescents differently than adults. In this population specifically, Anderson, Neuman, and Bliven (2015) found females had decreased muscle activity in the gluteus medius, vastus medialis oblique, and vastus lateralis, and decreased neuromuscular control and core stability which ultimately affected functional movement. This finding was further supported by Lockie et al. (2015) who studied nine female athletes who were between 18-28 years of age and participated in a team sport. The idea that women consistently perform better or worse in certain tasks than men can have important implications on how females are able to move, play, or adapt to training stimulus. Furthermore, Lin, Casey, Herman, Katz, and Tenforde (2018) performed a literature review of common sport injury differences by sex, finding 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. Therefore, this information may indicate a need to approach athletics and training differently between sexes in youth athletics, where this may not be the case after athletes reach full maturity.

In addition to sex differences occurring within varying maturity levels, younger populations differ from adults in terms of functional movement due to physiological development status. Bardenett et al. (2015) studied a group of high school athletes who participated in fall sports in an effort to validate a composite score of 14 on the FMS as an accurate injury risk indicator in this population. As a result, they found no correlation in those with composite scores of 14 or below and an increased incidence of injury; instead, they found more injuries in athletes who were older (Bardenett et al., 2015). This is important because it emphasized how cut-off scores for younger populations can differ from adult norms. Therefore, FMS norms determined from studies on adult populations should not necessarily be used with children or adolescents. Schneiders et al. (2011) supported this idea by suggesting future research should focus on developing normative data for specific populations, age groups, and sports so that physical therapists, coaches, and athletic trainers have data to which to compare their athletes' results.

The youth and high school athletic populations have not been studied extensively in past FMS research. There are limited data for FMS scores in younger populations, so normative values have not been developed. The differences between males and females below the age of 18 years have not been determined. This is why the present study sample included both male and female athletes. In addition, the athletes injury history and incidence over the season were obtained, because injury has been shown to dramatically effect functional movement patterns and capacity. Furthermore, little is understood about how competitive American high school sports are affecting athletes' neuromuscular control and functional movements (i.e., biomechanical composition of movement). For these reasons, the purpose of this study was to determine if functional movement changes over the course of a high school competitive basketball season. Furthermore, functional movement differences between males and females were evaluated. An additional purpose was to examine the relationship between pre- and post-season composite FMS scores of those who experienced an injury over the season and those who did not.

Method

Participants

Volunteers for functional movement assessment were 18 high school basketball players (10 males and 8 females; Age, *Mean* ± *S.D.* = 15.6 ± 1.5 years). Participants 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. Athletes participated in basketball practices lasting approximately two hours, five days a week with the exception of competitions that took place 2-3 days a week. The participants also completed weight training at moderate intensity that was planned and overseen by a Certified Strength and Conditioning Specialist (CSCS) two days a week throughout the season.

Inclusion criteria. To be included in this study participants were required to be between 14-18 years of age and members of the high school basketball team (varsity and junior varsity) for the 2019-2020 season. The athletes were also cleared for physical activity by a physician after a pre-participation physical exam, which was also a requirement to be a member of the team.

Exclusion criteria. Athletes who had sustained an injury that would have limited their participation in practice or games at the time of testing (pre- or post- season), or had any upper or lower extremity surgery in the past 30 days were excluded from the study (Bring et al., 2018). An injury that occurred outside of the athletic setting but still resulted in participation restrictions also excluded an athlete from the study. If the athlete sustained an injury during the duration of the study but was no longer on participation restrictions at the time of testing, he or she was eligible to remain in the study. 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 ATC, physical therapist, physician, or other health care provider, and was restricted from complete participation for one or more exposures (practice or game)" (Bardenett et al., 2015, p. 305). Additionally, individuals were excluded from the study if they did not complete the entire competitive season, or if they were unable to complete any of the testing sessions in the designated amount of time.

Procedure

Recruitment. Participants were recruited from a rural high school in northwest Ohio. Initially, permission was obtained from the Athletic Director of the high school to contact the head coaches of each team in order to recruit the athletes needed for data collection. Afterwards, permission was also obtained from the head coaches from each team to contact and collect data from their athletes. At this point, all appropriate documents were submitted to the Bowling Green State University Institutional Review Board (BGSU IRB) for approval. Once the BGSU IRB approved the study, the first contact with the participants was made.

Obtaining consent. During this initial contact with potential participants the purpose and details of the study were explained in detail, including each task in the Functional Movement Screen. All participants were also provided with participant assent (Appendix A) and parental consent (Appendix B) 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 the orientation session.

Instrumentation. The Functional Movement Screen is a tool to determine functional movement ability and is comprised of seven functional tests and three clearing tests. 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. Explicit descriptions, depictions, and scoring of each of the 10 listed tasks are described by Cook, Burton, and Hoogenboom (2006a, 2006b). Each of the seven functional tests are scored from "0" to "3". A score of "0" indicating the task could not be performed without experiencing pain and "3" signifying mastery of the movement (Anderson, Neumann, & Bliven, 2015; Cook, Burton, & Hoogenboom, 2006a, 2006b). Both the left and right side of the body are scored separately and the lower score of the two was recorded, with differences noted (Cook, Burton, & Hoogenboom, 2006a, 2006b). In addition, the three clearing tests are scored as either positive or negative based on if pain was present (positive score) or not (negative score) (Cook, Burton, & Hoogenboom, 2006a, 2006b). All of the scores from these seven tests are added together to provide a composite score with a possible outcome of "0" to "21" (Anderson, Neumann, &

Bliven 2015; Cook, Burton, & Hoogenboom 2006a, 2006b). A higher composite score signifies greater functional movement ability, whereas a lower score indicates impaired ability and possible increased risk of injury (Anderson, Neumann, & Bliven, 2015; Chapman, Laymon, & Arnold, 2014; Chimera, Smith, & Warren, 2015; Garrison et al., 2015).

Testing Sessions. Beardsley and Contreras (2015) and Frost, Beach, Callaghan, and McGill (2012) argued against the reliability of the FMS as they experienced improvements in FMS scores in their control group and contested that changes could have been related to prior test exposure (i.e., the “practice effect”), feedback received, or day-to-day variation in movement and neuromuscular control. These researchers also challenged the validity of the FMS. They stated that an athlete can alter how they perform each of the seven tasks depending on load and resistance, experience and exposure to the test, and setting (Beardsley & Contreras, 2015; Frost et al., 2012). To minimize the effects of these extraneous variables all participants were required to perform an orientation session to familiarize themselves with the tasks in an effort to eliminate the practice effect. 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 them at this time and they were given time to practice each task. 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.

All data were collected from 7:45 a.m. to 6:00 p.m. All participants completed testing within two weeks prior to the first official day of practice and within two weeks after their season was completed. Before beginning the screening, participants provided basic demographic information along with a brief training and injury history by completing a questionnaire (Chimera, Smith, & Warren, 2015)(see Appendix C).

After completing the documents, participants performed a warm-up consisting of five minutes of light jogging or walking (similar to the warm-up used by Anderson, Neumann, and Bliven, 2015). After the warm-up each participant performed all 10 of the FMS tasks in accordance to the testing guidelines provided by Cook, Burton, and Hoogenboom (2006a, 2006b). The participants performed testing in athletic clothes and comfortable athletic footwear, in which the researcher ensured fit and tied properly. In addition, verbal feedback was limited and remained consistent throughout pre- and post-season testing sessions. All testing procedures lasted approximately 15-20 minutes including completion of questionnaires and performing the warm-up.

Confidentiality. All participant information remained private and individuals were not identified. Participants' information was stored in the researcher's private home office. All information was typed into programs on a password-protected computer; once this was done all paper copies of data collected were shredded. Only the researcher and the advisor working directly on the study had access to the data. Each individual was assigned a random identification number, and this was used to specify their information during the study and for subsequent analyses. Publications in which data will be presented will be by group values such as means, standard deviations, etc., and not by individual participant scores.

Statistical Analysis. Statistical analyses were calculated using IBM SPSS Statistics 24 software (IBM Corp., Armonk, NY, USA). A mixed-design repeated measures ANOVA was performed to examine the main effects of Sex (2: Male, Female) and Time (2: Pre-, Post-season), $p \leq 0.05$. The dependent variable was FMS composite score. Individual FMS task scores were compared pre- to post-season using Wilcoxon signed-rank tests, $p \leq 0.05$. In addition, a mixed-design repeated measures ANOVA was performed to examine the main effects of Injury

(2: Injury during the season, No injury during the season) and Time (2: Pre-, Post-season), $p \leq 0.05$; the dependent variable was FMS composite score.

Results

Functional Movement Screen Interrater Reliability

Interrater reliability was assessed using three FMS Level 1 Certified examiners in real time. Twelve subjects were evaluated by all three raters for all seven tasks and for the three clearing tests. IBM SPSS Statistics 24 software was used to calculate the Intraclass Correlation Coefficient and Krippendorff's alpha (KALPHA) (Hayes & Krippendorff, 2007) to determine the interrater reliability between the three raters for each task. Results from this analysis are shown in Table 1. The intraclass correlation coefficient calculation 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 has been shown to have moderate to good interrater and intrarater reliability with an ICC of .843 (95% CI = 0.640, 0.936) (Cuchna, Hoch, & Hoch, 2015) and an ICC of 0.74-0.76 (Teyhen, et al., 2012) respectively, even with novice raters. Moreover, the FMS has been shown to have fair to high real-time intrasession (ICC, SEM = 0.98, 0.25) and intersession (ICC, SEM = 0.92, 0.57) reliability (Onate, et al., 2012).

Furthermore, KALPHA was calculated for each of the FMS test scores because these are ordinal data from three raters (Hayes & Krippendorff, 2007). A KALPHA score of 0.8 or above indicates acceptable reliability (Shultz, Anderson, Matheson, Marcello, & Thor, 2013); where 1.00 represents perfect reliability and 0.00 indicates the absence of reliability (Hayes & Krippendorff, 2007). 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 our analyses, the entire population was set at 10,000. All tasks met this criterion except for the right leg and left leg inline 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 inline lunge values did not meet the KAPLPHA of 0.8, thus indicating poorer reliability for these tasks. 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 inline lunge tasks. In addition, the KALPHA for the squat (.78) and the left hurdle step (.78) both suggest moderate interrater reliability in these tasks. 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, we concluded there was low reliability among the three raters for the left and right inline lunge, and moderate reliability for the deep squat and left hurdle step. These findings are similar to the findings of Teyhen et al. (2012) who performed reliability testing and reported lowest levels of interrater agreement for the in-line lunge and rotary stability tests between novice raters.

Table 1

FMS Inter-Reliability Among Three Raters

FMS Task	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 Inline Lunge	0.55	(0.33, 0.77)	0.82
Left Inline Lunge	0.44	(0.16, 0.67)	0.99
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. 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 (Hayes & Krippendorff, 2007)

Demographics

There were 18 high school basketball players who participated in the study. The girl's season started in late October and lasted 18 weeks. The boy's season started the beginning of November and lasted 17 weeks. Participant demographics can be found in Tables 2, 3, and 4. Approximately 50 percent of the participants were members of their high school's Varsity basketball teams, while the other half were on the Freshmen or Junior Varsity teams. Both teams practiced five days a week lasting from two hours to two hours and 30 minutes, until games started. Once competitions began, games took place 2-4 times a week with 2-5 practices per week, accordingly. Eight male athletes were right-hand dominant, and two were left-handed. As 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 experiencing a musculoskeletal injury at some point prior to pre-season testing.

Table 2

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)	16.5 ± 1.3	15-18	16.3 ± 1.4	15-18	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	60-76

Composite FMS Scores

No significant differences were found for the main effects of Time [$F(1,16) = 2.810$, $p = 0.113$, 1-β =0.351] or Sex [$F(1, 16) = 0.180$, $p = 0.677$, 1-β = 0.068] of composite FMS scores, or for the interaction of Time × Sex [$F(1, 16) = 0.057$, $p = 0.814$, 1-β = 0.056]. Average composite scores pre- and post-season are shown in Table 3, and average composite scores by sex are shown in Table 4.

Table 3

Means and Standard Deviations of Composite FMS Scores for Pre- and Post-Season (N = 18)

	Pre-Season	Post-Season			
	Mean ± SD	*Mean ± SD*	*F*	*p-value*	1-β
FMS Composite Score	16.22 ± 2.13	17.11 ± 1.41	2.81	0.113	0.351

* $p \leq 0.05$

Table 4

Means and Standard Deviations for Composite FMS Scores of Male (n = 10) and Female (n = 8) Participants

	Males	Females			
	Mean ± SD	*Mean ± SD*	*F*	*p-value*	1-β
FMS Composite Score	15.80 ± 4.12	16.50 ± 1.65	0.180	0.677	0.068

* $p \leq 0.05$

Individual FMS Task Scores

Results from the Wilcoxon Signed Rank tests are shown in Table 5. No significant differences were found between individual FMS task 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 in individual FMS tasks are shown in Table 6.

Table 5

Wilcoxon Signed-Rank Results for Pre-Season vs. Post-Season and Males (*n* = 10) *vs. Females (n = 8)*

FMS Task	*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
Inline 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 Athletes who Increased, Decreased, or Remained the Same in Each FMS Task Score (N = 18)

	Deep Squat			Hurdle Step			Inline Lunge			Shoulder Mobility		
	+	-	/	+	-	/	+	-	/	+	-	/
Male	3	2	5	3	2	5	2	4	4	1	2	7
Female	1	2	5	3	3	2	1	0	7	1	1	6
Total	4	4	10	6	5	7	3	4	11	2	3	13

	Active Straight Leg Raise			Trunk Stability Pushup			Rotary Stability		
	+	-	/	+	-	/	+	-	/
Male	5	2	3	4	2	4	1	1	8
Female	1	0	7	3	1	4	2	1	5
Total	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.

Injury Prevalence

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. Results from the 2 × 2, repeated measures ANOVA for Time (2: Pre-season, Post-Season) × Injury prevalence (2: Injured, Uninjured) are displayed in Table 7. There were no significant differences in main effects for Time [$F(1,16) = 3.853$, $p = 0.067$, 1-β = 0.454] or Injury [$F(1,16) = 1.235$, $p = 0.283$, 1-β = 0.182] for composite FMS scores. No significant interaction was found for the interaction effect of Time × Injury [$F(1,16) = 0.825$, $p = 0.377$, 1-β = 0.137].

Table 8

Mean and Standard Deviation of Composite FMS Scores for Injured (n = 4) and Uninjured Participants (n = 14)

	Injured	Uninjured			
	Mean ± *SD*	*Mean* ± *SD*	*F*	*p-value*	1-β
FMS Composite Score	17.38 ± 0.48	15.75 ± 3.56	1.235	0.283	0.182

* $p \leq 0.05$

Discussion

The purpose of this study was to determine if participating in a competitive season of high school basketball season affected functional movement ability as assessed by the FMS. Changes in FMS scores could have significant impact on function and movement habits later in life. Furthermore, a secondary purpose of the study was to determine if functional movement capacity differed between sexes in high school athletes. Differences, or lack thereof, could have important implications on how groups of youth athletes are trained, especially in comparison to their adult counterparts where these differences may no longer exist. In addition, the FMS is frequently used as an injury prediction tool, but its validity in youth populations has been questioned. Therefore, this study also examined the relationship between composite scores of those who experienced an injury during the season and those who did not.

Impact of the Basketball Season on FMS Scores

Functional movement was neither negatively, nor positively influenced by the basketball season. The same was true when the total group was separated by sex. Additionally, individual

FMS task scores were not significantly impacted in either direction after the basketball season. These results were supported by Sprague, Mohka, and Gatens (2014) who also observed 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). However, they did report increases in the mean scores for deep squat and inline lunge, and a decrease in the mean score active straight-leg raise after the seasons for all athletes (Sprage, Moka, & Gatens, 2014). This could be attributed to the difference in sports (i.e., volleyball and soccer vs. basketball in the present study), the intensity of training between the high school versus the collegiate levels, or other factors that may have differed between these two samples. In contrast, Bond et al. (2019) 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 task improvements in the deep squat, hurdle step, and in-line lunge. It is important to note that this sample of collegiate athletes were post pubescent, 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. On the other hand, an increase may 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. This should be considered when weighing the pros and cons of athletic participation at this level.

Sex Differences

While the present study observed no significant difference in scores between males and females, the literature seems to be conflicted in this area. On this topic, Anderson, Bliven, and Neuman (2019) found variances in FMS composite scores of males and females. When they examined a much larger group (*N* = 60) of secondary school athletes than the present study, they found females demonstrated a significantly lower FMS composite score (Anderson, Bliven, & Neuman, 2019). Abraham, Sannasi, and Nair (2015) found the same trend in their assessment of 1,005 school aged students (Age: 10-17 years) who were recreationally or competitively physically active. However, the difference in scores was quite small with the male’s mean score being less than one point greater than females (Abrham, Sannasi, & Nair, 2015). It is also important to note this study took place in India where the culture and emphasis on youth sports could greatly impact how and when children learn to be physically active. On the other hand, Pfeifer et al. (2019) assessed 136 youth athletes (Age: 11-18 years), 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 (12.26). Whereas, Loudon et al. (2014) studied a wide range of adult runners (Age: 18-52 years; *N* = 43) found no differences in composite FMS scores between males and females. In another adult sample (Age: 18-40 years) of recreationally active individuals, Schneiders et al. (2011) 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 have inherent differences from adults and may be developmentally different between the sexes during youth, and therefore should be treated differently by sex when it comes to athletic or sports training. Further research is warranted in this area.

Injury and FMS Scores

It was also suspected that an injury occurring during the season would negatively affect functional movement capacity. However, when the composite FMS scores of those who experienced an injury were compared to those who did not, there were no significant differences in scores. No differences were found between the pre-season scores and the post-season composite scores between the two groups, either. However, these conclusions should be interpreted cautiously due to the very small sample sizes in this study.

The range of composite FMS pre-season scores for those who experienced an injury was 16-17. Garrison et al. (2015) investigated the use of an FMS cut-off score as an injury prediction tool for 160 male and female collegiate athletes. Thus, resulting in support of the commonly used cut-off score of <14 for indicating an increased risk for lower scores (Garrison et al., 2015). In a previously mentioned study by Pfeifer et al. (2019), correlations were found suggesting a cut-off score of 15 or below may be a better indicator of increased injury risk in youth athletes. However, Bring et al. (2018) assessed the ability of an FMS score to predict injury in 183 high school and college runners (age: 13-22 years) and found no relationship between any composite score, including the suggested <14 or <15 cut-off, and injury incidence. They also found no significant differences in individual FMS task scores of those who experienced an injury and those who did not (Bring et al., 2018). In addition, Sorenson (2009) evaluated the FMS as an injury prediction tool in high school basketball players specifically (N = 112) and reported no relationship between any FMS composite score and incidence of injury during the subsequent basketball season, as well. These findings were reinforced in the present study whereas there was no difference in scores between those who experienced an injury and those who did not. However, this conclusion is limited due to the small samples sizes (only 4 players were injured) in this study.

Furthermore, Barnett et al. (2015) found no conclusive relationship between FMS composite scores and injury incidence in male and female high school athletes (*N* = 167); however, they did find that other factors may be more pertinent in indicating injury risk. For example, they found that older athletes were more likely to experience an injury than younger athletes (Barnett et al., 2015). With the small sample size and limited age range in the present study it is difficult to determine if this trend was apparent since two of the injured athletes were 14 years of age, one was 17, and one was 18.

Barnett et al. (2015) also found that previous injury is another factor that puts one at an increased risk of suffering a new injury. In the present study three of four athletes of those suffering an injury had reported a previous history of injury. However, 67 percent (12 of 18) of the study sample reported a previous injury and only 22 percent (4 of 8) suffered an injury during the season. Thus, based on the present results and sample, no definitive conclusions can be made. However, based on previous studies and evidence presented, age of the athlete, previous playing experience, and injury history may be accurate predictors of injury in the adolescent population rather than the FMS composite score, thus warranting further research in this area.

Conclusions

In conclusion, FMS composite scores in this study did not appear to change between the beginning of the basketball season and the end. There were also no differences between male and female average composite scores, or pre- and post- season scores based on sex. Individual tasks scores followed the same pattern, with no differences noted pre- to post-season, or between sexes. Finally, for the small group of participants who experienced an injury over the season, there was no differences between their composite scores at the beginning of the season and the uninjured participants. There were also no significant differences between their scores at the end of the season and the uninjured group, as may have been expected due to their injuries.

The results of the present study and the current literature identifies 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 players. Furthermore, the idea that one’s composite FMS score could predict injury risk does not appear appropriate for this age group. This is important to keep in mind when using the FMS as a screening tool in high school and adolescent athletes. However, a key limitation of the present study was the rather small sample size, so the resulting findings may not directly apply to the larger population. Nevertheless, these data will add to the growing body of literature on this young high school athletic population which has been limited in previous research. Further research relating to adolescents’ functional movement 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 an active lifestyle long into adulthood.

References

Abraham, A., Sannasi, R. & Nair, R. (2015). Normative values for the functional movement screen in adolescent school aged children. *International Journal of Physical Sports Therapy, 10*(1), 29-36.

Anderson, B. E., Neumann, M. L., & Bliven, K. C. H. (2015). Functional movement screen differences between male and female secondary school athletes. *The Journal of Strength and Conditioning Research, 29*(4), 1098-1106.

Bardenett, S. M., Micca, J. J., DeNoyelles, J. T., Miller, S. D., Jenk, D. T., & Brookes, G. S. (2015). Functional movement screen normative values and validity in high school athletes: Can the FMS™ be used as a predictor of injury? *International Journal of Sports Physical Therapy, 10*(3), 303-308.

Beach, T. A. C., Frost, D. M., & Callaghan, J. P. (2014). FMS scores and low-back loading during lifting: Whole-body movement screening as an ergonomic tool? *Applied Ergonomics, 45*, 482-489.

Beardsley, C., & Contreras, B. (2014). The functional movement screen: A review. *Strength and Conditioning Journal, 36*(5), 72-80.

Bond, C. W., Dorman, J. C., Odney, T. O., Roggenbuck, S. J., Young, S. W., & Munce, T. A. (2019). Evaluation of the functional movement screen and a novel basketball mobility test as an injury prediction tool for collegiate basketball players. *Journal of Strength and Conditioning Research, 33*(6), 1589-1600.

Bring, B.V., Chan, M., Devine, R.C., Collins, A.L., Diehl, J., & Burkam, B. (2018) Functional movement screening and injury rates in high school and collegiate runners: A retrospective analysis of 3 prospective observational studies. *Clinical Journal of Sport*

Medicine, 28(4), 358-363.

Chapman, R. F., Laymon, A. S., & Arnold, T. (2014). Functional movement scores and longitudinal performance outcomes in elite track and field athletes. *International Journal of Sports Physiology and Performance*, *9*, 203-211.

Chimera, J. N., Smith, C. A., & Warren, M. (2015). Injury history, sex, and performance on the functional movement screen and Y balance test. *Journal of Athletic Training, 50*(5), 475-485.

Cook, G., Burton, L., & Hoogenboom, B. (2006a). Pre-participation screening: The use of fundamental movements as an assessment of function – part 1. *North American Journal of Sports Physical Therapy, 1*(2), 62-72.

Cook, G., Burton, L, & Hoogenboom, B. (2006b). Pre-participation screening: The use of functional movements as an assessment of function – part 2. *North American Journal of Sports Physical Therapy, 1*(3), 132-139.

Cook, G. (2010). *Movement: Functional movement systems: Screening, assessment, and corrective strategies.* Santa Cruz, CA: On Target Publications.

Cuchna, J. W., Hoch, M. C., & Hoch, J. M. (2015). The interrater and intrarater reliability of the functional movement screen: A systematic review with meta-analysis. *Physical Therapy in Sport*, 1-9.

Frost, D. M., Beach, T. A. C., Callaghan, J. P., & McGill, S. M. (2012). Using the Functional Movement Screen to evaluate the effectiveness of training. *Journal of Strength and Conditioning Research, 26*(6), 1620-1630.

FunctionalMovement.com (2019). FMS: Move Well, Move Often. Retrieved from: https://www.functionalmovement.com/

Garrison, M., Westrick, R., Johnson, M. R., & Beneson, J. (2015). Association between the functional movement screen and injury development in college athletes. *International Journal of Sports Physical Therapy, 10*(1), 21-28.

Gutstafson, A. (2019). Functional movement testing and subjective well-being of female track and field athletes: Pre- and post- indoor season. [Masters Project, Bowling Green State University]. *Masters of Education in Human Movement, Sport, and Leisure Studies Graduate Projects*, 73. https://scholarworks.bgsu.edu/hmsls_mastersprojects/73

Hayes, A. F., & Krippendorff, K. (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures, 1*(1), 77-89.

Kiesel, K., Plisky, P., & Butler, R. (2011). Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scandinavian Journal of Medicine & Science in Sports, 21*, 287-292.

Lin, C. Y., Casey, E., Herman, D. V., Katz, N., & Tenforde, A. S. (2018). Sex differences in common sports injuries. *American Journal of Physical Medicine and Rehabilitation, 10,* 1073-1082.

Lockie, R. G., Schultz, A. B., Callaghan, S. J., Jordan, C. A., Luczo, T. M., & Jeffriess, M. D. (2015). A preliminary investigation into the relationship between functional movement screen scores and athletic physical performance in female team sport athletes. *Biology of Sport, 32*(1), 41-51.

Loudon, J. K., Parkerson-Mitchell, A. J., Hildebrand, L. D., & Teague, C. (2014). Functional movement screen scores in a group of running athletes. *Journal of Strength and Conditioning Research, 28*(4), 909-913.

O'Connor, F. G., Deuster, P. A, Davis, J., Pappas, C. G., & Knapik, J. J. (2011). Functional movement screening: Predicting injuries in officer candidates. *Medicine & Science in Sports & Exercise, 43*(12), 2224-2230.

Onate, J. A., Dewey, T., Kollock, R. O., Thomas, K. S., Van Lunen, B. L., DeMaio, M., & Ringleb, S. I. (2012). Real-time intersession and interrater reliability of the functional movement screen. *Journal of Strength and Conditioning Research, 26*(2), 408-415.

Pfeifer, C. E., Sacko, R. S., Ortaglia, A., Monsma, E. V., Beattie, P. F., Goins, J., & Stodden, D. F. (2019). Functional movement screen in youth sport participants: *Evaluating the proficiency barrier for injury*. *International Journal of Sports Physical Therapy, 14*(3), 436-444.

Schneiders, A. G., Davidsson, A., Horman, E., & Sullivan, S. J. (2011). Functional movement screen™ normative values in a young, active population. *The International Journal of Sports Physical Therapy, 6*(2), 75-82.

Shultz, R., Anderson, S. C., Matheson, G. O., Marcello, B., & Thor, B. (2013). Test-retest and interrater reliability of the functional movement screen. *Journal of Athletic Training, 48*(3), 331-336.

Sorenson, E. A. (2009). *Functional movement screen as a predictor of injury in high school basketball athletes* (Doctoral dissertation). Retrieved from ProQuest (3399157).

Sprague, P. A., Mohka, M., & Gatens, D. R. (2014). Changes in functional movement screen scores over a season in collegiate soccer and volleyball athletes. *Journal of Strength and Conditioning Research, 28*(11), 3155-3163.

Teyhen, D. S., Shaffer, S. W., Lorenson, C. L., Halfpap, J. P., Donofry, D. F., Walker, M. J., Dugan, J. L., & Childs, J. D. (2012). The functional movement screen: A reliability study. *Journal of Orthopaedic & Sports Physical Therapy, 42*(6), 530-540.

Appendix A

Informed Assent Form

Movement ability in high school basketball players: Pre- and post-season

Key Information

As part of this study you will be asked to complete a functional movement screen which is comprised of seven screening tests (e.g., deep squat, lunge) and three clearing tests (e.g., movements to assess whether pain is present). There will be three sessions to complete including an orientation, pre-season test, and post-season test. Each session will require approximately 35-45 minutes to complete this low-intensity physical activity. As a result of participation, you will receive free functional movement testing and corrective exercises to address any areas of weakness.

Who is the Researcher?

My name is Nikole Keil and I am a Graduate Student in Kinesiology at Bowling Green State University. I am inviting you to participate in a research study to fulfill my master's degree requirements. Participation is completely voluntary. If you agree to participate now, you can change your mind later. There are no consequences, whatever you decide.

What is the purpose of this study?

The purpose of this study is to use a functional movement screening tool to assess athletes' functional movements before and after a competitive high school basketball season. Functional movement assesses areas of muscular weakness, mobility limitations, and differences between the limbs of the left and right sides. The benefits of the study to you include identifying any functional movement weaknesses you may have, and if identified, you will receive corrective exercises at the end of the study. These exercises will be specific to your screening results and if completed properly will potentially correct these weaknesses.

What will I be asked to do?

Total participation (2 hours and 15 min) includes an orientation session and two testing sessions each of which should take about 35 to 45 minutes.

You will: 1) schedule a time using *Remind* for each of these sessions in the Elmwood High School gymnasium, 2) wear clothing and shoes appropriate for physical activity, 3) complete a brief questionnaire about your basic demographics, two questionnaires about your athletic identity and sport motivation, and a training and injury history form, 4) perform a five-minute warm up, and 5) complete the screening test.

After you have read this consent form, you can agree to participate or not. If you wish not to participate, we will thank you for your time and efforts to assist us, and you may leave the meeting.

The orientation session will take approximately 30 minutes and will be performed in a small group setting (maximum of 5 participants at a time). The session is to familiarize you with the study procedures, particularly the screening tasks you will be preforming during the testing sessions.

For the pre-season testing session, after the questionnaire and a five-minute warm up consisting of light jogging is completed, the screening will be administered. The Functional Movement Screen (FMS) will be the screening tool used. The FMS screen includes seven functional movement tests and three clearing tests. You will have three trials for each of the seven functional movement tests if needed and one trial for the clearing tests. The order of tests and the instructions you will be given are as follows:

1. The Deep Squat- with a light-weight bar held overhead slowly squat as deep as possible and return to a standing position.

2. Hurdle Step (Left & right)- positioning a dowel across shoulders, step over the elastic hurdle and touch heel to the floor and return the moving leg back to the starting position, slowly and controlled. Repeated with opposite leg.

3. Inline Lunge (Left & right)- the dowel is placed vertically behind the back, the hand opposite to the front foot will grasp dowel at the cervical spine. The other hand will be placed on dowel at the lumbar spine. Step forward with one foot, moving in a downward motion until your thigh is parallel with the floor. Bring forward foot back to return to a standing position. This will be repeated with the opposite leg.

4. Shoulder Mobility (Left & right)- Make a fist with both hands and bring one arm behind your head as far as possible. Bring your opposite arm behind your back and bring your fists as close together as possible. This will be repeated with your arms performing the opposite movement.

5. Impingement Clearing Test (Left & right)- Place palm of your hand on the opposite shoulder. Raise your elbow as high as possible with your hand remaining in contact with your shoulder.

6. Active Straight-Leg Raise (Left & right)- While on the floor, lay on your back with your arms at your sides. Raise one leg as high as you can, keeping your knee straight. Your other leg should remain down and straight. This will be repeated with the opposite leg.

7. Trunk Stability Pushup- While on the floor, lay on your stomach with the balls of your feet touching the floor. Have your hands be palm down on the floor. You will have your thumbs lined up with your chin. Keeping your knees and hips straight, press up your body into a pushup position (up on the balls of your feet and hands). Your starting hand position can be changed if needed.

8. Press-up Clearing Test- While on the floor, lay on your stomach with the balls of your feet touching the floor. Have your hands be palm down on the floor. You will have your

thumbs lined up with your chin. Keep your hips in contact with the floor and press up with your hands.

9. Rotary Stability (Left & right)- Begin in a position where you are on your hands and knees. At the same time, extend one arm forward while straightening the same sided leg behind you. Keeping the arm and leg in the air, bring the extended leg and arm together, touching knee to elbow. This will be repeated with the opposite leg and arm.

10. Posterior Rocking Clearing Test- Begin in a position where you are on your hands and knees. Move into a position to where your buttock touches. Keep your hands out in front of you, with your arms straight and hands flat on the floor.

This pre-season testing session is projected to take approximately 35-45 minutes.

The post-season session will follow the exact same protocol as the first session and take approximately 35-45 minutes.

Do I have to complete all tasks and testing sessions?

Your participation in this study is completely voluntary. You are free to stop participation at any time. You may decide to skip questions, not do a particular task, or discontinue participation at any time without penalty. You must remain a part of the basketball team to continue participation in this study. Deciding to participate or not will not affect your relationship with the Elmwood High School Athletics Department, the coaching staff, Bowling Green State University, or anyone involved in the research.

Are there risks?

As an athlete who participates in exercise on a daily basis, the risks of participation are minimal and no more than are encountered during a basketball practice. There is a slight risk of muscle strain or sprain if you stretch too far during testing, or a risk of falling due to tripping or slipping during the warm-up or screening tasks.

In the very unlikely event that you do experience a problem or injury occurs, seek medical treatment. The cost of such treatment will be at your expense. In the event that such an injury would occur, the researcher is First Aid and CPR/AED certified, will be FMS Level I certified, meaning they are knowledgeable in how to conduct and instruct each task safely, and will be monitoring you throughout testing.

Privacy Protection

Your information will remain private and you will not be identified. Your information will be stored in a locked office in Eppler South at Bowling Green State University. All information will be typed into programs on a password-protected computer; once this is done all paper copies of data collected will be stored in a locked file cabinet. The hard copy of the consent form will be kept in a folder in a locked cabinet in my advisor's office. Only the researchers and their research assistants working directly on the study will have access to the data. You will be assigned an ID# and this will be used to specify your information during the study.

Contact Information

If you have any questions about this research study or your participation in the testing please contact me, Nikole Keil, work: 419-583-6044, njkern@bgsu.edu, or my advisor Dr. Darby, work: 419-372-6903, ldarby@bgsu.edu. You may also contact the Office of Research Compliance at 419-372-7716 or orc@bgsu.edu, if you have any questions about your rights as a participant in this testing.

Statement of Assent

I have been informed of the purposes, procedures, risks and benefits of this study. I have had the opportunity to have all my questions answered and I have been informed that my participation is completely voluntary. I agree to participate in this research. A copy of this form will be provided to me upon request.

_______________________________________ ___________________

Printed Name Date

_______________________________________ I am above the age of 18: YES____NO_____

Participant Signature

Appendix B

Informed Consent Form

Movement ability in high school basketball players: Pre- and post-season

Key Information

As part of this study your child will be asked to complete a functional movement screen which is comprised of seven screening tests (e.g., deep squat, lunge) and three clearing tests (e.g., movements to assess whether pain is present). There will be three sessions to complete including an orientation, pre-season test, and post-season test. Each session will require approximately 35-45 minutes to complete this low-intensity physical activity. As a result of participation, your child will receive free functional movement testing and corrective exercises to address any areas of weakness.

Who is the Researcher?

My name is Nikole Keil and I am a Graduate Student in Kinesiology at Bowling Green State University. I am inviting your child to participate in a research study to fulfill my master's degree requirements. Participation is completely voluntary. If you agree to participate now, you can change your mind later. There are no consequences, whatever you decide.

What is the purpose of this study?

The purpose of this study is to use a functional movement screening tool to assess athletes' functional movements before and after a competitive high school basketball season. Functional movement assesses areas of muscular weakness, mobility limitations, and differences between the limbs of the left and right sides. The benefits of the study to your child include identifying any functional movement weaknesses they may have, and if identified, they will receive corrective exercises at the end of the study. These exercises will be specific to their screening results and if completed properly will potentially correct these weaknesses.

What will I be asked to do?

Total participation (2 hours and 15 min) includes an orientation session and two testing sessions each of which should take about 35 to 45 minutes.

Your child will: 1) schedule a time using *Remind* for each of these sessions in the Elmwood High School gymnasium, 2) wear clothing and shoes appropriate for physical activity, 3) complete a brief questionnaire about their basic demographics, two questionnaires about their athletic identity and sport motivation, and a training and injury history form, 4) perform a five-minute warm up, and 5) complete the screening test.

After you have read this consent form, you can agree to allow your child to participate or not. If you wish for them not to participate, we will thank you for your time and efforts to assist us, and you may discard this form

The orientation session will take approximately 30 minutes and will be performed in a small group setting (maximum of 5 participants at a time). The session is to familiarize your child with the study procedures, particularly the screening tasks they will be preforming during the testing sessions.

For the pre-season testing session, after the questionnaires and a five-minute warm up consisting of light jogging is completed, the screening will be administered. The Functional Movement Screen (FMS) will be the screening tool used. The FMS screen includes seven functional movement tests and three clearing tests. Your child will have three trials for each of the seven functional movement tests if needed and one trial for the clearing tests. The order of tests and the instructions your child will be given are as follows:

1. The Deep Squat- with a light-weight bar held overhead slowly squat as deep as possible and return to a standing position.

2. Hurdle Step (Left & right)- positioning a dowel across shoulders, step over the elastic hurdle and touch heel to the floor and return the moving leg back to the starting position, slowly and controlled. Repeated with opposite leg.

3. Inline Lunge (Left & right)- the dowel is placed vertically behind the back, the hand opposite to the front foot will grasp dowel at the cervical spine. The other hand will be placed on dowel at the lumbar spine. Step forward with one foot, moving in a downward motion until your thigh is parallel with the floor. Bring forward foot back to return to a standing position. This will be repeated with the opposite leg.

4. Shoulder Mobility (Left & right)- Make a fist with both hands and bring one arm behind your head as far as possible. Bring your opposite arm behind your back and bring your fists as close together as possible. This will be repeated with your arms performing the opposite movement.

5. Impingement Clearing Test (Left & right)- Place palm of your hand on the opposite shoulder. Raise your elbow as high as possible with your hand remaining in contact with your shoulder.

6. Active Straight-Leg Raise (Left & right)- While on the floor, lay on your back with your arms at your sides. Raise one leg as high as you can, keeping your knee straight. Your other leg should remain down and straight. This will be repeated with the opposite leg.

7. Trunk Stability Pushup- While on the floor, lay on your stomach with the balls of your feet touching the floor. Have your hands be palm down on the floor. You will have your thumbs lined up with your chin. Keeping your knees and hips straight, press up your body into a pushup position (up on the balls of your feet and hands). Your starting hand position can be changed if needed.

8. Press-up Clearing Test- While on the floor, lay on your stomach with the balls of your feet touching the floor. Have your hands be palm down on the floor. You will have your

thumbs lined up with your chin. Keep your hips in contact with the floor and press up with your hands.

9. Rotary Stability (Left & right)- Begin in a position where you are on your hands and knees. At the same time, extend one arm forward while straightening the same sided leg behind you. Keeping the arm and leg in the air, bring the extended leg and arm together, touching knee to elbow. This will be repeated with the opposite leg and arm.

10. Posterior Rocking Clearing Test- Begin in a position where you are on your hands and knees. Move into a position to where your buttock touches. Keep your hands out in front of you, with your arms straight and hands flat on the floor.

This pre-season testing session is projected to take approximately 35-45 minutes.

The post-season session will follow the exact same protocol as the first session and take approximately 35-45 minutes.

Does your child have to complete all tasks and testing sessions?

Your child's participation in this study is completely voluntary. Your child, or you, are free to stop their participation at any time. They may decide to skip questions, not do a particular task, or discontinue participation at any time without penalty. Your child must remain a part of the basketball team to continue participation in this study. Deciding to participate or not will not affect your relationship with the Elmwood High School Athletics Department, the coaching staff, Bowling Green State University, or anyone involved in the research.

Are there risks?

As an athlete who participates in exercise on a daily basis, the risks of participation are minimal and no more than are encountered during a basketball practice. There is a slight risk of muscle strain or sprain if your child were to stretch too far during testing, or a risk of falling due to tripping or slipping during the warm-up or screening tasks.

In the very unlikely event that your child does experience a problem or injury occurs, seek medical treatment. The cost of such treatment will be at your expense. In the event that such an injury would occur, the researcher is First Aid and CPR/AED certified, will be FMS Level I certified, meaning they are knowledgeable in how to conduct and instruct each task safely, and will be monitoring you throughout testing.

Privacy Protection

Your child's information will remain private and they will not be identified. All information will be stored in a locked office in Eppler South at Bowling Green State University. All information will be typed into programs on a password-protected computer; once this is done all paper copies of data collected will be stored in a locked file cabinet. The hard copy of the consent form will be kept in a folder in a locked cabinet in my advisor's office. Only the researchers and their research assistants working directly on the study will have access to the data. Your child will be assigned an ID# and this will be used to specify your child's information during the study.

Contact Information

If you have any questions about this research study or your participation in the testing please contact me, Nikole Keil, work: 419-583-6044, njkern@bgsu.edu, or my advisor Dr. Darby, work: 419-372-6903, ldarby@bgsu.edu. You may also contact the Office of Research Compliance at 419-372-7716 or orc@bgsu.edu, if you have any questions about your rights as a participant in this testing.

Statement of Assent

I have been informed of the purposes, procedures, risks and benefits of this study. I have had the opportunity to have all my questions answered and I have been informed that my child's participation is completely voluntary. I agree to allow my child to participate in this research. A copy of this form will be provided to me upon request.

____

Name of Child (print)

____

Name of Parent or Guardian (print)

____ __________

Signature of Parent or Guardian Date

Appendix C

Name:____________________________________ **Date & Time:** ________________

Date of Birth: _______________________ **Height:** ______________ **Weight:** ______________

	Please Circle One:		
1. I am a ….	Male		Female
2. Years of experience playing basketball?	<1	1-3	3+
3. Years of experience weight training?	<1	1-3	3+
4. Are you able to practice without limitations?	Yes		No

If no, please explain. ____

5. Do you presently have any muscle or bone disorders? Yes No

If yes, please explain. ____

6. Have you ever had any nervous or cardiovascular disorders? Yes No

If yes, please explain. ____

7. Have you ever had any injuries to either hip/knee/ankle? Yes No

If yes, please give date, area including left or right side, and description. ______________________________

8. Have you ever had surgery on either hip/knee/ankle? Yes No

If yes, please give date, area including left or right side, and description. ______________________________

9. Have you ever had an injury to either shoulder/elbow/wrist? Yes No

If yes, please give date, area including left or right side, and description.______________________________

9. Have you ever had surgery on either shoulder/elbow/wrist? Yes No

If yes, please give date, area including left or right side, and description. ____________________________________