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THE RELATIONSHIP BETWEEN FUNCTIONAL MOVEMENT SCREEN SCORES AND INJURIES IN COLLEGE-AGED WATER POLO PLAYERS

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ABSTRACT

Background: The Functional Movement Screen (FMS) is a series of functional movement tests designed to assess an individual's risk for injury within their certain sport, occupation, or lifestyle. To date, research has focused on FMS scores in land-based populations. No known FMS data has been published for aquatic athletes.
Objectives: To determine the relation between Functional Movement Screen scores and injury risk in college-aged water polo athletes as well as demographic and anthropometric measures.
Methods: Thirty-three members (14 male, 19 female) of a collegiate club water polo team (age = 20.636 ± 1.17 years, height = 1.765 ± 0.092 m, mass = 73.618 ± 10.095 kg, BMI = 23.523 ± 2.159 kg/m^2) participated in the study. Participants underwent an FMS assessment and were asked to record their past injury history before the current water polo season. As the season progressed, injuries that caused them to miss practice or game time were recorded. Group means and standard deviations were calculated for all measures. Fisher's Exact Test was used to determine the association between FMS scores and injury incidence. Two-tailed, two-sample t-tests were calculated to determine statistically significant differences between male and female water polo players for FMS scores, as well as demographic and anthropometric measures. Linear regression analysis was utilized to examine the association between age and BMI and FMS score. $P \leq 0.05$ denoted statistical significance a priori.
Results: No significant relations were found between FMS score and injury incidence ($P = 0.053$). Significant differences were found between male and female height ($P < 0.001$) and mass ($P < 0.001$). Age was found to be negatively correlated with FMS scores ($P = 0.025$). No significant difference was found between overall male and female FMS performance ($P = 0.811$). Statistically significant differences were found between male and female performance on the deep squat ($P < 0.001$, shoulder mobility ($P = 0.009$), active straight leg raise ($P = 0.001$), and trunk stability pushup tests ($P = 0.001$). No significant difference was observed between the number of male and female asymmetries on the bilateral FMS movement tests ($P = 0.589$).
Conclusions: FMS scores were not shown to have any significant relation with injury risk. The FMS was not a good predictor of injury incidence within this population. Males and females had similar FMS total scores and the same number of asymmetries on the bilateral tests. For the component tests of the FMS, males performed better than females on the trunk stability pushup and deep squat tests while females performed better than males on the shoulder mobility and active straight leg raise tests. Age, but not BMI, was found to be a significant predictor of FMS performance with older participants expected to score lower on the FMS.

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Chapter 1

Introduction

The strategic goal of water polo is similar in nature to soccer in that the objective of the game is to shoot the ball past a goalkeeper and into a net. However, water polo is played in a pool where the players' feet do not touch firm ground and body support and mobility in the water is produced by treading water and swimming. Players are allowed to touch the ball with only one hand at a time, except for the goalkeeper. They swim, as a team, up and down the pool to defend their own goal and score in the goal of their opponents. Players on the same team pass the ball to one another in search of the best position to create a shooting chance. Water polo is a contact sport that requires athletes to physically jostle for position in the water. A lot of grabbing, pushing, elbowing, punching, and scratching occurs under the water as players from opposing teams fight for possession of the ball and shooting opportunities.

The physicality and aquatic environment of water polo results in great physical demands on the bodies of the athletes, often resulting in injury. Shoulder pain as the result of impingement and/or rotator cuff strain is the primary complaint of water polo players, but facial injuries (lacerations, eye damage, facial an orbital bone fractures), cervical spine pain (degenerative changes and disc compression), and knee problems (degenerative changes and medial knee pain) are also common [1, 2].

The Functional Movement Screen (FMS) is a test composed of 7 different functional movement patterns and 3 pain provocation tests designed to assess a person's risk for injury [3, 4]. FMS testing had been used to assess a variety of populations, such as healthy adolescents, football players, officer candidates in the military, and collegiate track athletes [5, 6, 7, 8, 9, 10]. The

FMS has been shown to be a reliable assessment tool [6, 7, 8, 9, 10, 11]. To date, all FMS research has focused on land-based physically active populations and athletes. There are no known studies that used the FMS to assess the movement patterns and injury risk of aquatic athletes.

The objective of this study was to create an FMS profile and determine the relationship between FMS scores, demographic data, anthropometric measures and injury risk in Div. 1 collegiate water polo athletes. Based upon the different participation environments, we hypothesized that water polo athletes would have a different FMS score profile than presented in previous studies with land-based populations. We also hypothesized that athletes with lower FMS scores would have a higher risk of injury during the season and that age, BMI and sex would not be discriminating factors with regard to FMS score, based upon previous research [5].

Chapter 2

Literature Review

Water Polo

Water Polo is an aquatic sport with a rich history in modern society. It was the first team sport of the modern Olympic Games [1]. The popularity of the sport grew considerably throughout the twentieth century, spreading out to other parts of the globe from its origins in the British Isles. Today, countries from regions all over the world field competitive water polo teams in international contests. In the United States, water polo is especially popular in the western states, such as California. Universities and colleges from the state of California maintain a continuous presence in the National Collegiate Athletic Association (NCAA) National Championships.

Water polo is a rough and physical contact sport. Two referees normally patrol the pool deck during games to watch out for illegal contact, but they cannot see everything that goes on under the water. Players often grab, push, elbow, punch, and scratch their opponents under the water. Often times, illegal blows that are dealt above water go unnoticed by referees because of the large amount of splashing during these moments. Athletes mainly move around the pool using a front crawl or backstroke technique when they are not using their legs to tread water. Both swimming techniques involve propelling the body using the arms from an overhead position. Only one hand is allowed to touch the ball at a time, and the ball is normally thrown using an overhead throwing motion similar to that of a baseball pitcher. Players use their legs to propel their trunks above the water and throw the ball from a maximally abducted and externally rotated position of the shoulder with as much force as possible [12]. The repeated exertion of great forces on the tissues of the body while in awkward positions can sometimes cause injuries to the athletes.

Due to the fact that water polo players are constantly bringing their arms overhead to swim and throw the ball, a lot of stress is placed on the tissues around the glenohumeral joint. It has been well-documented that a high-incidence of shoulder pain and other shoulder injuries exists among water polo players [12, 13, 14]. This can stem from a variety of causes, one of the main ones being excessive mobility of the glenohumeral joint [1]. Too much mobility in this joint can eventually lead to the impingement of tissues against the coraco-acromial ligament, the inferior surface of the acromion, and the coracoid process [1]. Muscle imbalances of the shoulder stabilizers and rotators due to repetitive throwing at high velocities are also thought to be a cause of shoulder problems in water polo players [1]. More research still has to be done to determine other causes of shoulder pain in water polo players, but some of the more important factors thought to predispose water polo players to shoulder injuries are range of motion imbalances between the glenohumeral joints and muscle imbalances between the external and internal rotators of the rotator cuff [12, 13, 14, 15].

The Functional Movement Screen

Gray Cook, a physical therapist, and Dr. Lee Burton, a board-certified athletic trainer, are the founders of the Functional Movement Screen. The Functional Movement Screen was designed as a component to be included in pre-participation screenings to prepare an athlete for participation in their sport [3]. The founders of the FMS believed that there was a void in the current sports medicine model for assessing whether an athlete was ready to participate in their sport. The systematic approach of a medical physical and sport-specific performance tests did not provide enough solid information about an individual's overall functional movement [3]. The goal of the FMS is to identify any possible physical dysfunctions and compensatory movement patterns that could be part of an underlying larger functional limitation. Once the problem is identified, the athlete could be referred to the proper health professional that can help them correct or treat the dysfunction.

According to the kinetic link model, the body is a system of segments that are linked together and depend on one another in order to produce movement [3, 4]. Usually, these segments utilize a proximal to distal pattern of movement in order to accomplish the physical task at hand [3, 4]. Movement patterns can be learned and stored as motor programs in the brain with enough practice so that little to no cognitive input is required to initiate or perform the movement. Although this demonstrates the wonderful complexity of the human mind, problems can arise when these motor patterns are learned in a way that the movement is performed inefficiently or with compensatory components for a physical dysfunction. Developing motor programs with inefficient or compensatory movement patterns and using them repeatedly in a sport or occupation can lead to serious physical injury.

Therefore, it becomes paramount to discover any physical dysfunctions and poor functional movement patterns to prevent possible injury. The FMS takes a kinetic chain approach to identifying these dysfunctions and poor movement patterns that can put an athlete at a high injury risk [3, 5]. Subjects perform 10 different proximal to distal functional movement patterns to the best of their ability. The tests are designed to expose any right and left side imbalances, as well as weaknesses in mobility and stability throughout the kinetic chain system [3, 4]. Once the FMS identifies the dysfunction or poor movement pattern, action can be taken to rehabilitate the physical dysfunction and improve the subject's functional movement.

The FMS is the first functional movement evaluation standard of its kind. It provides quantitative data about a person's movement patterns that can be analyzed in a variety of ways and be shared throughout the scientific community. Data collected from FMS testing can be compared across different age groups, sexes, people of different occupations and sports, and other cohorts [5, 6, 7, 8 10, 11]. Testing data from each individual functional movement pattern can also be used to examine variances between how individuals performed on a certain movement pattern [5]. Many of the FMS movement patterns are performed using one limb first and then using the limb on the contralateral side of the body. The best score from each attempt on each side of the body is recorded, according to the scoring criteria, and analyzed to produce a final score for that movement pattern. Because movements using each side of the body are scored, the FMS is also helpful in identifying asymmetries in functional movement efficiency. The FMS is a valuable research tool for the sports medicine community that provides a quantitative standard to compare data across many different cohorts.

Current research has shown that the FMS is useful for injury prediction and prevention purposes [6, 7, 8, 9, 10, 11]. However, research has been inconclusive so far as to whether the FMS can be used as a predictor for athletic performance. While some propose that the FMS could be used as a tool in part of a greater system to improve athletic performance, most of the data in the literature suggest that predicting athletic performance is outside of the realm of the FMS [8, 16, 17, 18].

Functional Movement Tests

Subjects undergoing a functional movement screen perform seven different functional movement tests, along with three clearing tests. The performance on each movement test is scored according to standard scoring criteria [3, 4]. Seven of the ten movement patterns are scored on a scale of 0-3, and the other three movement patterns are graded either passing or failing. Each of the pass/fail clearing tests is associated with a graded movement test. If the subject fails one of those three clearing tests, then the graded test that the certain clearing test is associated with automatically receives a score of zero. All of the scores from each test are added up to produce a subject's final score. The maximum score any subject can receive is 21.

The following are the movement tests, in order, that the subjects perform during FMS administration: deep squat, hurdle step, inline lunge, shoulder mobility, active scapular stability (shoulder clearing), active straight leg raise, trunk stability pushup, spinal extension clearing, rotary stability, and spinal flexion clearing tests [3, 4].

The purpose of the deep squat is to evaluate the biomechanics of multiple parts of the body. It assesses the functional mobility and stability of the ankles, knees, and hips [3]. The subject goes into a deep squat while holding a long dowel above their heads. Holding the dowel while squatting helps to gauge an individual's bilateral and symmetrical mobility of the shoulders, as well as their mobility of the thoracic spine [3]. Further research into the biomechanics of the deep squat test have shown that individuals who score differently on this test exhibit significant biomechanical differences in the way they perform the movement [19]. This lends validity to the results of the FMS, suggesting that differing scores do indeed reflect fundamental differences in movement patterns. Although biomechanical analyses have not been performed on the other movement tests, the results of the first investigation do show promise.

The hurdle step evaluates the subject's ability to demonstrate efficient stride mechanics while going through a step motion [3]. It also challenges the individual's bilateral and overall functional mobility across the hip, knee, and ankle joints [3]. The inline lunge is a movement that evaluates the subject's mobility and stability of the hips and ankles, as well as the stability of the knee and the flexibility of the quadriceps muscles [3]. Both the hurdle step and inline lunge are performed with both right and left legs, with each side receiving a score.

The shoulder mobility test assesses the range of motion at the subject's shoulder joints [4]. The movement pattern requires sufficient internal rotation coupled with adduction, as well as external rotation coupled with abduction [4]. The shoulder mobility test is paired with a clearing test that is designed to reveal any major physical dysfunctions. One of the possible dysfunctions especially important for water polo athletes is increased external rotation coupled with decreased internal rotation and tightness in the pectoralis minor and latissumus dorsi muscles [4]. This dysfunction is commonly seen in overhead throwing athletes.

The active straight leg raise assesses the flexibility of the hamstring and gastroc-soleus muscles in one leg while challenging the subject to maintain active extension on the opposite leg and pelvis stability [4]. The trunk stability pushup involves performing a correct pushup with a modified hand position. The hands are placed further superior the shoulders in an attempt to challenge the subject's anterior/posterior spine stability and sagittal trunk stability [4]. The trunk stability pushup is paired with a clearing test designed to assess the subject's ability to stabilize the spine in the sagittal plane during full spinal extension [4].

The final graded test is the rotary stability test. The rotary stability test is very challenging, and requires a good deal of proprioception abilities and neuromuscular coordination to be performed well. It challenges the subject to maintain spine stability in multiple movement planes while coordinating simultaneous movement of the upper and lower limbs [4]. This movement pattern is paired with a clearing test that assesses trunk stability and symmetry while the spine is in full flexion [4].

FMS Administration with Different Populations

Due to the fact that the FMS was invented to be a component of sport pre-participation screenings, much of the research to date involving FMS testing have used athletes as their test subjects. Some of the major studies published regarding FMS testing looked at whether FMS could be used as a legitimate predictor for major injuries in NFL football players. These studies found that players who scored a 14 or below on the FMS had a significantly higher risk for injury over the course of a season [6, 11]. This data suggests that the quality and efficiency of a person's functional movement as determined by the FMS are significant factors for injury risk. The good news is that more research suggests that FMS scores in football players can be improved with proper training aimed at reducing functional movement asymmetries and compensatory movement patterns [20]. This can have practical implications for athletes looking to improve their overall functional movement to prevent possible future injuries.

Several other athletic and active populations have since been researched using FMS testing, including track athletes, hockey players, volleyball players, golfers, firefighters, and military personnel. One study in particular involved 38 Division I NCAA female collegiate track athletes [10]. The athletes all underwent an FMS test at the beginning of their season, and their injuries were tracked as the season progressed. The data showed that a score of 14 or below put that athlete at a higher risk for lower-body injury [10]. This study produced similar results to the studies involving football players, where a score of 14 or less was also associated with elevated injury risk. Other research investigations point to the same injury risk threshold of 14 or less on the FMS as a significant risk factor for injury prediction in military officer candidates and firefighters [7, 9] Normative FMS data has been published in the literature for a young, active population and a middle aged population [5, 27]. The researchers of the investigation involving the young population administered FMS tests to over 200 physically active females and males between the ages of 18 and 26. They found that the mean composite FMS score was 15.7 for the combined subject pool, 15.7 for males, and 15.6 for females [5].

Data published in the literature does suggest that FMS scores can help predict injury in a wide variety of land-based athletic and active populations, but no research has been done involving the FMS and aquatic athletes. It is impossible to conclude that a score of 14 or below is associated with elevated injury risk in aquatic athletes because of the different stresses and forces applied to the body during aquatic activity. This study investigated the relationship between poor FMS scores and injury risk in collegiate water polo athletes to address this lack of knowledge.

Tester Reliability

After the publication of studies that suggested FMS testing could be a legitimate predictor of bodily injury, the scientific community began to investigate into the reliability of the FMS. Researchers wanted to know if the FMS testing protocol was sound enough to produce minimal variation in scores due to different testers. They also wanted to know how consistent a tester was at determining accurate scores repeatedly by following the protocol. Another issue was whether a person needed extensive training to administer an FMS test, and whether untrained testers would give different scores than trained testers.

To answer these questions, researchers tested the inter- and intra-rater reliabilities of the FMS [21, 22, 23, 24]. They also looked into whether novice raters with little training can administer FMS tests just as well as trained rater [21, 25]. An interesting method used to measure inter-rater reliability researchers was recording video sessions of the subjects performing an FMS test and having different raters grade them to see if they produced similar scores [21, 22, 24, 25]. The researchers analyzed their findings using weighted Kappa statistics, Cohen kappa coefficients, and intra-class correlation coefficients (ICC's) to statistically measure the inter-rater reliability of the FMS. To measure test-retest and intra-rater reliability, some researchers either chose to have the raters score the same subject live a second time after a certain period of time had passed, or chose to have the raters evaluate an FMS video session twice on two separate occasions [22, 23, 24]. Often times, researchers included another aspect of reliability into their investigations by including trained and novice raters in their studies to see if they produced similar scores [23, 24, 25]. Some of these novice raters included students, physical therapists not certified in FMS, and athletic trainers [24]. In every study, the FMS demonstrated moderate to excellent intra- and inter-rater reliability, as determined by statistical analyses using Cohen kappa coefficients, ICC's, Krippendorff α, and percent agreement procedures [21, 22, 23, 24, 25]. The data from the research also suggested that the FMS could be administered accurately and effectively by both trained and untrained raters [21, 25].

Summary

It has been demonstrated through evidence-based research that the FMS is both a reliable and valid tool that can be used for the purpose of injury prediction and prevention. Studies have shown that a score of 14 or less on an FMS test indicate that the athlete/person that received that score is at an elevated risk for injury within their certain sport or occupation [7, 9, 10]. Published data has also suggested that the FMS is a test with good inter- and intra-rater reliability that can be carried out by both the trained and untrained [21, 22, 23, 24, 25]. Some evidence has demonstrated FMS scores can be predictors of athletic performance, but most research on this subject so far has been inconclusive [8, 16, 17, 18]. The purpose of this study was to investigate whether the relation between low FMS scores and elevated injury risk exists within a cohort of collegiate-aged water polo players.

Chapter 3

Methods

Participants

The participants in this investigation were all members of the Pennsylvania State University Men's and Women's Club Water Polo Teams. Both teams fall under the administration of Penn State Club Sports and compete in the Mid-Atlantic Region of the Collegiate Water Polo Association. A total of 33 players (14 male, 19 female) participated in this study (Table 1 and Table 2). Participants were recruited via word of mouth, email, and other electronic resources such as social media. Participation in this study was voluntary, and no incentives were given to the subjects. Each participant was asked to read and sign an informed consent form (Appendix A), as well as complete a subject recruitment form (Appendix A). The subject recruitment form contained inclusion and exclusion criteria for this study including being between the ages of 18 and 40, able to speak English, and currently cleared to participate in club water polo activities. The subjects also filled out past and current injury history forms during the testing session (Appendix A). These forms were all approved by the Pennsylvania State University Institutional Review Board (IRB). In order to protect the identity of the participants, all subjects were assigned a participant number before the administration of the FMS test. The participant number was used to identify all data collection sheets. The key with information regarding the association of participant numbers and corresponding names were kept in a locked file cabinet and only accessible by the principle researcher.

Experimental design

This descriptive cohort study was approved by the Pennsylvania State University Institutional Review Board (IRB). Prior to data collection, the principal investigator received two hours of training in the administration of FMS testing and spent two hours observing others performing the FMS. The training covered correct use of the FMS equipment, protocol, scoring criteria, and verbal instructions. In addition to the live training, the investigator was given written guidelines for scoring each test and verbal instructions to be used during test administration (Appendix B). The FMS has been shown to be reliable when administered by individuals with minimal training [21, 25]. Potential participants came to the Athletic Training Research Laboratory for data collection. All participants were read the subject recruitment script and then read and signed the informed consent form. Once the informed consent form was signed, the participant completed a current and past injury history form. Next, demographic and anthropometric data was collected including age, sex, height and mass. Dominant hand and foot were indentified. An FMS assessment was administered by the principle investigator.

The current injury history form (Appendix A) was used to record water polo-related injuries the participants suffered that required them to miss a practice or game during the course of the 2013-2014 competitive water polo seasons. Since data collection was unable to commence prior to the competitive seasons, all injury history was collected retrospectively. The men's water polo season ran from August to October of 2013, while the women's season ran from January to March of 2014.

FMS Testing Protocol

The FMS has an established protocol that is to be followed during every administration of the FMS test [3, 4]. The protocol includes a set of verbal instructions for each movement test that the rater reads to the participant verbatim. Raters are not to give any other outside information or verbal cues to the participant. However, subjects are allowed to ask the rater questions regarding the movement being tested if they do not understand the verbal instructions or require additional clarification. Participants can attempt a movement a maximum of three times, and the highest score of the three attempts is recorded.

The protocol includes scoring criteria for each of the seven functional movement tests and three clearing tests. The subjects perform each test in the following order during FMS administration: deep squat, hurdle step, inline lunge, shoulder mobility, shoulder clearing test, active straight leg raise, trunk stability pushup, spinal extension clearing test, rotary stability, and spinal flexion clearing test [3, 4]. Should refer to Appendix B where pictures of each test are shown.

The seven movement tests are scored on a scale of 0-3 (3 being the highest possible score) based upon movement quality, and the clearing tests are scored as pass or fail. The participant earns a score of three if they can perform the movement correctly without compensating at all [3]. The participant earns a score of two if they perform the movement, but with some compensatory movement patterns [3]. A score of one is given if the participant cannot perform the movement or cannot get into starting position for that certain movement test [3]. If pain is reported during any of the movements, the participant automatically receives a score of 0 for that test [3]. If a participant had pain on a clearing test they receive a “0” on the functional movement test associated with it: the shoulder clearing test with the shoulder mobility test, the spinal extension clearing test with the trunk stability pushup and the spinal flexion clearing test with the rotary stability test. Some functional movement tests (lunge, hurdle step, shoulder mobility and rotary stability) require evaluation of performance using both sides of the body. In other words, the participant performs the movement using one extremity and then performs the same movement again using the contralateral extremity. In these cases, the lower score out of the two is the one that contributes to the final score. After all of the functional movements are performed, the individual test scores are added to produce a final score. The maximum possible final score is 21. The FMS has been shown to have moderate to excellent intra- and inter-tester reliability [21, 22, 23, 24, 25].

Statistical Analyses

Descriptive statistics, including group means and standard deviations were calculated for all dependent variables of interest. Two-tailed, two sample t-tests were calculated to determine statistically significant differences between male and female water polo players for FMS scores as well as demographic and anthropometric measures. Linear regression analysis was utilized to examine the association between the predictor variable age and BMI, and the response variable FMS score. Contingency tables were constructed using injury incidence data. Fisher's exact test was calculated using the contingency tables to determine whether a significant relationship existed between FMS score and injury risk. An *a priori* alpha level of $P \leq 0.05$ denoted statistical significance for all analyses.

Chapter 4

Results

Anthropometric Participant Data

The age, height, and mass of each of the participants (33 total, 14 males, and 19 females) were recorded during the FMS testing session. The means and standard deviations for each measurement were calculated using Minitab statistical software. Table 1 displays the anthropometric data and statistical calculations for the combined subject pool of 33 water polo players. The measurement data is separated into male and female groups on display in Table 2.

Two-tailed, two-sample T-tests were performed using Minitab Statistical Software to compare male versus female values for each anthropometric measurement. Conclusions of these tests were based upon the resulting p values and 95% Confidence Intervals (CI) for each comparison. According to these tests, the only significant difference between male and female anthropometric data occurred in height ($P = 0.00005$) and mass ($P = 0.0002$). No significant differences were found between male and female age ($P = 0.224$) or BMI ($P = 0.347$).

Table 1 Combined Participant Anthropometric Data

Measurement	**N**	**M**	**SD**
Age (years)	33	20.636	1.168
Height (m)	33	1.765	0.092
Mass (kg)	33	73.618	10.095
BMI (kg/m^2)	33	23.563	2.159

All anthropometric measurements were taken during FMS testing session.

Table 2 Male vs. Female Anthropometric Data

Measurement	**Males (N = 14)**	**Females (N = 19)**	**P-Value**
Age (years)	20.929 ± 1.328	20.421 ± 1.017	0.244
Height (m)	1.834 ± 0.072	1.715 ± 0.069	0.00005
Mass (kg)	80.69 ± 8.850	68.406 ± 7.548	0.0002
BMI (kg/m^2)	23.987 ± 2.253	23.251 ± 2.093	0.347

P-values produced by Two-Tailed Two-Sample T-Tests. Values are mean ± SD.

Male versus Female Variances in FMS Performance

One of the goals of the investigation was to determine whether men and women performed differently on the FMS test. Two-tailed, two-sample T-tests were performed using Minitab Statistical Software to compare male versus female performance for total FMS, deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability pushup, rotary stability, active scapular stability clearing test, spinal extension clearing test, and spinal flexion clearing test. The findings of the statistical analyses suggest that there was no significant difference between the final FMS scores of the male and female participants (P = 0.811). These results are on display in Table 3.

Differences in performance between males and females on each of the seven individual FMS movement tests and three clearing tests were also investigated. No statistically significant differences were found between male and female performance on the hurdle step, in-line lunge, rotary stability test, active scapular clearing test, spinal extension clearing test, and spinal flexion clearing test. However, statistically significant differences were found to exist between male and female performance on the deep squat (P = 0.0001), shoulder mobility (P = 0.009), active straight leg raise (P = 0.001), and trunk stability pushup test (P = 0.001). These figures are on display in Table 4.

Table 3 Functional Movement Screen Scores - Males vs. Females

	N	Mean ± SD	Range	P - Value	95% CI
Combined	33	15.727 ± 1.807	11.0 - 19.0	0.811	(-1.465, 1.172)
Male	14	15.643 ± 1.393	13.0 - 18.0		
Female	19	15.789 ± 2.097	11.0 - 19.0		

P-values and Confidence Intervals for male versus female FMS scores produced by Two-Tailed Two-Sample T-Tests. Values are mean ± SD.

Table 4 Selected FMS Movement Test Scores – Males vs. Females

FMS Test	**Mean ± SD**		**P - Value**	**95% CI**
	Male	**Female**		
Deep Squat	2.786 ± 0.426	2.053 ± 0.524	0.0001	(0.384, 1.082)
Shoulder Mobility	1.643 ± 1.008	2.526 ± 0.612	0.009	(-1.460, -0.307)
Trunk Stability Pushup	2.643 ± 0.497	1.632 ± 1.065	0.001	(0.384, 1.639)
Active Straight Leg Raise	1.786 ± 0.579	2.526 ± 0.612	0.001	(-1.170, -0.311)

P-values and Confidence Intervals for male versus female FMS scores produced by Two-Tailed Two-Sample T-Tests. Values are mean ± SD.

Low FMS Score and Injury Risk

The number of injuries suffered by the water polo players during the 2013-2014 season was recorded and compared to FMS final scores in order to examine the relationship between FMS score and injury risk. The data compiled for injury incidence is shown in Table 5. Three participants suffered injuries that kept them out of practice or game time during the competitive water polo season, all of them male. A 2x2 contingency table displaying water polo injury incidence data for the 2013-2014 season was created using the FMS final score cutoff of 14 (Table 6) . This cutoff score was established by Kiesel et al. and other published researchers as an indicator of elevated injury risk across certain active populations [6, 7, 10]. Fisher's Exact Test was performed using the data from the contingency table to determine whether there was a significant correlation between low FMS score (14 or below) and injury incidence. The statistical analysis determined that there was no significant relationship between low FMS scores and injury incidence (P = 0.0513). The results of the Fisher's Exact Test are on display in Table 7.

Table 5 Injuries Suffered During Competitive 2013 – 2014 Water Polo Season

Category	**N**	**Number of Injuries**	**Mean ± SD**
Combined	33	3	0.091 ± 0.292
Male	14	3	0.214 ± 0.426
Female	19	0	0

Injury incidence collected by self-reported retrospective data from the participants.

Table 6 2x2 Contingency Table - Injury Incidence with Low FMS (≤ 14) Cutoff Value

	Serious Injury	
FMS Score ≤ 14	**Yes**	**No**
Yes	2	3
No	1	27

Injury incidence collected by self-reported retrospective data from the participants.

Table 7 Fisher's Exact Test Results

Test Characteristic	**Numeric Value**
Cell (1,1) Frequency (F)	27
Left-sided Pr <-	0.9982
Right-sided Pr >-	0.0532
Table Probability (P -Value)	0.0513
Two-Sided Pr >- P	0.0532

Fisher's Exact Test performed using injury incidence data from Table 6.

Analysis of Asymmetrical Performances on Individual FMS Movement Tests

An investigation was also done into whether the number of asymmetrical performances on the individual bilateral FMS tests (hurdle step, in-line lunge, shoulder mobility, active straight leg raise, and rotary stability tests) differed significantly between males and females. A Two-tailed, two-sample T-test was done on Minitab statistical software to analyze the data. The results indicate that no statistically significant difference existed between the number of asymmetrical performances in male and female participants as determined by the protocol of the FMS [3, 4] (P = 0.589). The results of this statistical analysis are shown in Table 8.

Table 8 Number of Asymmetrical Performances on Bilateral FMS Tests - Males vs. Females

	N	Mean ± SD	P - Value	95% CI
Male	14	1.429 ± 0.938	0.589	(-0.427, 0.758)
Female	19	1.263 ± 0.733		

P-values and Confidence Intervals for male versus female FMS scores produced by Two-Tailed Two-Sample T-Test. Values are mean ± SD.

Age and BMI as Predictors of FMS Score

Simple Multiple Linear Regression was performed using Minitab statistical software to determine whether the anthropometric measurements of age and/or BMI were reliable predictors of FMS score using the collected data. The regression equation used for the analysis reads as follows: FMS = 28.2 – 0.653 Age + 0.041 BMI. Overall, age and BMI were not found to be significant predictors of FMS score ($P = .067$). However, age was found to be a significant predictor of FMS score when BMI was held constant ($P = 0.025$). Age had a significant negative correlation with FMS score. Table 9 displays the data produced from the linear regression analysis.

Table 9 Age and BMI Correlations with FMS Score – Linear Regression Analysis

Regression Equation		FMS = 28.2 - 0.653 Age + 0.041 BMI			
Predictor	**Coefficient**	**SE Coefficient**	**T Value**	**P Value**	**VIF**
Constant	28.231	5.526	5.11	0	
Age	-0.6531	0.2776	-2.35	0.025	1.156
BMI	0.0413	0.1502	0.28	0.785	1.156
ANOVA	**DF**	**SS**	**MS**	**F**	**P Value**
Regression	2	17.266	8.633	2.97	0.067

Age and BMI data collected from water polo players during FMS testing session.

Chapter 5

Discussion

Anthropometric Measurements

Anthropometric measurements (age, height, mass and BMI) were taken from every water polo participant in this investigation. The male and female means and standard deviations agreed very well with established normative values in the literature for a young, active population [5]. An analysis of the anthropometric data was performed to determine whether there were any significant differences between the male and female participants for this measurement. The findings of the statistical analyses suggested that there were significant differences regarding male and female height and mass. However, there were no significant differences between male and female age or BMI calculations.

The results of the analyses make sense given that men, in general, have larger body frames than women. It has been well-documented that men are, on average, taller than women and possess a greater proportion of skeletal muscle mass [26]. Therefore, it is reasonable that statistical testing determined a significant difference between male and female height and mass. When the height and mass measurements were normalized in the calculation of BMI, no significant difference between males and females was discovered. This makes sense because BMI is a measure of a person’s mass to height ration (BMI = kg/m^2). A person’s mass is divided by the square of that person’s height, producing a value that can be compared against those of other individuals. The fact that BMI normalizes mass against height is what makes it such a valuable research tool for comparing people’s relative size.

With regards to age, all of the participants in this study were players on Penn State Men's and Women's Water Polo Teams. Every athlete was an undergraduate student at the university. The youngest athlete that participated in this investigation was 19 years old, and the oldest was 23 years old. Because all of the research subjects were college-aged athletes within four years of age apart, it makes sense that no statistically significant difference was found between male and female age.

Male versus Female FMS Performance

Although normative data for FMS testing is minimally available, current research indicates that no significant differences exist in final FMS scores between men and women [5]. The FMS is a tool that can be used to analyze the quality of an individual's overall functional movement regardless of gender. Although final FMS score has not been found to be significantly different between males and females, it has been shown that men and women do perform differently on individual FMS tests (i.e. deep squat, right and left hurdle step, etc.). Schneiders et al. [5] found that males on average performed better on the trunk stability pushup and rotary stability tests than female participants. Females performed better than males on average in the active straight leg raise and shoulder mobility tests.

In this investigation, males and females did not show any significant differences in Final FMS score. However, significant differences did exist between male and female performance on some individual FMS tests. Males performed better on average than females on the deep squat and trunk stability pushup tests. Females performed better than males on average in the shoulder mobility and active straight leg raise tests. Similar to the findings of Schneiders et al.[5], the males on average outperformed the females in the trunk stability pushup test, and the females outperformed the males on average in both the active straight leg raise and shoulder mobility tests. Unlike the literature data, males and females performed equally well on the rotary stability test.

The findings of these analyses make sense based on the different biological characteristics between males and females. Research shows that males on average perform significantly better than females on strength tests, while females on average outperform males in flexibility tests [28]. The data from this investigation lends evidence to the claim that males are stronger than females, while females are more flexible than males. To perform well on the trunk stability test, an individual must have considerable upper body and core strength [4]. Given the fact that males usually demonstrate greater upper body and overall strength than females, it is reasonable that they perform better on this test. The active straight leg raise and shoulder mobility tests are designed to assess one's hamstring/gastrocnemius-soleus flexibility and glenohumeral/scapular mobility, respectively [4]. Since females are usually more flexible than males, it makes sense that they generally outperform males on these tests. The deep squat test requires good overall body mechanics to be performed well (bilateral stability and mobility of the ankle, knee, hip joints, as well as the shoulders and thoracic spine) [3]. Perhaps there was some factor associated with the incorporation of proper functional mechanics across different joints into one graded movement that males were more adept at than females that caused them to perform better on average in the deep squat test. More research needs to be done in this area to determine a plausible cause for this phenomenon.

Low FMS Scores and Injury Risk

Based on the results of the Fisher's Exact Test, the relationship between low FMS scores (FMS $\leq$14) and injury incidence was statistically insignificant. Unlike established research available in the literature [6, 7, 10, 11], the findings from this study suggest that low FMS scores are not significantly correlated with an elevated injury risk. Therefore, FMS cannot be considered a reliable predictor of injury within this water polo player population.

One of the possible underlying causes for these results could be the relatively small number of injuries that occurred to the water polo players. Only three players out of the thirty-four in this study suffered injury during the 2013-2014 water polo season, all of them male. This trend contrasts the data published in the scientific literature, which suggest that there are no significant differences in injury incidence between collegiate male and female athletes [29]. In the investigation of low FMS scores and injury risk of NFL football players done by Kiesel et al., a total of 13 injuries were observed out of a participant pool of 46 athletes [6]. Because a substantial portion of the participant pool suffered an injury, Kiesel et al. were able to analyze their data using a statistical procedure called a Receiver Operator Characteristics (ROC) curve. Analysis of the ROC curve determined that the FMS final score of 14 or below was associated with a significantly higher risk for injury [6]. In this case, however, ROC curve analysis was not able to be performed because some of the values in the 2x2 contingency table were below 5. Fisher's Exact Test was the more appropriate statistical procedure. If more water polo players had participated in the study, perhaps there would have been a greater incidence of injuries that might have altered the relationship between low FMS scores and injury risk.

It is also important to consider the fact that this investigation was the first to attempt to describe the relationship between FMS scores and injury risk in a water polo athlete population. Each of the studies that found significant correlations between FMS final scores below 14 and elevated injury risk performed testing on land-based populations [6, 7, 10, 11]. Aquatic athletes face completely different physical demands than land-based athletes and physically active populations. Sports like swimming and water polo put the body in different positions and through different forces than other land-based sports. More research needs to be done in this realm of FMS testing to determine whether a significant relationship between low FMS scores and injury risk is found among other water polo and aquatic populations.

Asymmetrical FMS Performance Comparisons Between Males and Females

Some of the movement tests in the FMS call for performance of the movement with one limb or using one side of the body, and then performance of the same movement using the contralateral limb/side of the body. These are what are referred to as bilateral tests (hurdle step, in-line lunge, shoulder mobility, active straight leg raise, and rotary stability tests). Execution of the movement with each side of the body receives a score. If the two scores are the same, then that number is counted towards the final score. If the two scores are not the same, then this is what is referred to as an asymmetrical performance or asymmetry. The lower of the two scores is counted towards the final score.

The FMS is designed to detect such asymmetrical movement patterns so that the individual can eventually be trained/treated to correct them before a possible injury occurs [3,4]. One of the aims of this investigation was to determine whether male and female participants differed in the number of asymmetries observed during FMS testing. The findings of this research show that there was no statistically significant difference between the number of asymmetrical performances in males and females. Males and females on average had very similar numbers of asymmetries present when they were administered the FMS.

Published research in the literature claims that male and female athletes are at an equal likelihood of suffering an injury due to participation in their certain sport [29]. If asymmetrical movement patterns decrease the quality of an individual's overall functional movement, putting that person at a higher risk for injury, then it stands to reason that males and females should not show a significantly different number of asymmetries during FMS testing. If either males or females were more prone to utilizing asymmetrical movement patterns, then the gender with the higher number of asymmetries should suffer a proportionately higher amount of injuries in their sport. This, however, is not the case according to the evidence-based research available.

Little to no research has been done to verify the reliability of the FMS to detect asymmetries, nor on potential discrepancies in the number of asymmetrical movement patterns observed in males and females using the FMS. This investigation makes a significant contribution to the body of knowledge surrounding male versus female comparison of performance on individual FMS tests. More research should be done in this area to determine if the trend regarding asymmetrical performances observed among this population of collegiate water polo players is observed across other populations as well.

Age and BMI as Predictors for FMS Score

Research published in the literature suggests that age and BMI are significantly correlated with FMS score [26]. Perry and Khloe administered FMS tests to 622 Canadian middle-aged adults with the goal of establishing normative FMS data for that age group [26]. They investigated whether certain variables such as physical activity, age, and BMI were significantly correlated to an individual's outcome on the FMS. Their findings indicate that all three variables were significantly correlated to FMS scores [26].

In this investigation, the variables of age and BMI were considered as possible predictors FMS outcomes. Linear regression was used to determine whether either variable was significantly correlated to FMS score. The statistical analysis found that BMI was not correlated with FMS score when age was held constant. However, age was found to have a statistically significant relationship with FMS score when age was held constant. Age was negatively correlated to FMS performance. In other words, the older participants generally received lower FMS scores than the younger participants.

The lack of correlation between BMI and FMS score does not agree with the findings published by Perry and Khloe [26]. Their research suggests that both BMI and age are negatively correlated with FMS scores [26]. They cite possible reasons for these trends as neuromuscular degeneration due to aging, along with excessive weight gain/obesity leading to deficits in functional performance. Although these may be legitimate concerns for the middle-aged, they do not hold much validity considering the participants of this study were young, collegiate athletes. Unlike the Perry and Khloe investigation, none of the research participants chosen for this study had a BMI value in the obesity range (30 or greater). 25 participants had BMI values within the normal range (18.5 – 24.9); and 8 participants had BMI values in the overweight range (25 – 29.9). The fact that the vast majority of the subjects had BMI values within the same normal range was probably a determinant in the lack of statistical correlation between BMI and FMS score.

One aspect of the findings of this investigation that does agree with data published in the literature is the presence of a significant correlation between age and FMS score. Negative correlations between age and FMS score were found in this study and that of Perry and Khloe [26]. As previously mentioned, they cited neuromuscular degeneration due to aging as a possible cause for this correlation. Although their assertion might be valid for their population, it cannot be applied as drastically to this population of 19 - 23 year-olds. One possible reason for the negative correlation between age and FMS score within this population of water polo players may be the accumulation of injuries over time, causing functional movement deficits. The longer an athlete trains in his or her sport, the greater the likelihood may be of him or her getting injured. If not treated correctly, those injuries may go on to cause compensatory patterns in movement or other functional deficits that are detected by the FMS. More research needs to be done into whether longer involvement in a sport is related to higher incidence of sport-related injury to make any definitive conclusions.

Conclusions

With regards to the principle goal of this investigation, no strong conclusions could be made about the relation between low FMS scores and injury risk. Although other studies in current research indicated that a final FMS score of 14 or below is associated with a higher risk for injury for that individual [6, 7, 8, 9, 10, 11], the data from this investigation suggested that no such conclusion can be drawn with this cohort of water polo players. There was no significant difference between males and females with regard to total FMS scores or the number of asymmetrical performances on bilateral component tests. However, there were significant differences between male and female scores for some of the FMS component tests. Males scored significantly higher than females on the deep squat and trunk stability pushup test while females scored significantly higher than males on the shoulder mobility and active straight leg raise tests. Age was found to be a negatively correlated predictor of total FMS score when BMI was held constant. Older individuals were expected to have lower total FMS scores in this cohort.

Study Limitations

One of the major limitations of this study was due to time constraints caused by the back-logging of the Penn State Internal Review Board (IRB) System. The backlogging of the IRB system caused a delay in approval for this investigation. Because of this delay, the principal investigator could not meet the original experimental design goal of administering FMS testing before the men's and women's competitive water polo season and tracking injury incidence in real-time as the season progressed. Therefore, the water polo players were asked to provide retrospective data about any injures they suffered during the 2013-2014 water polo season. The fact that the injury data was self-reported by the players, and not objectively collected by the researcher, may have allowed for unwanted outside variables to influence the results. For example, players may have forgotten injury episodes or chosen not to report them.

Another major limitation of this study was sample size, specifically the number of injuries that occurred during the 2013-2014 competitive water polo season. The limited number of injuries (3) that occurred to the water polo players over the season may have influenced the statistical relationship between low FMS scores and injury risk. The Fisher's Exact Test determined the data unfit for claiming the presence of a significant correlation. The limited number of injuries might have been attributed to the fact that not every athlete volunteered for the investigation (limiting the overall sample size to N=34), or that some injuries were not reported by the players. Perhaps a larger sample size would have provided a larger number of injuries to compare with FMS scores to determine a possible correlation.

A final limitation arose from the novelty of the FMS. The FMS is a fairly new research tool that was created within the last 10 years. Research is still being done to determine its possible uses, validity, and reliability as a tool for sports medicine professionals. The pool of published normative FMS testing data is very small. Only two studies were found that provided any normative data to compare the results of this investigation to [5, 27]. If there were more normative data available, especially for variances according to individual FMS movement tests, a more in-depth analysis of the FMS testing data could have been performed.

Appendix A

Recruitment, Scoring, and Tracking Forms

Subject Recruitment Script

Hi, I am Brandon Cabarcas, an undergraduate Schreyer Honors College student in the Department of Kinesiology. I am currently conducting research for my honors thesis. My main goal is to determine if there is a relationship between Functional Movement Screen (FMS) scores and injury rates in water polo players. An additional goal is to establish an FMS score profile for water polo players.

If you qualify for this research project, you will be asked to undergo a Functional Movement Screen assessment which consists of 7 functional movements such as a squat and a lunge, plus 3 simple movements that check for pain. The Functional Movement Screen should take no more than 20 minutes. Let me demonstrate the different functional movements for you. In addition, you will be asked to provide a history of any significant injuries you've had in the past that required you to limit your activities and keep track of injuries you incur during the upcoming 2013-2014 club water polo season.

To qualify for this research project, you must:

1) be between 18 and 40 years old
2) speak English
3) be cleared to play club water polo for the 2013-2014 season

Please carefully read the informed consent form that I am handing you. If you have any questions regarding the form and/or the research, feel free to ask. If you do not have any questions and wish to participate in the research project, please sign both copies of the informed consent form and keep one for your records.

PENNSTATE

1855

Title of Project: The Relationship between Functional Movement Screen Score and Injuries in College-Aged Water Polo Players

Principal Investigator: Sayers John Miller, PhD, PT, ATC

Co-Investigator: Giampietro Vairo, MS, ATC,

Research Assistant: Brandon Cabarcas

Screening Checklist: Healthy subjects

Participant Identification Number: ____

As a general health screen, you must be able to answer 'YES' to the following questions.

1. Are you between 18 to 40 years old? **Yes** **No**
2. Do you speak English? **Yes** **No**
3. Are you currently cleared to participate in club water polo activities? **Yes** **No**

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The Pennsylvania State University

Institutional Review Board

Office for Research Protections

Informed Consent Form for Biomedical Research

The Pennsylvania State University

Study Title: The Relationship between Functional Movement Screen Score and Injuries in College-Aged Water Polo Players

Principal Investigator: S. John Miller, PhD, PT, ATC
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Co-Investigator: Giampietro Vairo, MS, ATC – 814.865.2725; jlv103@psu.edu

Research Support: Brandon Cabarcas –305. 213.7786; bcc5118@psu.edu

1. **Purpose of the study:** The proposed study's objective is to determine the relationship between Functional Movement Screen scores and injury rates in college-aged water polo players.

2. **Procedures to be followed:** You will be asked to perform ten movements as specified by the protocol of the Functional Movement Screen. The Functional Movement Screen includes the following movements: a full squat, a step over a small hurdle, a lunge, reaching behind your back with your arms, reaching across your body with one hand to touch your opposite shoulder, lying on your back and raising one leg, a push up, extending your back, flexing your back and balancing on one hand and knee. You will also be asked to provide a history of significant injuries you've had in the past and to keep track of injuries that you incur during the 2013-2014 club water polo season.

3. **Discomforts and Risks:** The discomforts and risks with participation in this type of research study are minimal. The Functional Movement Screen is made up of movements that are within expected ranges for physically-active people. To lessen the chance of injury, you will also be shown how to properly perform every task in the experiment. In addition, all items are self-limiting and you will decide to what extent you perform the items. Possible discomfort may consist of delayed onset muscle soreness 48 to 72 hours following testing. As with any research study, it is possible that unknown harmful effects may happen. However, the chance for injury in this type of research study is minimal and includes muscle strains, ligament sprains, fractures or aggravation of previously experienced symptoms. We will take every possible effort to watch for and help prevent against any discomforts and risks.

4. **Benefits:** You will receive information regarding your functional strengths and weaknesses.

5. **Duration of the study:** This study will take approximately 60-70 minutes.

6. **Right to ask questions:** Please contact John Miller at 865- 67828 with questions, complaints, or concerns about this research. You can also call this number if you feel that you have been harmed by the research study. If you have questions, concerns, or problems about your rights as a research participant or would like to offer input, please contact Penn State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

7. **Statement of Confidentiality:** Your participation in this research is confidential. Research data will be stored and secured at 21 Recreation Building in a password-protected file. The Office of Human Research Protections in the US Department of Health and Human Services, the US Food and Drug Administration (FDA), the Office for Research Protections at Penn State may review records related to this project. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared. Furthermore, any data pertaining to this study will not use your name. Only study personnel will have access to the data.

8. **Voluntary Participation:** Your decision to participate in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

   If you are a student in a course taught by one of the study investigators, your participation or non-participation in this study will have no effect on your course grades.

9. **Injury Clause:** In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

You must be 18 years of age or older to take part in this study. If you agree to take part in this research study, please sign your name and provide the date below.

You will be given a copy of this signed and dated consent form for your records.

____

____

Participant Signature Date

Person Obtaining Consent Signature Date

Past Injury History

Participant No. _______

Have you ever had a significant injury that required you to see a physician or limit your activities? **Yes No**

For each significant injury please list the following:

1) Body part, including side
2) Diagnosis provided by physician or other health care professional, if known
3) Treatment (Surgery, immobilization , rehabilitation, none)
4) Length of time you were unable to participate in your normal activities

Injury 1:

1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 2:

1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 3:

1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 4:

1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 5:

1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Current Injury History

Participant No. _______

Age: ______________ Height: ______________ Weight: _______________ Sex: ____

Dominant Hand: ___________ Dominant Foot: _____________

Have you ever had a significant injury that required you to see a physician or limit your activities? **Yes No**

For each significant injury that requires you to see a medical practitioner or limit your participation that you incur during the 2013-2014 club water polo season please list the following:

1) Body part, including side
2) Diagnosis provided by physician or other health care professional, if known
3) Treatment (Surgery, immobilization , rehabilitation, none)
4) Length of time you were unable to participate in your normal activities

Injury 1:
1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 2:
1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 3:
1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

Injury 4:
1) Body part
2) Diagnosis
3) Treatment
4) Time out of activity

FUNCTIONAL MOVEMENT SCREEN

Subject No. ______________________ Date:________________

Hand length: _____________________ Tibial tuberosity height:___________

Test	Raw Score	Final Score
Deep Squat		
Hurdle Step – Left		
Hurdle Step – Right		
In-Line Lunge – Left		
In-Line Lunge – Right		
Shoulder Mobility – Left Bottom		
Shoulder Mobility – Right Bottom		
Active Impingement - Left		
Active Impingement – Right		
Active Straight Leg Raise - Left		
Active Straight Leg Raise - Right		
Push-up		
Lumbar Extension		
Rotary Trunk Stability - Left		
Rotary Trunk Stability - Right		
Lumbar Flexion		

TOTAL SCORE: ___________________

Appendix B

FMS Verbal Instructions and Scoring Criteria

VERBAL INSTRUCTIONS FOR THE FUNCTIONAL MOVEMENT SCREEN

The following is a script to use while administering the FMS. For consistency throughout all screens, this script should be used during each screen. The bold words represent what you should say to the client.

Please let me know if there is any pain while performing any of the following movements.

DEEP SQUAT

EQUIPMENT NEEDED: DOWEL

INSTRUCTIONS

- **Stand tall with your feet approximately shoulder width apart and toes pointing forward.**
- **Grasp the dowel in both hands and place it horizontally on top of your head so your shoulders and elbows are at 90 degrees.**
- **Press the dowel so that it is directly above your head.**
- **While maintaining an upright torso, and keeping your heels and the dowel in position, descend as deep as possible.**
- **Hold the descended position for a count of one, then return to the starting position.**
- **Do you understand the instructions?**

Score the movement.
The client can perform the move up to three times total if necessary.
If a score of three is not achieved, repeat above instructions using the 2 x 6 under the client's heels.

FMS

Hurdle Step

Equipment needed: Dowel, Hurdle

Instructions

- **Stand tall with your feet together and toes touching the test kit.**
- **Grasp the dowel with both hands and place it behind your neck and across the shoulders.**
- **While maintaining an upright posture, raise the right leg and step over the hurdle, making sure to raise the foot towards the shin and maintaining foot alignment with the ankle, knee and hip.**
- **Touch the floor with the heel and return to the starting position while maintaining foot alignment with the ankle, knee and hip.**
- **Do you understand these instructions?**

Score the moving leg.
Repeat the test on the other side.
Repeat two times per side if necessary.

Inline Lunge

Equipment needed: Dowel, 2x6

Instructions

- **Place the dowel along the spine so it touches the back of your head, your upper back and the middle of the buttocks.**
- **While grasping the dowel, your right hand should be against the back of your neck, and the left hand should be against your lower back.**
- **Step onto the 2x6 with a flat right foot and your toe on the zero mark.**
- **The left heel should be placed at ______________mark.** *This is the tibial measurement marker.*
- **Both toes must be pointing forward, with feet flat.**
- **Maintaining an upright posture so the dowel stays in contact with your head, upper back and top of the buttocks, descend into a lunge position so the right knee touches the 2x6 behind your left heel.**
- **Return to the starting position.**
- **Do you understand these instructions?**

Score the movement.
Repeat the test on the other side.
Repeat two times per side if necessary.

Shoulder Mobility

Equipment needed: Measuring device

Instructions

- **Stand tall with your feet together and arms hanging comfortably.**
- **Make a fist so your fingers are around your thumbs.**
- **In one motion, place the right fist over head and down your back as far as possible while simultaneously taking your left fist up your back as far as possible.**
- **Do not "creep" your hands closer after their initial placement.**
- **Do you understand these instructions?**

Measure the distance between the two closest points of each fist.
Score the movement.
Repeat the test on the other side.

Active Scapular Stability (Shoulder Clearing)

Instructions

- **Stand tall with your feet together and arms hanging comfortably.**
- **Place your right palm on the front of your left shoulder.**
- **While maintaining palm placement, raise your right elbow as high as possible.**
- **Do you feel any pain?**

Repeat the test on the other side.

Active Straight-Leg Raise

Equipment needed: Dowel, measuring device, 2x6

Instructions

- **Lay flat with the back of your knees against the 2x6 with your toes pointing up.**
- **Place both arms next to your body with the palms facing up.**
- **Pull the toes of your right foot toward your shin.**
- **With the right leg remaining straight and the back of your left knee maintaining contact with the 2x6, raise your right foot as high as possible.**
- **Do you understand these instructions?**

Score the movement.
Repeat the test on the other side.

Trunk Stability Pushup

Equipment needed: None

Instructions

- **Lie face down with your arms extended overhead and your hands shoulder width apart.**
- **Pull your thumbs down in line with the** ___ (forehead for men, chin for women).
- **With your legs together, pull your toes toward the shins and lift your knees and elbows off the ground.**
- **While maintaining a rigid torso, push your body as one unit into a pushup position.**
- **Do you understand these instructions?**

Score the movement.
Repeat two times if necessary.
Repeat the instructions with appropriate hand placement if necessary.

Spinal Extension Clearing

Instructions

- **While lying on your stomach, place your hands, palms down, under your shoulders.**
- **With no lower body movement, press your chest off the surface as much as possible by straightening your elbows.**
- **Do you understand these instructions?**
- **Do you feel any pain?**

Rotary Stability

Equipment needed: 2 x 6

Instructions

- **Get on your hands and knees over the 2x6 so your hands are under your shoulders and your knees are under your hips.**
- **The thumbs, knees and toes must contact the sides of the 2x6, and the toes must be pulled toward the shins.**
- **At the same time, reach your right hand forward and right leg backward, like you are flying.**
- **Then without touching down, touch your right elbow to your right knee directly over the 2x6.**
- **Return to the extended position.**
- **Return to the start position.**
- **Do you understand these instructions?**

Score the movement.
Repeat the test on the other side.
If necessary, instruct the client to use a diagonal pattern of right arm and left leg.
Repeat the diagonal pattern with left arm and right leg.
Score the movement.

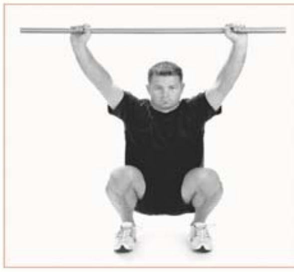
Spinal Flexion Clearing

Instructions

- **Get on all fours, and rock your hips toward your heels.**
- **Lower your chest to your knees, and reach your hands in front of your body as far as possible.**
- **Do you understand these instructions?**
- **Do you feel any pain?**

FMS SCORING CRITERIA

DEEP SQUAT

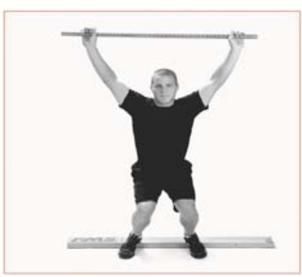


3

Upper torso is parallel with tibia or toward vertical | Femur below horizontal
Knees are aligned over feet | Dowel aligned over feet

2

Upper torso is parallel with tibia or toward vertical | Femur is below horizontal
Knees are aligned over feet | Dowel is aligned over feet | Heels are elevated



1

Tibia and upper torso are not parallel | Femur is not below horizontal
Knees are not aligned over feet | Lumbar flexion is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

HURDLE STEP

3

Hips, knees and ankles remain aligned in the sagittal plane
Minimal to no movement is noted in lumbar spine | Dowel and hurdle remain parallel

2

Alignment is lost between hips, knees and ankles | Movement is noted in lumbar spine
Dowel and hurdle do not remain parallel

1

Contact between foot and hurdle occurs | Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

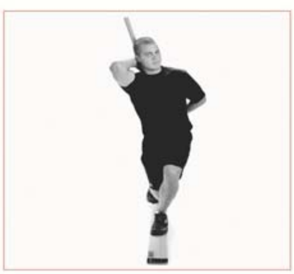
INLINE LUNGE

3

Dowel contacts maintained | Dowel remains vertical | No torso movement noted
Dowel and feet remain in sagittal plane | Knee touches board behind heel of front foot

2

Dowel contacts not maintained | Dowel does not remain vertical | Movement noted in torso
Dowel and feet do not remain in sagittal plane | Knee does not touch behind heel of front foot



1

Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

SHOULDER MOBILITY

3

Fists are within one hand length

2

Fists are within one-and-a-half hand lengths

1

Fists are not within one and half hand lengths

The athlete will receive a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

Clearing Test

Perform this clearing test bilaterally. If the individual does receive a positive score, document both scores for future reference. If there is pain associated with this movement, give a score of zero and perform a thorough evaluation of the shoulder or refer out.

ACTIVE STRAIGHT-LEG RAISE

3

Vertical line of the malleolus resides between mid-thigh and ASIS
The non-moving limb remains in neutral position

2

Vertical line of the malleolus resides between mid-thigh and joint line
The non-moving limb remains in neutral position

1

Vertical line of the malleolus resides below joint line
The non-moving limb remains in neutral position

The athlete will receive a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

FMS

TRUNK STABILITY PUSHUP

3

The body lifts as a unit with no lag in the spine

Men perform a repetition with thumbs aligned with the top of the head
Women perform a repetition with thumbs aligned with the chin

2

The body lifts as a unit with no lag in the spine
Men perform a repetition with thumbs aligned with the chin | Women with thumbs aligned with the clavicle

1

Men are unable to perform a repetition
with hands aligned with the chin

Women unable with thumbs aligned with the clavicle

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

Spinal Extension Clearing Test

Spinal extension is cleared by performing a press-up in the pushup position. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual does receive a positive score, document both scores for future reference.

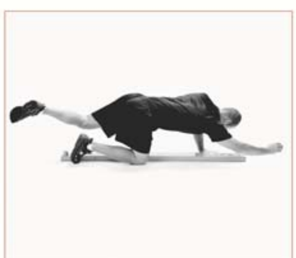
ROTARY STABILITY

3

Performs a correct unilateral repetition

2

Performs a correct diagonal repetition



1

Inability to perform a diagonal repetition

The athlete receives a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.

SPINAL FLEXION CLEARING TEST

Spinal flexion can be cleared by first assuming a quadruped position, then rocking back and touching the buttocks to the heels and the chest to the thighs. The hands should remain in front of the body, reaching out as far as possible. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual receives a positive score, document both scores for future reference.

BIBLIOGRAPHY

1. Colville JM, Markman BS. "Competitive Water Polo: Upper Extremity Injuries." *Clinics in Sports Medicine* 18.2 (1999): 305-12.

2. Brooks, JM "Injuries in Water Polo." *Clinics in Sports Medicine* 18.2 (1999): 313-19.

3. Cook G, Burton L, and Hoogenboom, B "Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function – Part 1." *North American Journal of Sports Physical Therapy* 1.2 (2006): 62-72.

4. Cook G, Burton L, and Hoogenboom B "Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function – Part 2." *North American Journal of Sports Physical Therapy* 1.3 (2006): 132-39.

5. Schneiders AG, Davidsson A, Horman E, and Sullivan, JS "Functional Movement Screen Normative Values in a Young, Active Populaion." *International Journal of Sports Physical Therapy* 6.2 (2011): 75-82.

6. Kiesel, K, Plisky PJ, and Voight MJ. "Can Serious Injury in Professional Football Be Predicted by a Preseason Functional Movement Screen?" *North American Journal of Sports Physical Therapy* 2.3 (2007): 147-58.

7. O'Connor F G, Deuster PA, Davis J, Pappas CG, and Knapik, J. "Functional Movement Screening: Predicting Injuries in Officer Candidates." *Medicine & Science in Sports & Exercise* 43.12 (2011): 2224-230.

8. Chapman RF, Laymon AS, and Arnold T. "Functional Movement Scores and Longitudinal Performance Outcomes in Elite Track and Field Athletes." *International Journal of Sports Physiology and Performance* 9.2 (2014): 203-11.

9. Chorba RS, Chorba DJ, Bouillon LE, Overmyer CA, and Landis JA. "Use of a Functional Movement Screening Tool to Determine Injury Risk in Female Collegiate Athletes." *North American Journal of Sports Physical Therapy* 5.2 (2010): 47-54.

10. Kiesel KB, Butler RJ, and Plisky PJ "Limited and Asymmetrical Fundamental Movement Patterns Predict Injury in American Football Players." *Journal of Sport Rehabilitation* (2014): in press.

11. Peate WF, Bates G., Lunda K, Francis S, and Bellamy K.. "Core Strength: A New Model for Injury Prediction and Prevention." *Journal of Occupational Medicine and Toxicology* 2.1 (2007): in press.

12. Webster, Marilyn J, Morris ME, and Galna B. "Shoulder Pain in Water Polo: A Systematic Review of the Literature." *Journal of Science and Medicine in Sport* 12.1 (2009): 3-11.

13. Jacqueline E. "Shoulder Pain and Flexibility in Élite Water Polo Players." *Physiotherapy* 79.10 (1993): 693-97.

14. McMaster WC, Long SC, and Caiozzo VC. "Isokinetic Torque Imbalances in the Rotator Cuff of the Elite Water Polo Player." *American Journal of Sports Medicine* 19.1 (1991): 72-75.

15. Witwer A, and Sauers E. "Clinical Measures Of Shoulder Mobility In College Water-Polo Players." *Journal of Sport Rehabilitation* 15.1 (2006): 45.

16. Okada, Tomoko, Kellie C. Huxel, and Nesser TW. "Relationship Between Core Stability, Functional Movement, and Performance." *Journal of Strength and Conditioning Research* 25.1 (2011): 252-61.

17. Benz, J. *Functional Movement Screen to Predict Athletic Performance*. Thesis. Kean University, 2010. Ann Arbor: ProQuest LLC, 2010. Print.

18. Parchmann CJ, and McBride JM. "Relationship Between Functional Movement Screen and Athletic Performance." *Journal of Strength and Conditioning Research* 25.12 (2011): 3378-384.

19. Butler, RJ, Plisky PJ, Southers C, Scoma C, and Kiesel KB. "Biomechanical Analysis of the Different Classifications of the Functional Movement Screen Deep Squat Test." *Sports Biomechanics* 9.4 (2010): 270-79.

20. Kiesel, K., P. Plisky, and R. Butler. "Functional Movement Test Scores Improve following a Standardized Off-season Intervention Program in Professional Football Players." *Scandinavian Journal of Medicine & Science in Sports* 21.2 (2011): 287-92.

21. Minick, KI, Kiesel, KB, Burton L, Taylor A, Plisky PJ, and Butler RJ. "Interrater Reliability of the Functional Movement Screen." *Journal of Strength and Conditioning Research* 24.2 (2010): 479-86.

22. Elizabeth PG, Gaudreault N, Chambers S, Boisvert C, Grenier A, Gagné G, and Balg F. "Functional Movement Screen Test: A Reliable Screening Test for Young Elite Ice Hockey Players." *Physical Therapy in Sport* (2013): 1-7.

23. Teyhen, Deydre S, Shaffer SW, Lorenson CL, Halfpap JP, Donofry DF, Walker MJ, Dugan JL, and Childs JD. "The Functional Movement Screen: A Reliability Study." *Journal of Orthopaedic & Sports Physical Therapy* 42.6 (2012): 530-40.

24. Shultz R, Anderson SC, Matheson GO, Marcello B, and Besier T. "Test-Retest and Interrater Reliability of the Functional Movement Screen." *Journal of Athletic Training* 48.3 (2013): 331-36.

25. Elias JE. "The Inter-rater Reliability of the Functional Movement Screen within an Athletic Population Using Untrained Raters." *Journal of Strength and Conditioning Research* (2014).

26. Janssen I, Heymsfield SB, Wang Z, and Ross R. "Skeletal Muscle Mass and Distribution in 468 Men and Women Aged 18-88 Years." *Journal of Applied Physiology* 89.1 (2000): 81-88.

27. Perry FT, and Koehle MS. "Normative Data for the Functional Movement Screen in Middle-Aged Adults." *Journal of Strength and Conditioning Research* 27.2 (2013): 458-62.

28. Kibler WB, Chandler TJ, Uhl T, Maddux, RE. “A Musculoskeletal Approach to the Preparticipation Physical Examination: Preventing Injury and Improving Performance.” *American Journal of Sports Medicine*.17.4 (1989): 525-531.

29. Sallis RE, Jones S, Sunshine G, Smith, and Simon L. "Comparing Sports Injuries in Men and Women." *International Journal of Sports Medicine* 22.6 (2001): 420-23.

ACADEMIC VITA

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Education

- The Pennsylvania State University, University Park, PA
  B.S. in Kinesiology: Movement Science Option
  Class of 2014

Honors and Awards

- Schreyer Honors College
- Bunton-Waller Fellow
- Dean's List Every Semester
- Penn State College of Human Health and Development: 2013 Kinesiology Scholarship

Association Memberships/Activities

- Kinesiology Club President: 2013-2014
- Kinesiology Club Vice President and Alternative Fundraisers Chairperson: 2012-2013
- Penn State Global Medical Brigades: 2012-2013
- Penn State Water Polo Team: 2010-2012

Professional Experience

- Medical Observership — Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL: July 2013
- Translator for Medical Brigade to Panama — Penn State Global Medical Brigades: May 2013
- Family Practice Shadowing —DMD Medical Group, Miami, FL: July 2013
- Orthopedic Surgery Shadowing — Mt. Nittany Medical Center, State College, PA: October 2012
- Physical Therapy Aide – Cora Rehabilitation Clinics, Miami, FL: Summer 2012
- Physical Therapy Aide – Miami Physical Therapy Group, Miami, FL: Summer 2011

Other Skills

- Bilingual – Spoken and written fluency in both Spanish and English.