Underlying Theoretical Components of the Functional Movement Screen

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ABSTRACT

The purpose of this study was to determine the number of constructs that can be identified in the Functional Movement Screen and determine which of the individual tests loaded into each construct. Three hundred and thirty male and female subjects, between the ages of 17 and 24, were recruited from a division I varsity athletics program. Subjects were asked to wear athletic shorts, a fitted athletic shirt, and athletic shoes. All subjects completed all seven FMS tests (Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-Up, and Rotational Stability). Athletes who completed the screen immediately following sport participation were excluded (N= 6) and those who wore ankle braces or any high-top shoe were also excluded (N=2). Two athletes were excluded because they suffered from delayed onset muscle soreness that inhibited their ability to perform the screen. One athlete was removed from the study because of a wrist injury that prevented the completion of all seven tests. Each test was completed, at most, three times and the best score was used for the final score. The FMS tests were evaluated on a four-point grading scale, 0-3, with a possible total score of 21. After exclusion criteria were evaluated, 319 subjects' data was analyzed for this study. Of those who completed the screen 283 (88.3%) had no previous knowledge of the FMS and 36 (11.3%) had previously done the screen. Age of subjects was 19.7 ± 1.4 years. Subjects' height was 178.1 ± 0.7 cm and weight was 73.7 ± 14 kg. Fourteen varsity sports were included in this study. Data was analyzed using exploratory factor analysis. Descriptive statistics and frequencies were also calculated. The exploratory factor analysis revealed that six of the seven items fit into three factors that met the criteria of an eigenvalue of 1.0 or greater and had a portion of more than 5% of the variance. Factor 1 included deep squat, hurdle step, inline lunge, and active straight leg raise and accounted for 9.8% of the variance. Theoretically, these four

tests loaded together because they all test lower extremity mobility and stability. All of the tests within this factor require proper mobility of the ankle, knee, and hip for the exercise to be done correctly. Factor 2 included the rotary stability test and accounted for 5.5% of the variance. This is the only test within the FMS that has the individual in a quadruped position. Further, the rotary stability test measures stability of the core, shoulders, and pelvis in a multi-plane movement pattern. Factor 3 included the push-up test and accounted for 5.1% of the variance. This test is the only test that challenges the upper body in a closed-kinetic chain manner and assesses spinal stability in a neutral position. Overall, these 3 factors accounted for 20.4% of the variance in the performance of the functional movement screen. For this analysis, the suppression threshold was set at 0.3. At this threshold, each test only loaded into one factor. The shoulder mobility did not load onto any factor. Overall, this study is the starting point in establishing a theoretical framework for the FMS.

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CHAPTER I

INTRODUCTION

The Functional Movement Screen (FMS) is a screening tool developed by Gray Cook and Lee Burton to identify any discrepancies in body movements.[1,2] In other words, the screen is done to evaluate how an athlete moves and performs different exercises. Furthermore, while the athlete performs the screen, the evaluator identifies any compensations, non-bilateral movements, or inconsistencies in the movement pattern.[1-3] The goal of the FMS is to aid sports conditioning specialists, athletic trainers, and coaches in developing injury prevention programs for their athletes. Gray Cook claims that the tests included in the FMS evaluate muscular mobility, stability, and core stabilization.[1,2]

The FMS was created to assess the development of functional movement and dynamic balance during movement oriented tests that require motor control.[1] Other motor pattern tests are typically used for infants and young children to identify delays in motor development.[4] The World Health Organization looked at the timeframe for children to reach six gross motor development milestones: sitting without support, hands-and-knees crawling, standing with assistance, walking with assistance, standing, and walking alone.[5] Cook's claim is that the FMS may be used to measure maturation of those same patterns.[1-3]

The FMS is comprised of seven tests that include Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-up, and Rotary Stability.[1,2] Each test included in the FMS is evaluated on a four-point grading scale, 0-3.[1,2] The total possible score given is 21.[1,2] Prediction studies have been done to determine the appropriate cut off score among those who obtained an injury. However, there are some variations in the literature.[6-9] One study, by Kiesel et al. in 2007, found that those who scored below a 14 were at a greater risk of being injured throughout the athletic season.[10] This study has become a standard for those using the FMS. However, other studies have been done to indicate a different cut-off value for the FMS.[7-10] Those studies have found the cut-off value to be higher, such as 16.5[8], 15.7,[7] and 15.5.[9]

Many researchers have taken the results of the FMS and then implemented prevention and/or intervention programs to help improve those scores and potentially lower the risk of injury.[11-15] The results of these studies found that intervention programs show promising results in improving FMS scores.[11,12] Specifically, Kiesel et al.[11] performed a study in 2009 and found that after an intervention program, the mean FMS scores increased in professional football players (mean for linemen: pre- 11.8; post- 14.8 and non-linemen: pre-13.3; post- 16.3). A study using military soldiers as subjects also found an increase in FMS scores after an intervention program (mean increase= 2.5 points).[12]

Although research related to the FMS is in its infancy, some published work has evaluated the reliability of testers using the FMS. Some studies evaluate only novice raters and others have compared FMS scores done by raters that have different levels of experience. [16-18] Among novice raters, moderate to good inter-rater reliability was reported (ICC=0.74).[17] One study compared testers with varying levels of experience and expertise using the FMS. The results showed that sufficient inter-rater reliability (ICC= 0.89) can be expected even with raters with varying degrees of experience.[18] Other research has reported adequate intra-rater reliability.[6,16-21] [16,17] Studies evaluating test intra-rater reliability have found ICC values of

0.76[17], 0.88[19], and 0.91[21]. Overall, the reliability of the FMS is good and allows researchers to evaluate change in scores overtime.

The creators of the FMS hypothesize that it can be used to evaluate mobility, stability, and core stabilization. However, there is no independent evidence to establish the theoretical framework for FMS. Further, no exploration has been done to uncover the underlying structure or constructs of the seven tests or how they relate to fundamental movement patterns. Ideally, the seven tests would be independent of one another and explain as much of the variance as possible. Therefore, the purpose of this study was to determine the number of constructs that can be identified in the FMS and determine which of the individual tests loaded into each construct.

Operational Definitions

Healthy- Individuals who are not concussed or have any of illness that could alter the results

Environment- All testing will be done in the main athletic training room, first aid room, or an axillary athletic training room

Subjects- Individuals who participate in Division I varsity collegiate athletics

Discrepancies- Imbalances shown when performing the FMS tests, compared bilaterally

Deep Squat- Believed that this test assesses the ability of the individual to fully dorsiflex the ankles, flex the knees and hips, extend the thoracic spine appropriately, and flex and abduct the shoulders when holding the dowel overhead

Hurdle Step- Theorized to test functional mobility and stability at the hips, knees, and ankles

In-line Lunge- Believed to be performed to assess ankle, knee, hip, trunk, and shoulder mobility and stability

Active Straight-leg Raise- Test that theoretically assesses active hamstring and gastrocnemius range of motion while maintaining a fixed pelvis and not allowing the opposite leg to lift from the ground

Trunk Stability Push-up- Believed that the test assesses spinal stability in a neutral position while performing a closed-kinetic chain push-up without allowing movement in the spine or hips

Shoulder Mobility- Hypothesized to assess bilateral shoulder adduction with internal rotation and shoulder external rotation with abduction

Rotary Stability- Assesses neuromuscular control while the individual flexes the shoulder while extending the knee and hip on the ipsilateral side with minimal weight transfer to the stationary side

Scoring System- Means of grading the quality of movement during the functional movement screen. Scores range from zero to three. The highest score an individual can receive is a twenty-one

Zero score- If the individual experiences pain anytime during the test or during the clearing assessment

One score- Represents inability to complete the test

Two score- Signifies completion of the test but with limitation or discrepancy

Three score- Indicates that the individual performed the test without difficulty or discrepancy

Clearing tests- The purpose of the clearing tests is to identify pain that may be a factor in the discrepancies found. If the individual has pain when performing the clearing test, that person automatically receives a zero as a score for that test

Assumptions

The following assumptions will apply to this study:

1. The participants will have similar background in terms of activity levels
2. The participants will perform the exercises at a maximal effort
3. The participants will be honest when completing the health history questionnaire
4. The participants will truthfully report any pain when performing the tests and/or the clearing examinations
5. The participants will follow the instructions provided and ask if they do not understand the instructions

Delimitations

The following delimitations will apply to this study:

1. All subjects will be Division I varsity athletes
2. The subjects will perform the Functional Movement Screen one time, completing all seven tests during that time
3. The tests will be given in the same order for every subject.
4. The Functional Movement Screen will be administered according to the protocol established by Gray Cook
5. The researcher will read the instructions directly and will provide no leading clues on how to perform the exercise
6. Only the FMS equipment will be used throughout the study
7. The clearing tests will be performed after the completion of the Shoulder Mobility, Rotary Stability, and Trunk Stability Push-up tests

8. Each test will be done, at most, three times and scores will be taken from the best trial
9. All testing will be performed by the same researcher
10. No subjects will be concussed or have a history of being concussed within 6 months of data collection
11. Any subjects with neurological symptoms will be excluded
12. Any subjects with a cold or illness of any sort that alters balance will be excluded
13. No orthopedic braces will be worn during data collection
14. All athletes will wear athletic shoes.

Limitations

There were a few limitations that need to be noted. A specific pool of division I varsity athletes' makes generalization difficult to other samples of active individuals. Also, shoe wear was not tightly controlled throughout the study. As long as the athlete was in an athletic-type shoe, he or she was able to be included in the screen. Further, a third of those screened for this study were members of the track and field and/or cross-country team. This large proportion could alter the results. Lastly, the location that the screen was performed in was poorly controlled. The screen was done in the main athletic training room with many distractions and traffic.

Statement of the Problem

Functional Movement Screen (FMS) is a tool used to evaluate movement patterns in order to identify discrepancies in athletes and other active individuals. The main goal of the FMS is to identify faulty movement patterns and correct them to improve movement/performance and to decrease the risk of injury. FMS is comprised of seven tests that require balance and mobility of those being tested. The tests include Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-up, and Rotary Stability. However, there is no empirical research to establish the theoretical framework for FMS. The purpose of this study is to determine the number of constructs that can be identified in the FMS and determine which of the individual tests load into each construct. Ideally, the tests will load together based on the primary movers during the test (i.e. upper extremity, lower extremity).

CHAPTER II

REVIEW OF LITERATURE

The Functional Movement Screen (FMS) is a tool used to evaluate movement patterns in order to identify deficiencies in athletes and other active individuals.[1,3] The goal of those who use the FMS is to identify any deficiencies and then to determine if these deficiencies will increase the chance of injury for an individual. By using the FMS to determine who is at a greater risk of injury, the developers of the FMS, Gray Cook and Lee Burton, [1,3] hope to aid sports conditioning specialists, athletic trainers, and coaches in developing prevention programs for those athletes. In this chapter, all research pertaining to the FMS will be discussed. Additionally, movement patterns that have the potential make up its theoretical framework, inter-rater and intra-rater reliability using the FMS,[6,16-18,20-22] cut-off values within the FMS to distinguish those at risk of obtaining injuries throughout a competitive season,[7-10] information to predict injury [8,10,19,23] and then compared that to intervention programs to see if FMS scores would change.[11-15] Some researchers have taken components of the FMS and used it as a comparative tool against other performance protocols to see if any correlation exists.[24,25]

Motor Development Patterns

Motor development is the study of changes in human motor behavior that occur over a lifespan, the processes that influence those changes, and other factors that may influence these changes.[26] The process of motor development is continuous and involves the interactions of several factors.[27,28] Such factors include neuromuscular maturation, the growth characteristics, the rate of development, the lasting effects of motor memory, and new motor experiences.[27]

Cook et al.[1,2] cited the need for an analysis of fundamental movement patterns in pre-participation screens.[1,2] Subsequently, the FMS was developed based on these movement patterns as an evaluative option that relates closely to what an athlete or client will do during activity.[3] The movements performed during activity are developed over time, beginning in infancy. The same movements and milestones are not used across various examination methods, making it hard for an overall picture of fundamental movement pattern development to be drawn from the literature. The FMS is an attempt to capture the complex construct of motor control, movement oriented tests that assess if functional movement and dynamic balance have been developed.[1]

Early Movement Milestones and Fundamental Movement Patterns

To determine early movement patterns, the World Health Organization (WHO) performed monthly examinations to look at the age windows for children to reach six gross motor development milestones: sitting without support, hands-and-knees crawling, standing with assistance, walking with assistance, standing and walking alone.[5] Using the child's age in months, fieldworkers recorded when a child was able to perform a task, but not necessarily the quality of the movements. This study by the WHO is significant as it included children from six geographically diverse countries: Brazil, Ghana, India, Norway, Oman and the USA.[5] Trained fieldworkers collected monthly information on children ranging from four to twelve months of age and bimonthly thereafter until all milestones were achieved or the child reached twenty-four months of age. In about 90% of the cases, the pattern observed followed a fixed sequence for five of the milestones (sitting without support, standing with assistance, walking with assistance, standing alone, and walking alone).[5] The windows of achievement overlap across the milestones. However, on average sitting without support occurred at 5.4 months, standing with assistance at

6.6 months, walking with assistance at 7.8 months, hands-and-knees crawling at 8.3 months, walking alone at 9.4 months, and standing alone at 10 months.[5] These actions are similar to those discussed and labeled by Burton and Miller[5] as early movement milestones and are almost always acquired before fundamental movement skills.

During the first 2 years of life, independent walking is the major motor development task.[27] The developmental changes leading to walking behavior are essentially a series of postural changes through which the child gains the motor control necessary to first assume upright posture, then maintain upright posture, and finally to walk independently.[27] Burton and Miller[4] cited that fundamental movement skills, usually developed between one and seven years of age, are the locomotor and object-control skills performed in an upright or bipedal position. The onset of walking is seen as the boundary between early movement milestones and fundamental movement skills.[4]

The early movement milestones defined by Burton and Miller[4] are similar to those discussed by the WHO. They are considered the movements developed in the time before a child attains upright or bipedal locomotion and include rolling over, crawling, creeping, sitting, standing, walking, and object manipulation.[4] Fundamental loco motor skills include walking, running, jumping, sliding, galloping, hopping, and leaping.[4] Lastly, fundamental object-control skills include throwing, catching, striking, bouncing, kicking, pulling and pushing.[4] Both the early movement milestones and fundamental movement skills are referred to as phylogenetic skills because of their universal occurrence, and together are viewed as components of all specialized movement skills.[4]

Proficiency in movement pattern execution has been described using terms ranging from immature to mature and from minimal form to sport skill form.[27] These may be terms that can be used when trying to make a comparison between the FMS and other scales that have tried to grade movement. Assumptions of motor assessment vary among the numerous tools according to the theoretical perspective of the developer creating the test. It is essential then that the clinician is aware of the theoretical framework behind the assessment tools they choose. That is true for both the FMS and the various infant development scales. A connection might be made as the literature hints that motor patterns may be considered mature years later when they have been developed or trained for an individual's activity. Fundamental patterns are integrated into more complex movement sequences, such as those required for specific games and sports. This somewhat follows what Cook claims when he states his tests are more advanced versions of the fundamental movements.[1-3,29]

The FMS Test

The FMS is comprised of seven tests, these tests include Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-up, and Rotary Stability. [1,3] Within each test of the FMS, the researcher must score the individual's performance. The scores follow a four-point scale. A score of three indicates that the individual performed the test without difficulty or discrepancy.[1-3] A score of two signifies completion of the test but with limitation or discrepancy.[1-3] A score of one represents inability to complete the test.[1-3] If the individual experiences pain anytime during the test or during the clearing assessment, a score of zero is given for that test.[1-3] The scoring system applies to all seven tests and the goal for each test is to achieve a score of three. Further, some tests have modifications for the different levels of scoring.[1,2] Three tests have clearing assessments that must be performed at the end of the test (Trunk Stability Push-up, Shoulder Mobility, and Rotary Stability).[2] The purpose of the clearing tests is to identify pain and if pain may be a factor in the discrepancies found. If the individual has pain when performing the clearing test, that person automatically receives a zero as a score for that test. [2] The highest score an individual can receive on the FMS is a twenty-one.[1,3]

<u>Deep Squat</u>

The first of the seven tests is the Deep Squat. When an individual completes a deep squat, he must be able to dorsiflex the ankles, flex the knees and hips, extend the thoracic spine appropriately, and flex and abduct the shoulders when holding the dowel overhead.[1] If the individual is unable to obtain a score of three, the individual performs the test again with a 2x6 plank under his heels.[1] It has been seen in other studies that differences found in scores of the deep squat were caused by altered mechanics in the hips, knees, and ankles and many of the differences found were between scores of three and one.[30] It has also been found that from the results of one study[11], failure to improve the FMS scores can be predicted by a low deep squat at initial collection of data.

To perform the deep squat test, the individual is instructed to stand with feet slightly wider then shoulder width apart so the instep of the foot is in line with the shoulders. Also, the subject's toes should be pointing straight ahead.[1] The individual then holds a dowel overhead with a wide grip, body position looks like a Y. The dowel should stay overhead with the shoulders flexed and abducted and the elbows fully extended.[1] Next, the individual is told to perform a slow, controlled squat until they reach below parallel with the floor (Figure 1a and 1b).[1]

A score of three is given if the individual can perform the test and maintain alignment of the dowel overhead, knees aligned over feet, femur achieves below parallel to the ground, and upper torso is parallel with tibia. If the individual cannot properly perform the test, a 2x6 foot board is placed under his feet and the test is done again. A score of two is given if the exercise is done successfully. A score of one is given if the individual cannot maintain balance and significantly deviates from the criteria to obtain a score of three. Zero is given to those individuals who experience pain.[1]

Hurdle Step

Next, the Hurdle Step test is done. It assesses functional mobility and stability at the hips, knees, and ankles.[1] This test should be done on both the left and right side. Before the subject performs the test, tibial height must be measured at the tibial tuberosity using the dowel to obtain height measurement. The hurdle cord will then be adjusted to that height. To perform the hurdle step, first the individual stands facing the hurdle with feet together and aligned to touch the base of the hurdle.[1] Further, the individual holds the dowel across the upper trapeziums.[1] Next, the individual is asked to step over the hurdle in a controlled manner and touch the heel to the floor.[1] After they complete a full touch of the heel to the floor, the individual returns to the starting position (Figure 2a and 2b).[1]

A score of three is given if the exercise is completely successfully, while maintaining proper balance and the dowel and string remain parallel. Two is given if alignment is lost between ankles, knees, and hips, if the dowel and string do not stay even, and movement is observed in the lumbar spine. A one is given if there is a complete loss of balance or the individual hits the hurdle with his foot. Zero is again given if there is pain at any point during the activity.[1]

In-Line Lunge

The In-Line Lunge is performed to assess ankle, knee, hip, trunk, and shoulder mobility and stability.[1,3] It should be done on both the right and left side. Prior to performing the in-line lunge, tibial length is measured from the floor to the tibial tuberosity. The same measurement taken from the Hurdle Step test should be used for the In-Line Lunge test.[1] The individual stands on the FMS board with the toe of one foot at the zero mark. The heel of the other foot is placed at the tibial height measurement. The dowel is placed behind the back, in-line with the spine. It should maintain contact with the head, thoracic spine, and sacrum throughout the entire movement. The hand opposite the front foot should hold the dowel behind the cervical spine, the other at the lumbar spine.[1] Next, the individual is asked to lower himself into a lunge position, touch knee to the board just behind the front foot, and then return to starting position (Figure 3a and 3b).[1]

When scoring this test, the front leg is the leg being scored. A score of three is given if the individual maintains dowel contact with lumbar spine, thoracic spine, and head, no obvious trunk movement, and the knee touches the board. A score of two is given if dowel does not maintain contact, movement is observed in the trunk, and the individual is unable to contact the ground when in the lunge position. One is given if a complete loss of balance is observed thus not allowing the individual to complete the test. A zero is given for any pain experienced through-out the exercise.[1]

<u>Active Straight-Leg Raise</u>

Cook[2,3] included the Active- Straight Leg Raise to assess active hamstring and gastrocnemius range of motion while maintaining a fixed pelvis and not allowing the opposite leg to lift from the ground.[2,3] This test should be done on both the left and right side. To perform this test the individual lies supine with head and arms flat on the floor and the FMS board perpendicular to the subject underneath the knees. Identification of the mid-point between the anterior superior iliac spine and the mid-point of the patella is made by the examiner and the dowel is placed at the mid-point.[2] This is used to identify which score is appropriate for the test. To receive a three, the individual should be maintain a fully extended knee and flex the hip so the lateral malleolus moves past the dowel.[2] The opposite leg must stay in full contact with the ground, both feet remain dorsiflexed and pointing towards the ceiling, and the individual's head should remain flat on the floor.[2] A score of two is given if the leg on the floor does not remain extended or that leg rotates to assist the opposite leg in performing the test. To achieve a score of two, the individual's lateral malleolus must be able to clear the dowel when it is placed between mid-thigh and patella. A score of one is given if the individual is unable to clear the dowel when it is place between mid-thigh and patella. Zero is given if there is pain.[2]

Shoulder Mobility

The Shoulder Mobility test assesses bilateral shoulder adduction with internal rotation and shoulder external rotation with abduction.[2,3] The individual must also have normal scapular mobility.[2,3] This test should be done on both the left and right side. The arm that is in shoulder abduction, flexion, and external rotation is that arm that should be scored. Prior to performing the Shoulder Mobility test, hand length is measured (in inches) using the dowel from the tip of the third finger to the most proximal wrist crease.[2] When performing the test, the individual should make his hands into a fist with thumbs inside the fist. Next, the individual is asked to maximally adduct, extend, and internally rotate one shoulder while maximally abducting, flexing, and externally rotating the other.[2] The position is held while the examiner measures the distance between the individual's hands at the closest point (Figure 5).

After completing the Shoulder Mobility test, the individual must perform a clearing assessment to rule out impingement of the shoulder (Figure 6).[2] This is done by placing the hand on the opposite shoulder then flexing the shoulder by bringing the elbow towards the forehead.[2]

If the individual experiences pain during the clearing test, a score of zero is then given.[2] A score of three is given when the fists are within one hand length apart; a two is given when the fists are within one and a half hand lengths; and a one is given if hands are farther than one and half hand lengths apart.[2] Zero is given if there is pain.

After completing the Shoulder Mobility test, the individual must perform a clearing assessment to rule out impingement of the shoulder.[2] This is done by placing the hand on the opposite shoulder then flexes the shoulder by bringing the elbow towards his forehead.[2] If the individual experiences pain during the clearing test, a score of zero is then given.[2] A score of three is given when the fists are within one hand length apart; a two is given when the fists are within one and a half hand lengths; and a one is given if hands are farther than one and half hand lengths apart.[2]

Trunk Stability Push-Up

The Trunk Stability Push-up is the only test that is individualized for males versus females. The test assesses spinal stability in a neutral position while performing a closed-kinetic chain push-up.[2,3] The individual lies on the floor in a prone position and then the hands are placed shoulder width apart at appropriate position. Women start with their thumbs aligned with the chin; men start with thumbs aligned at top of the forehead.[2] The individual then performs one push-up ensuring the chest and stomach come off the floor at the same time, the knees stay fully extended, and ankles remain dorsiflexed.[2] A score of three is given if the individual can complete the push-up correctly maintaining proper positioning. If the push-up cannot be performed with those hand positions, they are altered (men align with the chin; women align with the clavicle) and the push-up is performed again.[2] A score of two is given at this point if executed with no lag. A one is given if this position cannot be executed. This test requires a clearing assessment after.

The clearing assessment is done by performing a spinal extension maintaining pelvic contact with the ground and having full elbow extension (Figure 8).[2] If the individual experiences pain during the clearing test, a score of zero is then given.[2]

Rotary-Stability

The final test for the FMS is the Rotary-Stability test. This test requires neuromuscular control because the individual must flex the shoulder while extending the knee and hip on the ipsilateral side with minimal weight transfer to the stationary side.[2,3] This test is the only test within the FMS that may assess multi-plane motions. This test should be done on both the left and right side.

The individual starts in a quadruped position with the board parallel to the spine on the floor. The shoulders and hips are flexed to 90 degrees and the ankles are dorsiflexed on the floor to perform this test (Figure 9).[2] The individual's thumbs, knees, and feet must contact the outside of the board. Next, the individual is instructed to extend the hip and flex the shoulder on the ipsilateral side only enough to clear the floor (approximately 6 inches).[2] Then the individual flexes the hip and extends the shoulder on the same side so the elbow and knee touch, then resume the starting position.[2] If this is done accurately, a score of three is given. If this cannot be done by the individual, he is instructed to perform the same motions but with opposite leg and arm (Figure 10a, 10b, 10c, 10d).[2] A score of two is given when this is appropriately completely. If the individual is unable to complete the exercise without losing balance or not touching knee to elbow, a score of one is given. The clearing test is completed by having the individual rock his hips toward his heels. Then the individual is instructed to lower the chest and reach his hands in front of his body as far as possible (Figure 11). Zero is given if there is pain.[2]

Normative Values

When performing the FMS, the maximum score is a three for each test. Therefore, the maximum total score is 21.[1,3] However, not many individuals are capable of obtaining a perfect score. Cook[1,3] stated that the lower the score on the FMS, the greater the risk for injury. However, Cook has not provided a cut-off value for those at risk compared to those not at risk. Most researchers use the work done by Kiesel et al[10] to distinguish the cut-off values for their particular studies. The purpose of their study was to compare the FMS scores of professional football players to the incidence of injury through-out the season.[10] Kiesel et al.[10] created a receiver-operator characteristic curve to determine the appropriate cut-off score using the FMS by finding the mean FMS score of all subjects (16.9) to those who sustained an injury throughout the competitive season (14.3). The results of his study showed that maximum specificity (0.91) and sensitivity (0.54) was seen at a score of 14 out of 21.[10] This score of 14 has become the fundamental cut-off score used by many researchers.[6,7,10-13,22,23,30-33] However, Schneiders et al.,[7] stated that this cut-off value should be used with caution because the sample size was not diverse and suggests that future researchers have a more diverse athletic population. Schneiders et al.[7] evaluated a more diverse population (108 females and 101 males) and found a mean composite score of 15.7 for all subjects with no significant difference between males (15.8) and females (15.6). While, this study did not look at injury rates, Schneiders et al.[7], showed that the FMS can be used in mixed populations, which many studies have not demonstrated or evaluated. Another study used 622 healthy, middle-aged adults to provide normative data and identify variables that could affect FMS scores.[34] This study found the mean score for middle-aged men and women to be 14 (SD=2.8) and 14.5 (SD=2.8), respectively.[34] Variables found to negatively affect FMS scores were age, body composition (BMI), and varying levels of physical activity. [34] Other studies have also looked at injury rates and have indicated different cut-off values for the FMS.[6,9,15-17,21,22,25,32-35] Some studies suggest the cut-off value should be higher, 15.7[7], 16.5[8] and 15.5[9] were found to have higher specificity and sensitivity.

One study tried to predict injury rates among Division I women's basketball, soccer, and volleyball athletes using the FMS.[8] Brown[8] ran a receiver operator characteristic (ROC) curve analysis similar to the one conducted by Kiesel[10] and performed an odd ratios. The study found the cut-off score with the highest sensitivity (0.615) and specificity (0.738) to be 16.5 out of 21.[8] However, Brown[8] acknowledged many differences between his study and that of Kiesel et al.,[6] one of which being level of play between Division I female athletes and professional male football players. Conversely, a study done by Cuson[9] using the ROC curve analysis, found a total FMS score of 15.5 maximized sensitivity (0.50) and specificity (0.52).[9] In this study, male and female Division I basketball players were evaluated to determine the ability of the FMS to identify acute lower extremity injury.[9] Another study used a cut-off value of 16 for injury predictability in fire-fighters but provided no justification for this value.[14]

In addition, to finding normative values used within the FMS, Kiesel et al.[10] also compared professional football players' FMS scores to the likelihood of injury during the competitive season. He concluded that those athletes who had not sustained an injury acquired a mean score of 17.4; however, those who had sustained an injury throughout the season averaged a score of 14.3.[10] The study performed by Kiesel et al.,[6] looked at predictability among professional football athletes, which is not very representative of a total athletic population, so Chorba et al.[9] conducted a study that evaluated injury risk among female collegiate athletes. Chorba et al.,[23] found that of those who scored below a 14 on the FMS, 69% received an injury throughout the season. In addition, a cutoff score of 14 was used in a study on Marine Corp officer candidates.[7] It was found that risk of injury was 2 times higher among those with FMS scores ≤14.[7] Of those who scored ≤14, 45.8% ended up sustaining an injury. It was also seen that 30.6% of those who scored >14 also sustained an injury.[32] The FMS's ability to predict overuse injuries was inconclusive, had 12.5% of candidates with scores ≤14 sustained overuse injuries compared to 10.6% of those with scores >14.[32] They found no significant differences in FMS scores when comparing injured to non-injured athletes throughout their perspective seasons.[8] However, it was mentioned that after an odds ratio calculation was done using a cut-off of 16.5 out of 21, those who scored less than 16.5 were over 4 times more likely to be injured.[8]

Appal et al.[33] conducted a study testing a cutoff score of 14 for Division I male and female track and field athletes. There was no score difference between genders, but on average seniors (16.2±3.0) and juniors (16.2±2.8) scored higher than sophomores (14.7±3.0) and freshman (15.4±2.2).[33] FMS scores were similar for injured and non-injured athletes.[33] Results found that a FMS score of ≤14 was not a good predictor for track and field athletes. A more appropriate FMS score that maximized specificity and sensitivity could not be found, suggesting the FMS is not a strong injury predictor for athletes that mainly suffer from chronic and overuse injuries.[33]

O'Connor et al.[32] used a cutoff score of 14 to determine the FMS validity in 874 male Marine officer candidates. Candidates were separated into a 6-week short-cycle (SC) training group or a 10-week long-cycle (LC) training group. With a range of 6-21, the mean FMS score among all candidates was 16.6±1.7.[32] After review of all FMS scores, researchers further separated data into score groups of ≤14, 15-17, and ≥18 score groups. The risk of injury was significantly higher in the ≤14 score group, but also higher in the ≥18 score group for the 10-week training group .[32] When comparing injury and non-injury candidates, the scores for both were 16.7±1.7 with an odds ratio of 2.0 for sustaining a serious injury (95% CI = 1.0-3.8).[32] Sensitivity was 0.19 and specificity was 0.90.[32] Although sensitivity was low, it was concluded that scores of ≤14 were associated with higher risk of injury but further research was warranted.[32,33]

Although studies[6,9,15-17,21,22,25,32-35] have been done to provide researchers with a cut-off FMS score, ranging from 14 to 17, more research needs to be conducted. To date, the research done by Kiesel et al.[10] still appears to be the "gold standard" when determining a cut-off value for the FMS.

Reliability

Many studies involving the FMS have evaluated the intra-rater and inter-rater reliability.[6,16-18,20-22] These studies, however, lack consistency in the methods. Some studies evaluate only novice raters and others compare experience among raters. [16,17] Most researchers perform inter-rater and intra-rater reliability testing prior to the start of data collection to ensure satisfactory results.[6,16-21]

Inter-rater Reliability

Sorenson[19] completed an inter-rater reliability study and found that the median inter-rater reliability coefficient was acceptable (greater than 0.80) for all of the individual tests except for the rotary stability test (0.73).[19] Three studies have looked solely at the use of novice raters when evaluating the FMS. [16,17,22] Among novice raters, moderate to good reliability was reported (ICC$_{(3,1),}$[17]$_{(2,1)}$[22]=0.74[17], 0.76[22]). Other studies have tested reliability of the FMS using different levels of tester experience and knowledge. Good inter-rater reliability could be established at all levels of FMS expertise; however, those that have the most experience often times have the best reliability results.[6,18,21]

One study established good inter-rater reliability using two experts (FMS certified for more than 10 years) and two novices (FMS certified for less than a year), with excellent agreement on 14 out of the 17 tests[6]. Similar results were found ($ICC_{2,k}$= 0.72) in another study but different examiner expertise levels were used.[21] The researchers of this study used senior athletic training students, graduate athletic trainers, athletic trainers staffed at University of Toledo, and athletic trainers who had experience and were certified to score the FMS.[21] Another expertise comparison study was completed among 1) a physical therapy student who had performed over 100 FMS tests, 2) an Athletic Training faculty member with a PhD in Biomechanics and Movement Science, who had no experience with the FMS, 3) a physical therapy student who had no experience using the FMS.[18] Sufficient reliability between varying degrees of experience among the raters was found (ICC= 0.89).[18]

Although researchers use different methods to perform reliability studies, it is meaningful that they all find moderate to good reliability results. More research should be done to confirm the reliability studies that have already been completed.

Intra-rater Reliability

Intra-rater reliability studies have also been performed, which is very beneficial for future researchers and clinicians wishing to use the FMS. Generally the range of reliability has been seen from an $ICC_{(3,1)}$[17]$_{(2,1)}$[22]= 0.74- 0.91.[17-19,22] Brigle[21] found that those who have FMS experience and those who have the most clinical experience (regardless of FMS experience) have the best intra-rater reliability results ($ICC_{2,k}$= 0.91). Among other studies, Shultz, et al. [20] found sufficient results in intra-rater reliability (Kalpha= 0.61) and stated that changes in the scoring is a result of the individual being tested, not the rater.

Clinical Application

The main purpose of the FMS is to help clinicians, strength and conditioning coaches, and other members associated with athletic performance in assessing the chance of injury for each individual athlete tested.[1,3] Many clinicians have used the FMS in studies to predict injury rates among athletes.[8,10,31] Further, some researchers have taken the predictive value results and then incorporated it into an intervention program for athletes at risk of injury.[11-15] Due to the fact that Cook[1] encouraged clinicians to use the FMS as a predictor tool, it is important that sufficient research is available to add credibility to his claim.

Indicator of Athletic Performance

It has been stated that FMS scores may also be an indicator of athletic performance.[1,3] One study compared the relationship between the FMS and its ability to predict an individual's athletic performance as it relates to the one repetition max (1RM).[35] The researcher assessed strength, power, and velocity components of a movement and related them to the 1RM max and the FMS scores. The results of this study showed that FMS was not a good predictor of athletic performance and that one rep max had a better relationship to athletic performance.[35] One rep max was significantly correlated to all the dependent variables tested (club head swing velocity: r= 0.805; vertical jump: r= 0.869; 10m sprint: r= -0.812; 20m sprint: r= -0.872; and t-test completion time r= -0.758).[35] On the other hand, FMS had no significant correlation between any of the performance variables.[35] This information is viable for those looking to do more research on the FMS as a predictor of athletic performance because it does not show results in favor of the FMS, according to this one study.

<u>Intervention Programs</u>

Some researchers have taken the knowledge that a lower score indicates a higher chance of injury and then implemented an intervention program to correct the deficiencies.[11-15,36] The goal of these studies is to see if an intervention program focusing on the deficiencies will increase an individual's score on the FMS and lower the risk of injury.[11-15,36] A study performed using military soldiers as the subjects, implemented a functional training program that was designed to better their FMS scores and allow return to active duty at a faster rate.[12] The results of this study showed that implementation of a functional training program proved to be beneficial in raising the soldiers' FMS scores (mean improvement = 2.5 points).[12] It was noted that most improvements were found in the deep squat, active straight-leg raise, and shoulder mobility.[12] Another intervention study was done to evaluate if an off-season intervention program would improve scores of football players.[11] The results showed an improvement in FMS scores following the intervention (mean for linemen: pre- 11.8; post- 14.8 and mean for non-linemen: pre- 13.3; post- 16.3).[11] It must be noted that there was no control group for either study.[11,12]

One study examined the application of Kinesio Tape (KT) as a means of improving lower extremity FMS scores.[36] Sixteen Division II female varsity basketball players were tested, as well as 16 non-varsity female students.[36] All participants were first assessed performing the lower extremity FMS tests; the Deep Squat, Hurdle-step, and Inline Lunge. Scoring was modified to be more descriptive. Participants were randomly assigned into either the treatment or control group (n=16 each) [36] A second investigator applied KT (with 20-25% stretch and pressure downward to insertion) to the treatment group, immediately before the second test, along the Sartorius (hip flexion), Rectus Femoris (knee extension), Hamstrings (knee flexion), Patella, Tibialis Anterior (dorsiflexion), and Peroneus (plantar flexion).[36] All 32 participants were reassessed 2-4 days after the initial assessment. Results revealed a significant interaction for the Hurdle Step only, this may have been because it is a non-weight-bearing test. There were no differences in the Deep Squat and In-Line Lunge tests.[36]

Core Stability as it relates to the FMS

Core stability as it relates to the FMS has been evaluated in two studies.[14,15] This is an important factor to consider because many individuals fail to execute functional activities because of insufficient core strength and endurance.[1,2,14,15] One researcher attempted to establish a relationship between functional movement, core stability, and performance .[15] The researchers used a standard regression analysis to determine whether the FMS and core stability together could predict injury and performance success.[15] Core stability was measured using McGill's trunk muscle endurance tests (trunk flexor, back extensor, and right and left lateral trunk musculature).[15] The results showed that neither the FMS nor core stability could assist in predicting an individual's abilities when undergoing the performance tests used in this study.[15] However, the author mentions that the results seem odd because of the acknowledged importance of the core during the performance of the FMS tests.[15] The study done by Peate et al.,[14] used firefighters as subjects and assessed FMS scores and a core stabilization intervention program to lower the risk of injury due to the awkward positions they are placed in as a part of their job. Time lost from full duty activity decreased by 62% after an intervention program was completed. Also, total injury rates decreased to 44% with an implementation of an intervention program.[14]

More research needs to be done to show relationship between the FMS and core stabilization among injury rates in active individuals.

<u>Alternative Approach</u>

One study found in the literature took a different approach to scoring and analyzing the FMS. Frost et al.,[13] used firefighters and scored each individual on how they chose to perform each of the seven tests rather than how well they performed the tests. The protocol for the FMS instructs the evaluator to score based on how well the test is performed (i.e. no discrepancies in balance, muscle activation, and joint motion).[1, 17] Frost et al.,[13] however, chose not to give full descriptions of how to complete each exercise, rather evaluated movement patterns through each exercise.[1,2,13] There were two intervention groups and one control group. The average FMS scores did not change among any group or with use of any method following a 12 week training protocol.[13] However, there was change found pre- to post-intervention programs among the control group.[13] One flaw in the study could be that the researches decided to test how (i.e. technique) an individual performed the test, rather than using the standard protocol prescribed by Cook.[1,2,13]

Another study looked to investigate improving the precision of the FMS by implementing a 100-point scoring system.[37] The goal was to improve predictive values of the FMS by providing more information to be evaluated through itemized scoring. Thirty middle-school age subjects were recorded performing the FMS and assessed by FMS certified raters.[37] Examiners were able to view the tape as many times as possible. The 100-point scale scores the movement quality from 1 (unable to produce movement) to a maximum score, which differed for each test (indicating no compensatory movement to complete the pattern).[37] Each of the seven FMS movements were given weighted values (totaling 100 points) and each were considered as a lower-level or higher-level task. The inline lunge (20) was weighted highest, followed by the deep squat (18), hurdle step (18), trunk stability push up (12), rotary stability (12), active straight-leg raise (10), and then the shoulder mobility (8) test.[37] The 100 point scale ICC was 0.99 for the overall score on the FMS.[37] The researchers acknowledged the reliance of video-based assessment as a downfall of the 100-point scale and reliability may be inflated as a result. Suggested studies were to look at real-time examinations (without assessing by video) of experienced FMS raters to see if the 100-point scale could be performed with efficiency.

Other Pre-participation Screening Tools

Some researchers have made an effort to compose a different pre-participation screening tool that relates to the FMS.[24] The researchers have done five to ten years of testing using many different, unspecified battery tests, modifying them, and resulting with nine tests.[24] Frohm et al.,[24] used modified versions of the deep squat, in-line lunge, straight-leg raise, push-up, shoulder mobility, and the rotary stability, plus one test from the United States Tennis Association (single-leg squat) and two tests from within the research group (double-leg straight-leg raise and seated rotation) to configure a nine-test screening tool. The researchers decided to test each subject without shoes, which does not seem to represent an athletic environment in which shoes are always worn. Reliability of this testing protocol is good (ICC= 0.80).[24] However, it does add three additional tests and time for the clinician compared to the FMS, which is something a clinician may consider when choosing a predictive battery-tool such as this one and the FMS.

The study by O'Connor et al.[32] recorded physical fitness testing scores out of 300 points. Points were given based on performance doing pull-ups to exhaustion, two minute abdominal crunches, and a three mile run. Those candidates with scores <280 were found to be 2.2 times likely to have a FMS ≤14 and significantly more likely to incur injury.[32] Further, physical fitness scores were found to be just as predictive of future injury as FMS scores, and had a higher sensitivity.

An article by Kritz, et al.,[25] discussed the importance of static posture assessment protocols over that of functional movement protocols, such as the FMS. The authors asked the question of whether standing static posture will be predictive about how an athlete will move while performing his specific sport.[25] Based on the literature to date, no conclusions can be made as to whether a specific static posture will benefit athletic performance.[25] However, no research was found to say a certain static posture would hinder the athlete. This is of interest because static discrepancies may be beneficial to the sport in which that athlete is involved and this should be addressed before dynamic discrepancies are identified and interpreted.[25]

Further, no research has been found on the validity of the FMS, which would be extremely beneficial to clinicians hoping to use the tool. Also, it would allow better comparison between FMS and other functional screening tools.

CHAPTER III

METHODS

Subjects

Three hundred and thirty male and female subjects, between the ages of 17 and 24, were recruited from a division I varsity athletics program. Subjects were asked to wear athletic shorts, a fitted athletic shirt, and athletic shoes. Individuals were excluded if he or she had an acute boney, ligamentous, or soft tissue damage that inhibited his/her ability to complete the screen. Subjects were also excluded if he or she was suffering from a concussion, any neurological conditions, or an illness that could alter the results (i.e. common cold, ear infection, etc.). Ankle braces were not allowed to be worn during the study. All exclusion criteria were addressed following the completion of the study. Prior to participation, all subjects read and signed an informed consent form approved by the University's Institutional Review Board for the Protection of Human Subjects, which also approved this study.

Instrumentation

The Functional Movement screen kit was used for this study. This included a 2x6 foot board with half-inch increments, plastic tubing and elastic tubing to create a hurdle, and a 4-foot long dowel with half-inch increments used for the deep squat, hurdle step, in-line lunge, shoulder mobility, and active straight leg raise.

Procedures

Prior to the start of testing, each subject filled out a health history questionnaire. Height and weight measurements were also taken. Proper instructions for performing each of the seven FMS tests was given and the researcher demonstrated each test for the subject to ensure understanding.

All subjects completed the entire Functional Movement Screen testing protocol one time. The subjects were informed that the session would take approximately 15-20 minutes. Each test of the FMS was completed at most three times and the best score was used for the final tally. If the subject scored a three on the first attempt, no further attempts were necessary. Each test included in the FMS was evaluated on a four-point ordinal grading scale, 0-3, with a possible total score of 21. Each test was evaluated visually and scored by one researcher. The seven tests included: Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-Up, and Rotational Stability.

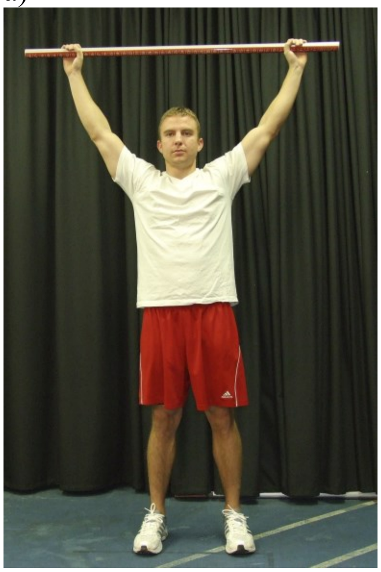
Deep Squat

To perform the deep squat test, the individual was instructed to stand with feet slightly wider then shoulder width apart so the instep of the foot was in line with the shoulders. Also, the subject's toes pointed straight ahead.[1] The individual then held a dowel overhead with a wide grip, body position looked like a Y. It was instructed that the dowel stayed overhead with the shoulders flexed and abducted and the elbows fully extended.[1] Next, the individual was told to perform a slow, controlled squat until they reached below parallel with the floor (Figure 1a and 1b).[1]

A score of three was given if the individual could perform the test and maintain alignment of the dowel overhead, knees aligned over feet, femur achieved below parallel to the ground, and upper torso was parallel with tibia. If the individual could not properly perform the

Figure 1a: Frontal view of the Deep Squat in the start position; b: Frontal view of the deep squat in the down position

a)



b)

test, a 2x6-foot board was placed under the heels of the individual's feet and the test was done again. A score of two was given if the exercise is done successfully. A score of one was given if the individual cannot maintain balance and significantly deviated from the criteria to obtain a score of three. Zero was given to those individuals who experienced pain.[1]

Hurdle Step

Next, the Hurdle Step test was done. This test was done on both the left and right side. Before the subject performed the test, tibial height was measured at the tibial tuberosity using the dowel to obtain height measurement. The hurdle cord was then adjusted to that height. To perform the hurdle step, first the individual stood facing the hurdle with feet together and aligned to touch the base of the hurdle.[1] Further, the individual held the dowel across the upper trapeziums.[1] Next, the individual was asked to step over the hurdle in a controlled manner and touch the heel to the floor.[1] After they completed a full touch of the heel to the floor, the individual returned to the starting position (Figure 2a and 2b).[1]

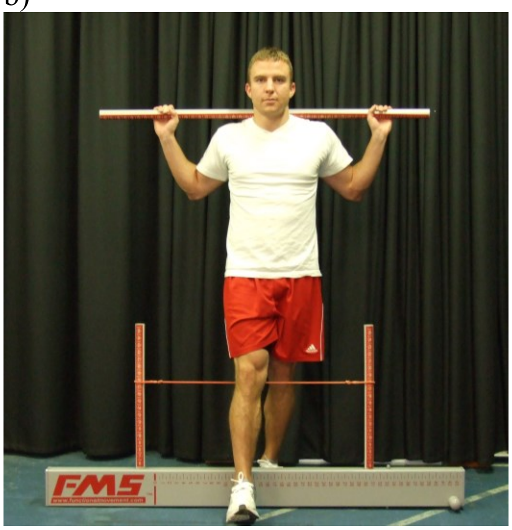
A score of three was given if the exercise was completed successfully, while maintaining proper balance and the dowel and string remained parallel. Two was given if alignment was lost between ankles, knees, and hips, if the dowel and string did not stay even, and movement was observed in the lumbar spine. A one was given if there was a complete loss of balance or the individual hit the hurdle with his foot. Zero was again given if there was pain at any point during the activity.[1]

In-Line Lunge

The In-Line Lunge was done on both the right and left side. The same measurement taken from the Hurdle Step test was used for the In-Line Lunge test.[1] The individual stood on the FMS board with the toe of one foot at the zero mark. The heel of the other foot was placed at the tibial

Figure 2a: Frontal view of the Hurdle step; b: Frontal view of Hurdle step with heel touchdown
a)

b)



height measurement on the board. The dowel was placed behind the back, in-line with the spine. Ideally, the dowel maintained contact with the head, thoracic spine, and sacrum throughout the entire movement. The hand opposite the front foot held the dowel behind the cervical spine, the other at the lumbar spine.[1] Next, the individual was asked to lower himself into a lunge position, touch knee to the board just behind the front foot, and then return to starting position (Figure 3a and 3b).[1]

When scoring this test, the front leg was the leg being scored. A score of three was given if the individual maintained dowel contact with lumbar spine, thoracic spine, and head, no obvious trunk movement, and the knee touched the board. A score of two was given if dowel did not maintain contact, movement was observed in the trunk, and the individual was unable to contact the ground when in the lunge position. One was given if a complete loss of balance was observed thus not allowing the individual to complete the test. A zero was given for any pain experienced through-out the exercise.[1]

Active Straight-Leg Raise

The Active- Straight Leg Raise was done on both the left and right side. The individual was told to lay supine with head and arms flat on the floor and the FMS board perpendicular to the subject underneath the knees. Identification of the mid-point between the anterior superior iliac spine and the mid-point of the patella was made by the examiner and the dowel was placed at the mid-point.[2] This was used to identify which score was appropriate for the test (Figure 4).

To receive a three, the individual had to maintain a fully extended knee and flexed hip so the lateral malleolus moved past the dowel.[2] The opposite leg must have stayed in full contact with the ground, both feet remained dorsiflexed and pointing towards the ceiling, and the

Figure 3a: Lateral view of the start position of In-line lunge; b: Lateral view of the down position of the In-Line lunge

a)

b)

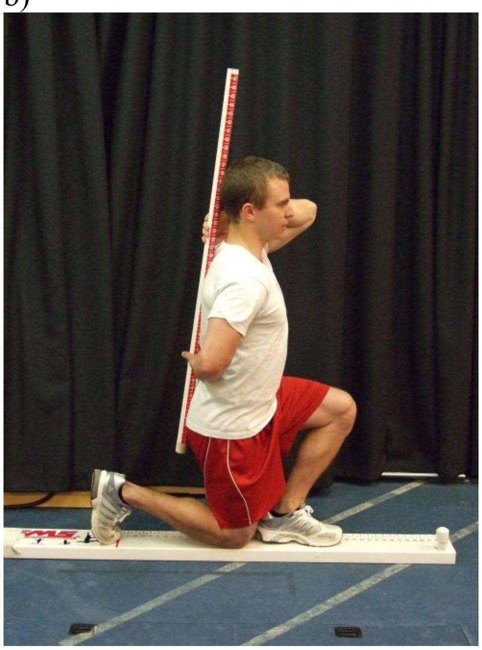
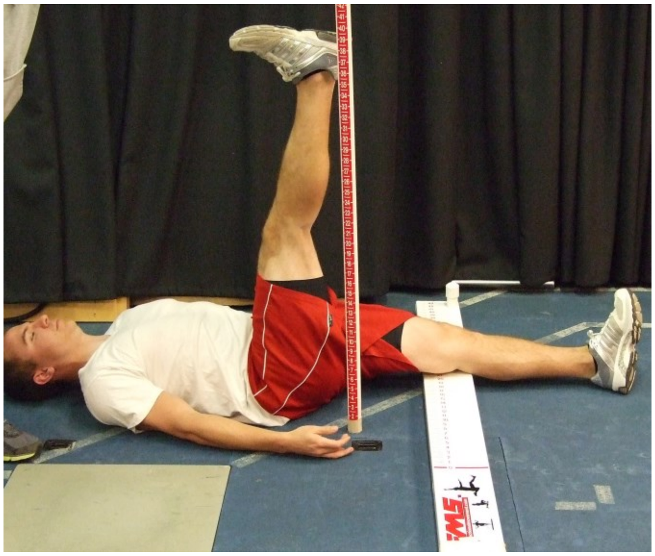


Figure 4: Lateral view of the Active Straight leg raise



individual's head remained flat on the floor.[2] A score of two was given if the leg on the floor did not remain extended or that leg rotated to assist the opposite leg in performing the test. To achieve a score of two, the individual's lateral malleolus must have cleared the dowel when it was placed between mid-thigh and patella. A score of one was given if the individual was unable to clear the dowel when it was placed between mid-thigh and patella. Zero was given if there was pain.[2]

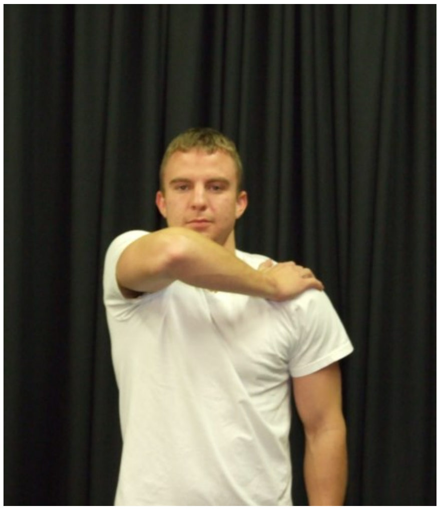
Shoulder Mobility

The Shoulder Mobility was done on both the left and right side. The arm that was in shoulder abduction, flexion, and external rotation was that arm that was scored. Prior to performing the shoulder mobility test, hand length was measured (in inches) using the dowel from the tip of the third finger to the most proximal wrist crease.[2] When performing the test, the individual made his hands into a fist with thumbs inside the fist. Next, the individual was asked to maximally adduct, extend, and internally rotate one shoulder while maximally abducting, flexing, and externally rotating the other.[2] The position was held while the examiner measured the distance between the individual's hands at the closest point (Figure 5).

After completing the Shoulder Mobility test, the individual performed a clearing assessment to rule out impingement of the shoulder (Figure 6).[2] This was done by placing the hand on the opposite shoulder then flexing the shoulder by bringing the elbow towards the forehead.[2] If the individual experienced pain during the clearing test, a score of zero was then given.[2] A score of three was given if the fists were within one hand length apart; a two was given if the fists were within one and a half hand lengths; and a one was given if hands were farther than one and half hand lengths apart.[2] Zero was given if there was pain.

Figure 5: Shoulder Mobility

Figure 6: Shoulder Mobility Clearing Test



Trunk Stability Push-up

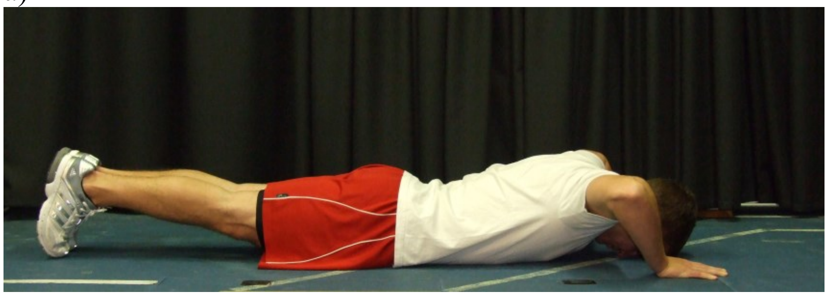
The Trunk Stability Push-up was the only test that was individualized for males versus females. The individual was told to lie on the floor in a prone position and then the hands were placed shoulder width apart at appropriate position. Women started with their thumbs aligned with the chin; men started with thumbs aligned at top of the forehead.[2] The individual then performed one push-up ensuring the chest and stomach came off the floor at the same time, the knees stayed fully extended, and ankles remained dorsiflexed (Figure 7a, 7b, and 7c).[2] A score of three was given if the individual could complete the push-up correctly maintaining proper positioning. If the push-up could not be performed with those hand positions, they were altered (men aligned with the chin; women aligned with the clavicle) and the push-up was performed again.[2] A score of two was given at this point if executed with no lag. A one was given if this position could not be executed. This test required a clearing assessment after. The clearing assessment was done by performing a spinal extension maintaining pelvic contact with the ground and having full elbow extension (Figure 8).[2] If the individual experienced pain during the clearing test, a score of zero was then given.[2]

Rotary Stability

The final test for the FMS was the Rotary-Stability test. This test was the only test within the FMS that assessed multi-plane motions. This test was done on both the left and right side. The individual started in a quadruped position with the board parallel to the spine on the floor. The shoulders and hips were flexed to 90 degrees and the ankles were dorsiflexed on the floor to

Figure 7a: Lateral view of the Push-up in down position; b: Lateral view of the Push-up in mid-phase; c: Lateral view of Push-up in up position

a)



b)

c)

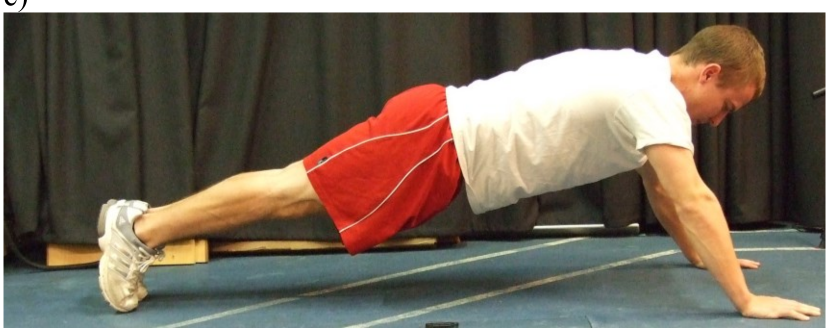


Figure 8: Push-up clearing test

perform this test (Figure 9).[2] The individual's thumbs, knees, and feet maintained contact on the outside of the board. Next, the individual was instructed to extend the hip and flex the shoulder on the ipsilateral side only enough to clear the floor (approximately 6 inches).[2] Then the individual flexed the hip and extended the shoulder on the same side so the elbow and knee touched; followed by another leg extension, shoulder flexion (Figure 10a and 10b). It ended when the subject resumed the starting position.[2] If this was done accurately, a score of three was given. If the individual could not do this, he was instructed to perform the same motions but with opposite leg and arm (Figure 10c and 10d).[2] A score of two was given when this was appropriately completed. If the individual was unable to complete the exercise without losing balance or not touching knee to elbow, a score of one was given. The clearing test was completed by having the individual rock his hips toward his heels. Then the individual was instructed to lower the chest and reached his hands in front of his body as far as possible (Figure 11). Zero was given if there was pain.[2]

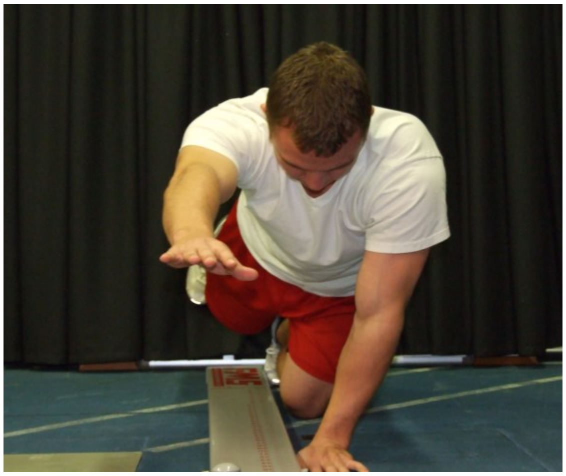
Statistical Analysis

Spearman correlation was conducted on all variables to evaluate the relationship between the variables. The Spearman correlation was calculated to determine the appropriate rotation to use for the exploratory factor analysis. Due to the large sample size, variables were considered correlated if there was a correlation greater than 0.5.[38] As a result of the Spearman correlation, principle axis factoring for the extraction method with a varimax rotation was performed through SPSS (Version 20) on the seven items from the Functional Movement Screen. An exploratory factor analysis was chosen for the statistical analysis because the research being done is in its "early" stage and this provides a tool for consolidating variables and generating hypotheses for future research studies.[38,39] An exploratory factor analysis is run when the researcher solely

Figure 9: Start position for Rotary Stability

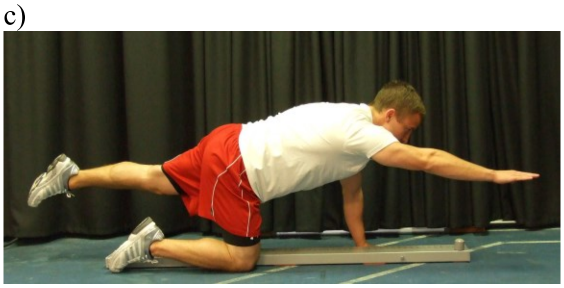
Figure 10a: Frontal view of the Rotary stability extended for score of 1; b: Lateral view of the of the Rotary stability for score of 1; c: Lateral view of the knee to elbow touch of the Rotary stability for score of 2; and d: Lateral view of the Rotary stability extended for a score of 2

a)



b)

c)



d)

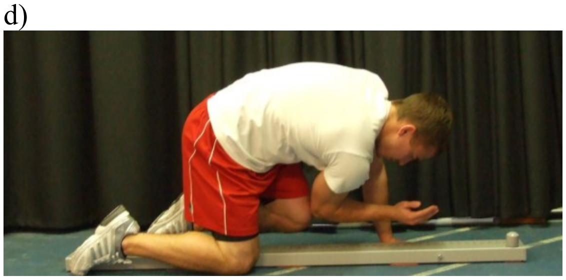
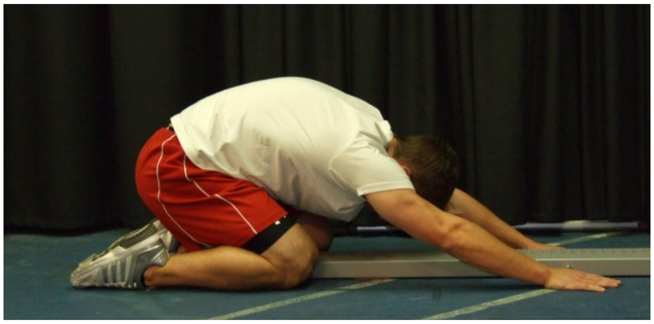


Figure 11: Rotary stability clearing test



wants to explore the data structure.[40,41] The seven tests were: Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-Up, and Rotational Stability. Factors were included if they had an eigenvalue greater than 1.0 and explained greater than 5% of the variance. For the analysis, the suppression threshold was set so that each test only loaded into 1 factor. As a secondary analysis, pearson product moment correlations were calculated comparing overall FMS scores to weight (kg), age (years), and height (cm) independently.

CHAPTER IV

RESULTS

Descriptive Statistics

Initially, 330 Division I varsity athletes were screened. Athletes who completed the screen immediately following sport participation were excluded (N= 6) and those who wore ankle braces or any high-top shoe were also excluded (N=2). Two athletes were excluded because they suffered from delayed onset muscle soreness that inhibited their ability to perform the screen. One athlete was removed from the study because of a wrist injury that prevented the completion of all seven tests. As a result, 319 subjects' data were analyzed for this study. Of those who completed the screen 283 (88.3%) had no previous knowledge of the FMS and 36 (11.3%) had previously done the screen. Age of subjects was 19.7 ± 1.4 years. Subjects' height was 178.1 ± 0.7 cm and weight was 73.7 ± 14 kg. As a secondary analysis, pearson product moment correlations were calculated on the overall FMS score and weight; FMS score and age; and FMS score and height. There was a significant correlation between overall FMS score and an individual's weight ($r = -0.22$, $p = 0.001$). There was no significant correlation found between overall FMS score and age ($r = 0.05$, $p = 0.93$) or between the overall FMS score and athlete height ($r = -0.10$, $p = 0.08$). Fourteen varsity sports were included in this study. Table 1 includes a complete breakdown of the different sports included in the study. The minimum, maximum, mean, and standard deviation for each of the FMS tests, and final scores can be found in Table 2. Table 3 shows the frequency of scores for each individual test.

Table 1: Number of athletes per sport included in analysis

Sport	Male	Female
Basketball	16	13
Soccer	23	31
Softball	NA	18
Field Hockey	NA	16
Baseball	41	NA
Wrestling	21	NA
Rowing	NA	22
Volleyball	NA	16
Swimming	2	1
Diving	9	3
Water Polo	NA	1
Track and Field	22	19
Cross Country	22	16
Tennis	7	9

Table 2: Descriptive statistics for the individual tests of the Functional Movement Screen tests and the total final score

Test	Minimum	Maximum	Mean	Standard Deviation
Deep Squat	1	3	2.4	0.6
Hurdle Step	0	3	2.3	0.6
In-Line Lunge	1	3	2.8	0.5
Shoulder Mobility	0	3	2.3	1.0
Active Straight-Leg Raise	1	3	2.6	0.6
Push-up	0	3	2.2	1.0
Rotary Stability	0	3	2.0	0.4
Total Score	9	21	16.6	2.0

Table 3: Frequency distribution on scores for each test of the Functional Movement Screen

	0	**1**	**2**	**3**
Deep Squat	0	11	160	148
Hurdle Step	1	16	197	105
Inline Lunge	0	5	70	244
Shoulder Mobility	33	17	90	177
Active Straight-Leg Raise	0	16	96	207
Push up	14	75	54	176
Rotary Stability	7	5	287	20

Factor Analysis

Based on the previously established criteria for the spearman correlation, none of the individual tests were significantly correlated with each other (Table 4).[38] As a result, principle axis factoring for the extraction method with a varimax rotation was performed on the seven items from the Functional Movement Screen. The exploratory factor analysis revealed that six of the seven items fit into three factors that met the criteria of an eigenvalue of 1.0 or greater and had a portion of more than 5% of the variance (Table 5). Factor 1 included deep squat, hurdle step, inline lunge, and active straight-leg raise tests and accounted for 9.8% of the variance. Factor 2 included the rotary stability test and accounted for 5.5% of the variance. Factor 3 included the push-up test and accounted for 5.1% of the variance. Overall, these 3 factors accounted for 20.4% of the variance for the entire functional movement screen. The different tests and the factor loadings are shown in Table 6. For this analysis, the suppression threshold was set at 0.3. At this threshold, the shoulder mobility did not load onto any factor.

Table 4: Spearman's rho correlations

	Deep Squat	Hurdle Step	Inline Lunge	Shoulder Mobility	Active Straight-Leg Raise	Push-Up	Rotary Stability
Deep Squat	1						
Hurdle Step	.16	1					
Inline Lunge	.20	.19	1				
Shoulder Mobility	.06	.06	.10	1			
Active Straight-Leg Raise	.21	.09	.16	.11	1		
Push-Up	-.01	.01	-.07	-.17	-.13	1	
Rotary Stability	.03	.08	.08	.06	.09	.05	1

Table 5: Cumulative variance and eigenvalue for the three retained factors from the exploratory factor analysis

	Factor 1	**Factor 2**	**Factor 3**
Proportion of Variance	9.8	5.5	5.1
Cumulative Variance	9.8	15.3	20.4
Eigenvalue	1.6	1.1	1.0

Table 6: Factor analysis rotated component matrix (factor loadings)

Test	Factor 1	Factor 2	Factor 3
Deep Squat	**.57**	.04	.01
Hurdle Step	**.31**	.29	.07
Inline Lunge	**.35**	.23	.07
Shoulder Mobility	.07	.27	.15
Active Straight Leg Raise	**.37**	.04	.21
Push-Up	.05	.00	**.53**
Rotary Stability	.04	**.41**	.06

CHAPTER V

DISCUSSION

There is currently no evidence in the literature indicating the rationale of test selection within the Functional Movement Screen (FMS). In addition, there has been no research on how the individual tests relate to one another. The current study evaluated all seven tests to determine how they relate to one another using an exploratory factor analysis. Interestingly, all exercises that emphasized lower extremity movements loaded into factor 1. These included the deep squat, hurdle step, inline lunge, and active straight-leg raise. Factor 2 included rotary stability alone. Factor 3 was solely the push-up test. The following paragraphs will provide some theoretical framework to explain the factor loading identified in this study.

Factor 1 is comprised of those tests that incorporate primarily lower body movements. The deep squat is performed in a closed kinetic chain manner and challenges bilateral mobility of the hips, knees, and ankles.[1-3] It primarily assesses hamstring and gastrocnemius flexibility. Secondary, this test assesses shoulder mobility by having the dowel placed directly overhead with extended elbows. As a result, this test challenges total body neuromuscular control and mechanics. The active straight-leg raise is performed in an open kinetic chain manner and challenges the ability to disassociate one leg from the other while maintaining core stability.[1-3] The active straight-leg raise also assesses mobility of the ankle, knee, and hip, similarly to the deep squat. Further, the active straight-leg raise significantly challenges hamstring flexibility through the full range of motion.[1-3] The in-line lunge places the lower and upper extremity in an unbalanced position while challenging the core to stabilize with the feet in a narrow base of support (tandem stance).[1-3] Furthermore, the test assesses hip, knee, ankle, and foot mobility and stability.[1-3] The hurdle step requires proper coordination and stability while one leg bears the body weight and the other leg travels over the hurdle. [1-3] This test challenges stability of the core and pelvis while bearing the load of the individual's body and also challenges mobility of the ankle, knee, and hip moving freely in space.[1-3] Similar to the active straight-leg raise and in-line lunge, this test requires disassociation of the legs while maintaining a stable core.

Theoretically, these four tests loaded together because they all test lower extremity mobility and stability.[1,2] All of the tests within this factor require proper mobility of the ankle, knee, and hip for the exercise to be done correctly. The active straight-leg raise and the hurdle step require movement through an open kinetic chain pattern; whereas, the deep squat and in-line lunge were completed in a closed kinetic chain. Nonetheless, the all loaded together. Further, the active straight-leg raise, hurdle step, and in-line lunge require one leg to disassociate from the other to perform the exercise.[1,2] All tests require extreme core stability in order to achieve the best movement pattern.

Factor 2 included the rotary stability test alone. Rotary stability is the only test within the FMS that has the individual in a quadruped position, which would be reasoning behind it loading onto a factor alone. The rotary stability test measures stability of the core, shoulders, and pelvis in a multi-plane movement pattern.[1-3] Also, this test requires ipsilateral movement of the upper and lower extremity simultaneously. Results of the current study identify 287 subjects (90%) scored a two on this test. Given the low variance among scores, it makes this test difficult to compare to the other six tests. It is thought that the low variance is due to the complexity of this test, which would lead it to be unlike any of the other tests. This is also reflected in the very low spearman correlations identified between the rotary stability test and the other six tests, which ranged from .03-.09.

The final factor for this study incorporated the push-up alone. This test is the only one that challenges the upper body in a closed-kinetic chain manner and assesses spinal stability in a neutral position.[1-3] It is plausible for the push-up to load on to a factor by itself because it is the only test that looks at stability using the upper body. Also, this is the only test that differentiates between males and females for the starting position of the push-up; no other test within the screen alters a test because of gender.[1-3]

The shoulder mobility test did not load into any factor because it did not meet the suppression threshold standard (0.3) established at the beginning of the study. This test is the only test that measures true shoulder range of motion without any other body movements assessed. Further, this is the only test that is objectively scored. The shoulder mobility test combines extension, internal rotation, and adduction on one extremity and flexion, external rotation, and abduction in the other.[1-3] Given the uniqueness of this test, one could plausibly understand that it would not load on to any of the aforementioned factors.

It is believed that any healthy, active individual should be able to effectively complete the FMS because it tests fundamental movement patterns that relate to what an individual does during training.[3] However, previous research has established that other items, such as age, weight, and activity level affect performance of the FMS.[34] We found that an individual's weight was highly correlated to the overall score of the FMS. A secondary analysis showed the correlation was equal to -.22. As weight increased performance on the FMS decreased. Current research supports that weight could be a confounding variable affecting FMS scores. A study done by Perry used 622 healthy, middle-aged adults to provide normative data and identify variables that could influence FMS scores.[34] It was found that variables that affected FMS scores were age, body composition (BMI), and varying levels of physical activity.[34] Those individuals who had a BMI greater than 30 had lower scores than those with BMIs less than 30.[34] Further, the study by Kiesel, et al, found similar results investigating weight differences among professional football players compared to final FMS scores.[11] Linemen scored significantly lower (11.8 ± 1.8) than those in other positions (13.3 ± 1.9).[11] This current study showed that as weight increased, mean FMS scores decreased $\rho = -.223$ ($p<0.05$).

Interestingly, there was no significant correlation found between overall FMS score and age (0.05). This is likely due to the fact that the population of this study was a small age range (17-24; mean: 19.7 ± 1.4 years). One would assume that with a greater age range, the correlation would be greater and those of an older age would not perform as well as those of a younger age. Finally, the no significant relationship was identified between the overall FMS score and athlete height (-0.10). We had subjects with a wide range of heights for subjects (149.9cm – 213.6cm; mean: 178.1 ± 0.7 cm) so we are confident that height does not have a significant impact on overall performance of the FMS.

Limitations

The purpose of this study was to determine the number of constructs that can be identified in the FMS and determine which of the individual tests load into each construct. However, some limitations of this study must be addressed. The population for this study was restricted to Division I varsity intercollegiate athletes which limits the ability to generalize these findings to other populations. Of those athletes screened, approximately 1/3 of the athletes were a member of the track and field/cross country team. That large of a sample coming from one sport could impact the results given the nature of track and field compared to other intercollegiate sports. Further, location of the screening was not strictly controlled. Most of the screening took place in the athletic training room with continuous traffic and distractions. Ideally, the testing should have been done in a controlled laboratory setting. Lastly, subjects wore a wide variety of footwear for the screening. They were instructed to wear “athletic shoes” but there was no control for type of shoe (stability, minimalistic etc…).

Future Research

This is the first study that attempts to establish a framework for the Functional Movement Screen. Future research will be geared towards running a confirmatory factor analysis on a different sample. The results of this study found that only 20% of the variance was explained and, currently, there is no research stating what would be an appropriate amount of explained variance when evaluating functional movement patterns. However, future research should investigate this further. A break down of the seven different tests as well as potential confounding variables (weight, height, injury, etc) should be performed to determine what would allow for the most amount of variance to be explained. Further, the results of FMS scores among different populations should be compared to the current results to assess similarities and differences. A comparison of results among different sports would allow clinicians to acknowledge which sports may be at a greater risk of injury prior to the start of a competitive season.

Conclusion

The Functional Movement Screen is becoming a very popular evaluation tool in many different athletic settings; however, there is no research identifying a theoretical framework for the FMS. Further, not all of the tests loaded on to a factor. The question of whether these are truly the most appropriate tests for the screen is left to be answered. More research needs to be done to find which tests are most important in determining risk of injury for athletes. With more empirical evidence to support or refute the FMS, it will benefit clinicians in determining whether to use the FMS as a pre-participation screening tool for intercollegiate athletes.

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APPENDICES

APPENDIX A:

DATA PROCEDURES FORM/CHECKLIST

Procedures Protocol

Before the Subject Arrives

1. Set-up FMS equipment (2x6 board, dowel, hurdle supplies)
2. Have pencil and clipboard with
   a. Grading form
   b. protocol for each test

When Subject Arrives

1. Ensure the subject is properly clothed (athletic shoes, athletic shorts, and fitted top)
2. Have subject read and sign informed consent
   A. Ensure the subject has met the inclusion criteria.
   B. Determine if the subject meets any of the exclusion criteria
   C. Get age, height, and weight
3. Have the subject fill out the health history questionnaire on Google Docs.
4. Ask if the subject has any questions prior to initiation of the tests

5. Measure tibial height by measuring from the floor to the top center of the tibial tuberosity (can use hurdle height too)

6. Begin testing protocol (read word for word to the subject)—Make sure you say the FULL instructions before the test is completed!

   a. Deep Squat:

   Equipment: Dowel, 2x6 board

   i. Stand tall with your feet approximately shoulder width apart and toes pointing forward
   ii. Grasp the dowel in both hands and place it horizontally on top of your head so your shoulders and elbows are at 90 degrees
   iii. Press the dowel so that it is directly above your head
   iv. While maintaining an upright torso, and keeping your heels and the dowel in position, descend as deep as possible

v. Hold the descended position for a count of one, then return to the starting position

vi. Do you understand the instructions?

*SCORE the movement

*Allow three attempts at the movement

*If a score of three is not achieved, repeat above instructions using the 2 x 6 under the client's heels

b. Hurdle Step: TIBIAL HEIGHT! *Score the hurdle step leg*

Equipment: Dowel, Hurdle

i. Stand tall with your feet together and toes touching the test kit

ii. Grasp the dowel with both hands and place it behind your neck and across the shoulders

iii. 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

iv. Touch the floor with the heel and return to the starting position while maintaining foot alignment with the ankle, knee, and hip

v. Do you understand the instructions?

*Score the moving leg

*Repeat the test on the other side

*Allow three attempts at the movement

c. In-Line Lunge: *score the front leg*

Equipment: Dowel, 2x6 Board

i. Step onto the 2x6 with a flat right foot and your toe on the zero mark

ii. The left heel should be placed at (The tibial measurement) mark

iii. Both toes must be pointing forward, with feet flat

iv. Place the dowel along the spine so it touches the back of your head, your upper back and the top of your sacrum

v. 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

vi. 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.

vii. Return to the starting position

viii. Do you understand these instructions?

*Score the movement

*Repeat the test on the other side

*Allow three attempts at the movement

d. Shoulder Mobility: *measure the top shoulder*

Equipment: Measuring tape

*Prior to completion of the test, measure hand length by measuring the distance from the distal wrist crease to the tip of the longest digit

i. Stand tall with your feet together

ii. Make a fist so your fingers are around your thumbs

iii. 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

iv. Do not "creep" your hands closer after their initial placement

v. 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

CLEARING TEST:

i. Stand tall with your feet together and arms hanging comfortably

ii. Place your right palm on the front of your left shoulder

iii. While maintaining palm placement, raise your right elbow as high as possible

iv. Do you feel pain? If pain, a score of zero is given

***Repeat the test on the other side**

e. Active Straight-Leg Raise:

Equipment: Dowel, measuring tape, 2x6 board

***tester instructions: find the position between the ASIS and the joint line of the knee and place the dowel at that position, perpendicular to the ground. If the malleolus passes the dowel, give a 3. If it does not, move the dowel between the knee joint and hip joint.**

i. Lay flat on your back with the back of your knees touching the floor and your toes pointing up

ii. Place both arms next to your body with the palms facing up

iii. With the right leg remaining straight and the back of your left knee maintaining contact with the floor, raise your right foot as high as possible

iv. Do you understand these instructions?

*Score the movement

*Repeat the test on the other side

f. Trunk Stability Push-up

i. Lie face down on your stomach with your arms extended overhead and your hands shoulder width apart

ii. Pull your thumps down in line with the _____ (forehead for men, chin for women)

iii. With your legs together, pull your toes toward the shins (dorsiflex), maximally extend your knees, and raise your elbows off the ground

iv. While maintaining a rigid torso, push your body as one unit into a pushup position

v. Do you understand these instructions?

*Score the movement

* Allow three attempts at the movement

*Repeat the instructions with appropriate hand placement, if necessary

Tester instructions: If the subject is unable to perform the action, men should move their hands to align with the chin and women should move their hands to align at shoulder level

CLEARING TEST:

i. While lying on your stomach, place your hands, palms down, under your shoulders

ii. With no lower body movement, press your chest off the surface as much as possible by straightening your elbows

iii. Do your understand these instructions?

iv. Do you feel any pain? If pain, a score of zero is given

g. Rotary Stability *measure the upper limb* (need a soft surface)

Equipment: 2x6 Board

i. Get on your hands and knees over the 2x6 board so your hands are under your shoulders and your knees are under your hips

ii. The thumbs, knees, and toes must contact the sides of the 2x6 board, and the toes must be pulled toward the shins

iii. At the same time, reach your right hand forward and right leg backward, like you are flying

iv. Then without touching down, touch your right elbow to your right knee directly over the 2x6

v. Return to the extended position

vi. Return to the start position

vii. Do you understand these instructions?

*Score the movement

*Repeat the test on the other side

Tester instructions: if a score of three is not attained, have the person perform a diagonal pattern using the opposite shoulder and hip in the same manner. During this diagonal variation, the arm and leg need not be aligned over the board; however, the elbow and knee DO need to touch over it.

*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

CLEARING TEST:

i. Get on all fours, rock your hips toward your heels

ii. Lower your chest to your knees, and reach your hands in front of your body as far as possible. (prayer position)

iii. Do you understand these instructions?

iv. Do you feel pain? If pain, a score of zero is given

APPENDIX B

DATA COLLECTION FORM/HEALTH HISTORY QUESTIONAIRE

Underlying Theoretical Components of the Functional Movement Screen Scoring Sheet

Date_______ Consent Form Signed______ History Form Completed______

Height________ Weight________ Age______ Gender____

Tibial Height _______ Hand Length _______ Prior FMS_____

TEST		RAW SCORE	FINAL SCORE	COMMENTS
Deep Squat				
Hurdle Step	**R**			
	L			
Inline Lunge	**R**			
	L			
Shoulder Mobility	**R**			
	L			
Impingement Clearing Test	**R**			
	L			
Active Straight-leg Raise	**R**			
	L			
Trunk Stability Push-up				
Press-up Clearing test				
Rotary Stability	**R**			
	L			
Posterior Rocking Clearing Test				
Total				

The Functional Movement Screen

Please fill this form out to the best of your ability. All information will be kept confidential

Research Study I.D. #

Please provide your full name.

What is your sex?

- Male
- Female

How old are you?

Are you currently suffering from any illness (i.e. common cold, ear infection, sinus infection)?
please indicate your current condition if you have one.

Do you suffer from any condition or injury that may affect your balance?
If so, please explain in detail.

Have you suffered from any injury within the past six months that caused you to miss a day

of exercise or training? (i.e. joint sprains, muscle strains, fractures)
If so, please explain in detail.

Do you currently have any orthopedic problems? (i.e. joint sprains, muscle strains, fractures)
If so, please explain in detail.

Have you ever had any major surgeries? (Excluding dental)
If so, please explain in detail

Are you currently undergoing any rehabilitation for a current or past injury?
If so, please explain in detail.

How often a week do you participate in physical activity?
Physical Activity can be defined as weight training, walking, running, jogging, swimming, etc

- I do not participate in physical activity
- About once a week
- 1-2 times per week
- 3-4 times per week
- 5 -6 times per week
- I participate in physical activity everyday

When participating in physical activity, on average, how long is each training session?

- I do not participate in physical activity
- 10-20 minutes
- 20-30 minutes
- 30-40 minutes
- 40-50 minutes
- 60 or more minutes

When participating in physical activity, how would you rate the intensity of each training session

- I do not participate in physical activity
- light intensity
- moderate intensity
- high intensity
- Very rigorous intensity

Please list the activities you participate in for physical activity.
(i.e. bike riding, trail running, elliptical, etc)

Are you or is there a chance you could currently be pregnant?

- I am a male
- Yes
- No

Are you a Varsity Athlete at Indiana University?
If yes, please list the sport and position/event.

Did you participate in Varsity athletics in High School, Junior College, or at another University?

- Yes
- No

If you answered yes to the previous question, what sport and position did you participate?

Do you participate in club or intramural sports?

- Yes
- No

If you answered yes to the previous question, what sport and position did you participate?

Could we contact you in the future for further questions regarding your Functional Movement Screen results?

If so, please provide your name and email address below

Submit

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APPENDIX C

RELIABILITY DATA

Intrarater Reliability

ICC (2,1) - Total

												Mean	SD
					ICC (2,1) =	0.85					Day 1	14.6	2.27
bms	tms	ems	k	n	SEM =	0.961		SD (the largest)			Day 2	15.1	2.51
10.670	1.250	0.810	2.000	10.000				2.5					
			A3-C3		9.860		SQRT(I5)	0.384251					
			A3+(D3-1)*C3		11.480		1-F3	0.148					
			D3*(B3-C3)/E3		0.088								
			F5+F6		11.568								

ICC (2,1) - DS

												Mean	SD
					ICC (2,1) =	0.80					Day 1	2.1	0.74
bms	tms	ems	k	n	SEM =	0.31		SD (the largest)			Day 2	2.3	0.68
0.911	0.200	0.089	2.000	10.000				0.7					
			A3-C3		0.822		SQRT(I5)	0.442552					
			A3+(D3-1)*C3		1.000		1-F3	0.196					
			D3*(B3-C3)/E3		0.0222								
			F5+F6		1.022								

ICC (2,1) - HS

												Mean	SD
					ICC (2,1) =	0.57					Day 1	2.1	0.57
bms	tms	ems	k	n	SEM =	0.393		SD (the largest)			Day 2	2.2	0.63
0.561	0.050	0.161	2.000	10.000				0.6					
			A3-C3		0.400		SQRT(I5)	0.654529					
			A3+(D3-1)*C3		0.722		1-F3	0.428					
			D3*(B3-C3)/E3		-0.0222								
			F5+F6		0.700								

ICC (2,1) - IL

												Mean	SD
					ICC (2,1) =	0.16					Day 1	2.3	0.48
bms	tms	ems	k	n	SEM =	0.643		SD (the largest)			Day 2	2.5	0.71
0.422	0.200	0.311	2.000	10.000				0.7					
			A3-C3		0.111		SQRT(I5)	0.918607					
			A3+(D3-1)*C3		0.733		1-F3	0.844					
			D3*(B3-C3)/E3		-0.0222								
			F5+F6		0.711								

ICC (2,1) - SM

												Mean	SD
					ICC (2,1) =	0.95					Day 1	2	0.94
bms	tms	ems	k	n	SEM =	0.208		SD (the largest)			Day 2	1.9	0.99
1.828	0.050	0.050	2.000	10.000				0.9					
			A3-C3		1.778		SQRT(I5)	0.230756					
			A3+(D3-1)*C3		1.878		1-F3	0.053					
			D3*(B3-C3)/E3		0								
			F5+F6		1.878								

ICC (2,1) - ASLR

												Mean	SD
					ICC (2,1) =	0.88					Day 1	2.4	1
bms	tms	ems	k	n	SEM =	0.316		SD (the largest)			Day 2	2.4	0.84
1.533	0.001	0.111	2.000	10.000				0.9					
			A3-C3		1.422		SQRT(I5)	0.351147					
			A3+(D3-1)*C3		1.644		1-F3	0.123					
			D3*(B3-C3)/E3		-0.022								
			F5+F6		1.622								

ICC (2,1) - TSPU

												Mean	SD
					ICC (2,1) =	0.82					Day 1	1.9	1.1
bms	tms	ems	k	n	SEM =	0.426		SD (the largest)			Day 2	2.1	0.99
2.000	0.200	0.200	2.000	10.000				1					
			A3-C3		1.800		SQRT(I5)	0.426401					
			A3+(D3-1)*C3		2.200		1-F3	0.182					
			D3*(B3-C3)/E3		0								
			F5+F6		2.200								

ICC (2,1) - RS

												Mean	SD
					ICC (2,1) =	0.99					Day 1	1.8	0.42
bms	tms	ems	k	n	SEM =	0.031		SD (the largest)			Day 2	1.8	0.42
0.356	0.001	0.001	2.000	10.000				0.42					
			A3-C3		0.355		SQRT(I5)	0.074848					
			A3+(D3-1)*C3		0.357		1-F3	0.006					
			D3*(B3-C3)/E3		0								
			F5+F6		0.357								

Interrater Reliability

FMS test	**Pearson-R Value**
Deep Squat	0.78
Hurdle Step	0.75
In-Line Lunge	0.25
Shoulder Mobility	0.94
Active SLR	0.95
Trunk Stability Push-up	0.94
Rotary Stability	0.66