A Thesis

entitled

The Reliability of the Functional Movement Screen

by

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Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Exercise Physiology

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August 2010
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An Abstract of

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May 2010

The focus of injury prevention generally lies within recognizing muscular strength and flexibility imbalances. One method of detecting muscular strength and flexibility imbalances is the Functional Movement Screen<sup>TM</sup> (FMS<sup>TM</sup>). The purpose of this study is to investigate the reliability of the FMS<sup>TM</sup> since only one previous study has investigated the reliability of this screening tool. Three subjects were recruited and were videotaped performing the FMS<sup>TM</sup> test. Thirty seven evaluators were divided into one of four groups, based on level of experience. The evaluators watched each video-subject perform each exercise three times. The evaluators then came back a week later and watched the video-subjects again, but in a different order. The results demonstrated significant Group by Time differences ($F_{3,33} = 3.67; p = .022$). The main effect for Time also was significant ($F_{1,33} = 4.55; p = 0.041$). Overall, the raters scored the video-subjects higher on Day 2 (13.77±0.98) than they did on Day 1 (13.46±0.92). As hypothesized, the individuals who were classified as being FMS<sup>TM</sup> experts had the highest rate of reliability (ICC = .946). Therefore, reliability of using the FMS<sup>TM</sup>, increases as clinical and FMS<sup>TM</sup> experience increases. These results indicate that the FMS<sup>TM</sup> has high reliability and can be confidently used by trained individuals.
For Debbie Binkley, my mother and best friend who taught me the meaning of unconditional love and support. Everything I have accomplished, from on the field, to the basketball court, and in the classroom, I owe to you. Thank you for always being in my corner. “Three fingers always and forever.”
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List of Abbreviations

ABC...Activities-Specific Balance Confidence Scale
ACL...Anterior Cruciate Ligament
ANOVA...Analysis of Variance
ASIS...Anterior Superior Iliac Spine
ATEP...Athletic Training Educational Program
BESS...Balance Error Scoring System
BOC...Board of Certification
DGI...Dynamic Gait Index
DHI...Dizziness Handicap Inventory
FMS\textsuperscript{TM}...Functional Movement Screen\textsuperscript{TM}
FSST...Four Square Step Test
GIRD...Glenohumeral Internal Rotation Deficit
ICC...Intraclass Correlation Coefficient
PEP...Prevent Injury and Enhance Program
ROM...Range of Motion
SEBT...Star Excursion Balance Test
SIPTP...Sports Injury Training Program
TUG...Timed Up and Go Test
Chapter 1

Introduction

1.1 Background

Research has been able to identify several intrinsic risk factors for athletic injuries that range from pathomechanical issues, to ligamentous laxity and other anatomical abnormalities. The focus of injury prevention generally lies within recognizing muscular strength and flexibility imbalances, but there are several other factors that may contribute to injury rates among athletes. These include inherent variables such as a person’s age, gender, and anatomy. Other factors that can contribute to injury rates include the biomechanics, fitness level, and altered central motor control of the athlete. However, muscular imbalances, which include muscular weaknesses and tightness, as well as general flexibility, are two primary indicators that athletic trainers rely on for detecting potential injury because they are easily identified and can be performed during pre-participation physicals.

Currently, rehabilitation has shifted away from targeting isolated muscles and moved towards a more comprehensive examination of various muscle imbalances throughout the body. For example, a physical therapist or athletic trainer who is treating a baseball pitcher for medial elbow pain might incorporate more core strength exercise s
and hip flexor stretches as opposed to just treating the source of the pain at the elbow. This means that researchers are now considering comprehensive movement patterns as a way to predict injuries. Plisky et al. hypothesized that tests assessing the multiple domains of function (balance, strength, and range of motion) may improve the accuracy of identifying athletes at risk for injury.

The Functional Movement Screen (FMS) is a tool that quantitatively measures movement patterns as a way to detect performance asymmetries. However, there is very little information regarding the FMS and its reliability. According to the developers of the FMS, it is a “ranking and grading system that documents movement patterns that are critical to normal function.” The test may best be performed during pre-participation exams and consists of seven movement patterns or tests. The tests are graded and a total score is then calculated at the completion of all seven movements with a total available score of 21 (each test gives a score of 0-3). A score of less than three on a test indicates that a person may have some type of muscular imbalance that could potentially lead to injury. A score of zero is given if the subject experiences pain during that particular test movement. One study has suggested that athletes who score 14 points or higher are considered to have no serious movement imbalances.

Although the FMS is widely used clinically as a means of measuring muscular imbalances and flexibility deficits, there is little research that backs up these claims. Specifically, there is very little investigation of the reliability of this screening tool among practicing clinicians and researchers. In this study, we aim to investigate the reliability of the FMS, specifically, if researchers can evaluate the same subject and give them a consistent FMS score. There are also two different categories of reliability
that will be measured: Intra-tester Reliability and Inter-tester Reliability. The first category of reliability is measuring how well each tester or rater, can consistently or repeatedly get the same resulting score. The inter-tester reliability, meaning between raters, is measuring how closely different raters, who are looking at the same subject, can come to the same resulting score. The inter-tester reliability in this study will focus on whether or not the experience level of the raters has any effect on the ability to consistently assign the same FMS™ score for each subject that is viewed.

Currently, there are only two studies that have investigated the reliability of the FMS™. A study conducted by Anstee et al⁵ used eleven certified athletic trainers or physical therapists to score ten different subjects who were videotaped performing the Functional Movement Screen™. The results showed that single testers could grade consistently overtime, but the inter-tester reliability was not as strong. Lower inter-tester reliability coefficients were seen between testers during the dynamic exercises. The testers were able to give the same grade on the more static exercises, but did not always agree on the score that should be given for the dynamic tests. The current study will focus more on the effects that experience plays on the reliability of the FMS™. Clinical experience, as well as experience in using the FMS™ could effect the reliability of this screening tool. A second study that was just recently published in 2010 by Minick et al⁶, which investigated the interrater reliability of the FMS™. This study recruited forty subjects who were video-taped performed the FMS™. The videos were then scored by four raters, two of which were considered to be FMS™ experts, and two that were novices. The results showed that FMS™ testing can be reliable when individuals are assessing the subjects.
1.2 Statement of Problem

The FMS\textsuperscript{TM} has been in practice since 1995, and is accepted as a good means of quantitatively measuring muscular strength and flexibility imbalances. However, there is very little information about the test itself, and if it is an accurate way of predicting injuries. Since there is so little information about the test, there have not been many studies that have addressed the reliability of the FMS\textsuperscript{TM}. Although a few previous studies has investigated the reliability of FMS\textsuperscript{TM}, there is no current research has examined how clinical experience plays a role in the reliability of this test. Therefore, as the test is becoming a more popular method of injury prediction, establishing the reliability of this test has become an important factor as well.

1.3 Purpose Statement

The purpose of this study is to determine the inter-tester and intra-tester reliability of the FMS\textsuperscript{TM} between senior athletic training students, post-certification graduate athletic training students, certified athletic trainers, and other clinicians who have experience using the FMS\textsuperscript{TM}. This study will investigate if clinical experience and experience with FMS\textsuperscript{TM} contributes to the reliability of the test.

1.4 Hypothesis

1. The intra-tester reliability values will be high (> 0.70) among all levels of experience.
2. The group with the most experience with using the FMS \textsuperscript{TM} will have the highest intra-tester reliability.
3. Certified athletic trainers and the post-certification athletic training graduate students will demonstrate stronger intra-tester reliability compared to the senior student athletic trainers.

4. There will be significant differences in the reported FMS™ scores evaluated between the four groups.

1.5 Limitations

One limitation of this study is that there maybe variability within the defined groups. For example, a certified athletic trainer might have just graduated from graduate school, or might have been practicing for 15 -20 years. Another example is that the “most experienced group” is comprised of different types of clinicians ranging from athletic trainers to researchers. The study also has to assume that raters will not introduce any personal biases and will be honest in their answers. Also, there it will be difficult for the rater to give the video subjects a score of ‘0’ because they cannot ask the subjects if they have pain with each test.

1.6 Significance of the Study

The significance of this study is that by determining if the FMS™ has a high rate of reliability, researchers can generalize that almost anybody can use the FMS™ as a way to assess muscular strength and flexibility imbalances. Therefore, the same tester can look at the same subject and grade them consistently each time. This also means that two different testers can look at the same subject and can give them similar scores. If the tool is determined to be reliable, then there will be significant clinical relevance to this study.
Clinicians would have another tool that they can use for injury prediction by recognizing the muscular imbalances before they are able to contribute to injury. From this information, muscular imbalance and injury trends could be examined among certain types of sports at certain ages and protocols can be developed to help correct these deficits at younger ages.

1.7 Definitions

*Inter-tester Reliability*: Used to assess the degree to which different raters/observers give consistent estimates of the same phenomenon\(^7\).

*Intra-tester Reliability*: Used to assess the consistency of a measure from one assessment session to another\(^5\).
Chapter 2

Literature Review

2.1 Introduction

At the beginning of each school year, there are over 6 million high school and college athletes that undergo a pre-participation physical in order to compete in athletics. Normally, these exams include a thorough medical history, orthopedic screening, visual tests, height and weight measurements, heart rate, and blood pressure of the athlete. However, more and more physicians are starting to incorporate preventative measures in order to identify potential injury for the athlete. According to the American Medical Association, the purpose of a pre-participation exam is to "1) to identify those athletes who have medical conditions that place them at substantial risk for injury or sudden death and disqualify them from participation or ensure they receive adequate medical treatment before participation and 2) to not disqualify athletes unless there is a compelling medical reason." Although muscular and flexibility imbalances will not lead to sudden death, these deficiencies can lead to a substantial risk for injury. Therefore, every pre-participation physical should include a screen that detects these imbalances. A study by Carek et al, looked at effectiveness of the pre-participation physical and concluded that pre-
participation exams generally fail in this attempt to prevent injuries. Now that researchers are producing more evidence that injury is linked to strength disorders, it is important that physicians and athletic trainers screen for these imbalances during pre-participation physical exams.

One way to discover these muscular asymmetries is through the Functional Movement Screen™. FMS™ is a quantitative approach to identifying muscular asymmetries in both the lower and upper extremities. The test is composed of several different fundamental movements that can help clinicians identify those who are at risk for injury. Because this test incorporates the lower and upper extremities, as well as places subjects in fundamental movement patterns, it has been a widely utilized tool during pre-participation physicals as a means of injury prevention. However, no study has investigated the reliability of the screening tool and if the clinician’s experience level influences the reliability of the Functional Movement Screen™.

The first test of the Functional Movement Screen™ is the deep squat which is used to assess symmetrical and functional mobility of the hips, knees, and ankles. This is a closed kinetic chain exercise (which will be described in Chapter 3) that can give insight into several possible clinical implications. The first implication is that poor performance on this test can indicate that the athlete has limited mobility in the upper torso. This limited mobility can be attributed to poor glenohumeral and/or thoracic spine mobility⁹.

The second test is the hurdle step which is performed bilaterally. Like the deep squat, this test assesses the functional stability of the hips, knees, and ankles. However, this test also allows the clinician to see imbalances during the stepping motion. If
imbalances are seen on this test, this could be an indication that there is poor stability of the stance leg, or that there is poor mobility of the step leg. This test combines closed kinetic chain components, as well as open kinetic chain components.

The in-line lunge test assesses hip and trunk stability/mobility, as well as ankle and knee stability, and quadriceps flexibility. This test also gives insight into the individual’s ability to perform rotational, deceleration, and lateral movements. This test can indicate that the individual has poor hip mobility of either leg, as well as adductor weakness and abductor tightness. For example, tightness of the rectus femoris on the stance leg might illicit poor results.

The fourth test is for shoulder mobility, which includes the scapula and thoracic spine. The test combines shoulder internal rotation with adduction and shoulder external rotation with abduction. This test has many implications for overhead athletes. It is widely accepted that overhead athletes have exaggerated external rotation and limited internal rotation. This internal rotation deficit has been linked to the high rate of elbow and shoulder injuries that are seen in overhead athletes. Although most clinicians focus on the individual’s internal and external rotational deficits, poor performance on this test might also indicate that is some type of scapulothoracic dysfunction, as well as shortening of the pectoralis major/minor and latissimus dorsi muscles.

The fifth test is the active straight leg test that will give the clinician a good idea of the individual’s hamstring flexibility, as well as their lower abdominal stability. The next test is the push-up test which is aimed to investigate the individual’s trunk stability. Poor performance on this test would indicate a need to work on the individual’s trunk stabilizers. Finally, the rotational stability test looks at the individual’s trunk stability in
both the sagittal and transverse planes during asymmetric upper and lower extremity movement.

2.2 Related Topics

Most people have a dominant or preferred side of their body, which can lead to muscular imbalances. These muscular asymmetries and flexibility differences between the two halves of the body are generally considered to be risk factors for injury. Obvious candidates for these asymmetries are baseball pitchers, who have a dominant throwing arm and soccer players who have a pre-preferred kicking leg. A study by Rahnama et al. 13 looked at a comparison between preferred and non-preferred strength and flexibility in the legs of soccer players. The authors recognize that muscular asymmetries could lead to injury, so they wanted to investigate whether or not having a preferred leg can lead to these asymmetries. The investigators recruited forty-one soccer players who were injury free at the time of the testing. Strength was measured bilaterally for both the knee flexors and extensors with an isokinetic dynamometer. Flexibility of the subject’s hip was measured using a standard goniometer and was also performed bilaterally. The results showed that there were no significant differences in knee extensor strength, but there was significant weakness in the preferred leg during knee flexion at 2.09 rad/s. There were also no significant differences in hip flexibility when compared bilaterally. However, the authors believe that the knee flexors were weaker in the dominant leg due to the different actions of each leg during a kick. They concluded that this slight difference is enough to cause muscular asymmetries that could lead to injury.
Pre-participation physical exams not only make coaches and medical personnel aware of current injuries, but give them insight to potential injuries that might have otherwise gone undetected until the injury occurred. One way to screen for these potential injuries is to examine the athlete’s flexibility, strength, and muscular endurance. A study conducted by Kibler et al\textsuperscript{14}, looked at these musculoskeletal factors in two thousand one hundred seven athletes. The investigators grouped the subjects according to sport and sex in hopes of finding a trend between male and female athletes who participated in varying sports. From this study, they concluded that females were more flexible than males in all categories, but males were stronger than females in all strength measurements. Athletes that participated in overhead throwing sports were tighter on their dominant side compared to their non-dominant arms. More specifically, overhead athletes, regardless of sex, had significant internal rotation deficits in the shoulder. Athletes who are considered to participate in lower extremity sports demonstrated tighter leg muscles compared to overhead athletes. This study was able to determine that flexibility and muscular strength is sport specific. From this information, future studies can develop more sport specific musculoskeletal screenings in hopes of preventing injury.

A study by Croisier et al\textsuperscript{15}, advanced the pre-participation screening, by linking strength imbalances to hamstring injury rates in soccer players. This study recruited 687 professional soccer players and had them perform isokinetic testing to determine if the subjects had muscular imbalances. Once a subject was determined to have an imbalance, they were either placed in a group that performed isokinetic strength exercises in efforts of correcting the problem, or in the group that received no intervention. The results showed that subjects with strength imbalances have a statistically greater chance of
suffering a muscle injury if they receive no treatment to help correct the imbalances. Subject’s that had the strength intervention also had a higher rate of muscle injury when compared to those with no strength imbalances. From these results, the investigators concluded that isokinetic testing was a good predictor of strength imbalances which is a factor in muscle injuries.

A study by Lehance et al, also investigated how muscular strength and balance effects injury rates among professional and junior elite soccer players. The purpose of this study was to determine if muscular imbalances that are detected in pre-participation physicals, can be used to predict injury rates. This study recruited 57 professional and junior elite soccer players that were divided into three groups: PRO, n=19; U-21, n=20 and U-17, n=18; where U-21 are the athletes that are under 21 years of age and U-17 are subjects that are under 17 years of age. First the investigators obtained a medical history, focusing on any previous lower leg injuries. The investigators then took bilateral isokinetic measurements in order to assess the strength of the hamstrings and quadriceps muscles. These measurements were obtained using an isokinetic dynamometer (Cybex). A second testing session required the subjects to perform a vertical jump and a 10 m sprint. The vertical jump was assessed using the Optojump System, which was able to measure the time of flight of the subject. The subjects were tested during the preseason and then again 1 month prior to their playoffs. The results showed that the PRO group ran statistically faster and jumped statistically higher than the other two groups. If you normalize for body mass, there was no significant difference between the three groups in terms of the isokinetic testing. Of the 57 subjects, 32 or 56% of the subjects presented with some type of muscular imbalance. Thirty-six out of 57 players self-reported having
sustained a previous major lower limb injury. Of these 36 players that reported previous injuries, 23 still showed significant muscular imbalance (64%). From this data, the investigators concluded that isokinetic testing is not only a good predictor of injury, but should also be implemented as a means of reducing the chances of injury.

Clinicians feel that it is important to recognize an athlete’s muscular imbalances during a pre-participation physical in order to help prevent injury because many studies have shown that muscular imbalances are an intrinsic factor in developing injuries. A study by Witvrouw et al\textsuperscript{17}, sought to prove this idea. The investigators in this study recruited 249 male soccer players and measured the flexibility of their hamstrings, quadriceps, adductor, and gastrocnemius bilaterally with a standard goniometer. From the original 249 subjects recruited, 103 had to be excluded from the study because they had a history of a lower extremity injury within the past 2 years. The investigators acknowledge that previous injuries are strong intrinsic risk factors for the prediction of injury because the athletes are more likely to suffer another injury. Since the objective of this study is to link muscle flexibility to injury rates, the subjects cannot have had a previous injury within the past two years. Of the 146 subjects, sixty seven of them sustained an injury to the lower extremity during this study. A little less than half of those 67 injuries (31 injuries) involved the hamstrings. The quadriceps and adductor muscles contributed 13 injuries each respectively. The remaining 10 injuries involved the calf muscles. However, the subjects who suffered an adductor or calf injured, had no flexibility differences when compared to the uninjured group\textsuperscript{16}. From this information, the investigators concluded that a decrease in quadriceps flexibility is a strong predictor for
quadriceps muscle injury. Therefore, identifying these individuals during a pre-participation exam could help prevent injury.

Injury to the Anterior Cruciate Ligament (ACL) is perhaps the most publicized injury that can be attributed to muscular imbalances; such as over reliance on the quadriceps and greater valgus angles at the knee. There have been several programs, such as the Prevent Injury and Enhance Performance (PEP) which are aimed at correcting these imbalances in order to prevent injury. A study by Lim et al. ¹⁸ sought to investigate whether or not female basketball players can increase their muscular strength and flexibility with the Sports Injury Training Program (SIPTP). This study recruited 22 high school female basketball players who had no known history of lower extremity injuries. The subjects were divided into two groups: (1) Experimental groups that performed the (SIPTP) and (2) the control group that performed their regular training program. The subjects had to perform a rebound jump task in which they were instructed to jump vertically with maximal effort to catch a basketball that was suspended from the ceiling. The subject would land on a force plate in order to calculate their maximum jump height. The study also utilized three-dimensional motion analysis cameras to calculate the knee flexion angle, interknee distance, knee internal rotation angle, knee extension moment, knee valgus moment. Electromyographic data was obtained from the rectus femoris and the biceps femoris during the test as well. The participants were tested during the preseason and then again 8 weeks from the initial preseason test. The results showed that the experimental group had less valgus stress at the knee and lower hamstring to quadriceps ratios. From this study, we can conclude that it is vital to detect muscular
asymmetries during pre-participation physicals in order to lower the athlete’s risk for ACL injury by correcting the problems prior to the season starting.

A study by Kramer et al\textsuperscript{19} also looked at factors that are associated with ACL injuries. The authors hypothesized that females who had a previous history of ACL injuries, were more likely to have structural abnormalities, such as malalignments, flexibility imbalances, and poor postural control. The investigators used 33 subjects who had ACL reconstructive surgery within the past five years and 33 subjects without ACL injuries were used as the control group. First they measured general laxity of the subjects using the Beighton laxity scale (0—No laxity and 1—laxity present). Laxity was measured for the following: opposition of thumb to palmar forearm, hyperextension of the 5\textsuperscript{th} metocarpophalangeal joint, hyperextension of the elbows, hyperextension of the knee, and ability of the subject to touch the floor with both palms while maintaining knee extension. The investigators then examined the subject’s foot type, Morton’s toe, navicular drop, pelvic tilt, leg length, tibial varum, standing Q angle, genu recurvatum, and femoral antversion. Range of motion was measured for ankle dorsiflexion and hamstring flexibility. The Thomas test was used to measure the range of motion for the hips and the Ober’s test was used to measure the flexibility of the iliotibial band and the tensor fascia latae. The Balance Error Scoring System (BESS) exam was used to measure the subject’s postural control. The results showed that generalized laxity, greater genu recurvatum, and decreased iliotibial band flexibility were the factors that were most associated with ACL injuries. There was also a significant correlation with previous ankle sprains and ACL injuries. The author’s concluded that taking range of motion measurements, postural control assessments, recognition of body malalignments, and a
thorough history can identify risk factors and perhaps prevent the incidence of ACL injuries in females.

Muscular asymmetries that lead to injuries are also apparent in the upper extremities as well. It has been well established that muscular strength and range of motion (ROM) imbalances are seen in overhead athletes, such as baseball and tennis players, and that these asymmetries lead to shoulder pain. More specifically, players have increased external ROM and decreased internal ROM. Athletes also demonstrate tighter posterior musculature when compared to their non-dominant arm. This condition is most commonly known as Glenohumeral Internal Rotation Deficit or GIRD. Most of the research pertaining to GIRD is targeted towards collegiate and professional baseball players. However, in a study by Trakis et al.\textsuperscript{20}, focusing on potential ROM and strength deficits in youth baseball players indicated that recognition and prevention of shoulder strength and flexibility needs to begin at a younger age. The study recruited 23 high school baseball pitchers, 12 of which had a history of shoulder pain and 11 of which had no such history. The investigators measured each subject’s internal and external rotation as well as the strength of their lower trapezius, upper middle trapezius, rhomboids, latissimus dorsi, supraspinatus, internal rotators, and external rotators. The investigators compared the ROM and strength between dominant and non-dominant arms of the subjects who had pain with the subjects who had no history of pain. The results showed all of the pitchers had significant loss of internal rotation and an increase in external rotation on their dominant arms compared to their non-dominant arms. There were no significant ROM differences between the two groups. However, the group that experienced pain had stronger internal rotators and weaker external rotators. They
concluded that the group that experienced pain had weakened posterior shoulder musculature. Therefore, recognition of the muscular asymmetries could potentially be detected by the FMS™ and an injury prevention program could be initiated at a younger age.

A study by Krivickas et al. investigated the relationship between ligamentous laxity and lower extremity tightness. The investigators recruited 131 men and 70 women who competed in Division I college athletics. They assessed ligamentous laxity on a 9-point scale, with a score of 0 being tight and 9 being hyperlax. Muscle tightness was assessed in the iliotibial band by using the modified Ober’s test and iliopsoas tightness was assessed using the Thomas test. The rectus femoris, hamstrings, and gastrosoleus tightness was measured using a standard goniometer. Injuries that limited activity were recorded with both the location of the injury and the type of injury that occurred. Based on the results, the author’s concluded that tight muscles are related to injuries in men, but not in women. They also speculated that preseason recognition of muscular tightness and flexibility programs could decrease injuries in college male athletes.

There have been many studies that have recognized the importance of identifying flexibility and muscular asymmetries which have led to several tests that are aimed at detecting these imbalances. The Star Excursion Balance Test (SEBT) is one such tool that is used to measure balance in individuals who have a pathologic lower extremity deficiency. The SEBT is also used to assess a person’s coordination, flexibility, and strength. Subject’s who perform poorly on this test may be at risk for lower extremity injuries. A study conducted by Plisky et al. investigated the relationship between poor scores on the SEBT and their subject’s risk of lower extremity injury. The investigators
recruited 235 high school subjects to participate in the study. Prior to each testing session, the subject would complete a questionnaire pertaining to any current or previous lower extremity injuries. The subject would then perform the SEBT reach distances in the anterior, posteriormedial, and posteriolar lateral directions. Injury rates were also recorded throughout the season. The results indicated that subjects with a decreased reach distances were significantly more likely to suffer an injury to the lower extremity during the season. The injury rate increased for females who had decreased reach distances. From the results, the authors suggested that the SEBT should be incorporated into pre-participation physical exams as a means of injury prevention.

The SEBT is widely used as a means of injury prediction, assessment of dynamic balance, and can be used to help make return to play decisions. Since it has become a popular tool, Kinzey et al. tested the reliability of the SEBT to see if researchers and clinicians should be using the test. The investigator’s used twenty healthy subjects and had them perform two sessions of the SEBT. During the session, each subject would perform five trials in each of the four directions. From the data, they calculated the reliability estimates by using intraclass correlation coefficients. The results ranged from 0.67 to 0.87, which makes the SEBT a reliable tool. The FMS™ is starting to become a widely used tool, but there is no current research that has tested the reliability of the Functional Movement Screen™.

The Functional Movement Screen™ was then developed to test more functional movement patterns of the athlete and is now being used in conjunction with other standard tests to detect asymmetries. The developers of the Functional Movement Screen™ also published a two part article that describes the test and its possible ability of
recognizing imbalances that could lead to injury. The first part of the article discusses the deep squat, hurdle step, and in-line lunge. The second article describes the active straight leg raise, trunk stability push-up, rotary stability, and the shoulder mobility test. The specifics of the tests and how to score the test will be described later.

There is little research regarding the FMS™ and the correlation between an individual’s score and the likelihood that the individual will suffer a serious injury. However, a study by Kiesel et al., found a relationship between an athlete that exhibits poor fundamental movement patterns and the likelihood of an injury to that athlete. The author’s defined a fundamental movement pattern as the basic movement that is utilized to simultaneously test ROM, stability, and balance. The investigators used the FMS™ to test 46 professional football players during pre-participation physicals. Each subjected performed all seven FMS™ tests and injuries were documented throughout the season. The study revealed that a player who scored less than 14 points on the test were eleven times more likely to suffer an injury during the season. The authors also went on to state that due to the nature of the sport, the probability of suffering an injury throughout the season is higher when compared to other sports. To address this issue, they ran pre-test and post-test probability rates. Therefore, if an athlete’s score on the FMS™ was less than 14, their probability of suffering a serious injury went from 15% to 51%. Based on these results, the authors concluded that professional football players with an FMS™ score of less than 14 have a greater chance of suffering an injury.

An abstract was published that investigated the intratester and intertester reliability of the Functional Movement Screen™. Anstee et al., recruited ten subjects who would be filmed performing the FMS™ and eleven certified athletic trainers or
physical therapists to score the subjects performing the FMS™. The investigators videotaped each subject performing three trials of each of the seven tests. The examiners then watched an instructional video that described how to score the FMS™ and then watched the videos of each video participant performing the test. The examiners then watched the same video a week later with the subjects appearing in a different order. The results showed that intratester reliability between Days 1 and 2 were 0.98. the intertester reliability on Day 1 was 0.66 and 0.63 on Day 2. They concluded each examiner could grade the test consistently over time, but different examiners did not always agree on the score of each test. They went on to state that the reliability of the more dynamic tests were lower than the reliability of the static tests. The author’s noted that future studies should investigate how experience of the examiner effects the scoring of the FMS™.

A second paper, published by Minick et al., used a similar methodology and concluded that FMS™ test is reliable when raters are trained and instructed on how to score the test. In this study, the investigators video-taped forty subjects performing each of the seven exercises three times each. The investigators recruited four people to score each video-tape. Two of these raters were considered to be very experienced in using and scoring the FMS™. The other two raters completed FMS™ training, but were considered novices in using and scoring FMS™. The novice raters agreed on the scoring on 14 of the 17 tests they viewed. The experts also have statistically strong agreements on 13 of the 17 tests. From these results, the investigators concluded that FMS™ tests that have been evaluated by those who have been trained to use the FMS™ test can be considered reliable.
2.3 Conclusion

In summary, millions of student-athletes are required each year to pass a physical examination before they are cleared for participation. This exam includes, but is not limited to, assessing the athlete’s weight, height, vision, heart rate, blood pressure, flexibility, and muscular strength, in attempt to recognize existing injuries and preventing future injuries. Current research is demonstrating injury has been linked to muscular flexibility and strength imbalances and that these imbalances, if recognized early enough, can be corrected. One method of measuring these imbalances is with the FMS™. The FMS™ test is able to assess both the lower and upper extremity through a range of functional movement patterns. This test is now being used in conjunction with other standard tests in order to detect asymmetries that could potentially lead to injury. However, only two studies have investigated the reliability of the FMS™. Therefore, more research needs to be dedicated to examining the reliability of the FMS™ test and how clinical experience effects the reliability scores.
Chapter 3

Methodology

3.1 Experimental Design

This was a repeated measure study that is investigating how experience using the Functional Movement Screen™ and how clinical experience affects the intra-tester and inter-tester reliability of FMS™ testing. These group membership numbers were based on sample of convenience of the University of Toledo.

Prior to the data collection, three subjects that were recruited from the university community were videotaped performing the FMS™ test. The participants signed an informed consent agreement allowing for the videotape to be used for this study and will performed three trials of each exercise. The examiners were read and given a script that described each exercise and how it is to be graded. Also, they watched a video of a subject who is demonstrating each exercise. Prior to the testing, each rater completed a consent and demographics form that described their level of clinical experience and experience with FMS™. The examiners viewed each of the three video-taped subjects and graded the video subjects on each exercise according to the script that was presented by the study investigator. Then a week later, they watched the same videos again, only in a different-randomized order, and graded each video subject on each exercise. After the
scores from the evaluators were collected, the investigator performed statistical tests to
determine the intersession reliability of FMS$^\text{TM}$ scoring in order to reveal if experience
affects the reliability of FMS$^\text{TM}$ scoring.

3.2 Subjects

This study recruited 37 subjects, all of which were certified athletic trainers or
athletic training students. These raters volunteered to participate. The raters were
recruited from the students from the University of Toledo undergraduate and graduate
athletic training programs, the clinical athletic trainers are recruited from the University
of Toledo Athletic Department and the Medical Center, as well as the athletic training
faculty from the Department of Kinesiology. Additionally, there were three subjects
recruited from the university community that were videotaped while performing the
FMS$^\text{TM}$ which was shown to the evaluators to score. The thirty seven evaluators were
divided into four groups, based on level of experience. The video subjects ranged in age
from 18-40 years old, with a mean of 21 years old. Because the investigators wanted to
have varying abilities in performing the FMS$^\text{TM}$, the subjects were not be excluded from
the videotape if they did not perform well on the test. Exclusion criteria included a
history of balance disorders, or a concussion or lower extremity surgery in the previous
six months. The first group of evaluators consisted of sixteen senior athletic training
students who were currently enrolled in the Athletic Training Educational Program
(ATEP) at the University of Toledo. The inclusion criteria for this group were (1) A
minimum of 3 years in the ATEP, (2) no previous experience with the FMS$^\text{TM}$, and (3)
completion of lower and upper extremity evaluation course. The exclusion criteria for
this group were (1) possession of an athletic training certification or license, (2) previous experience with the FMS™, or (3) holding any other medical professional licensure.

The second group of evaluators consisted of ten graduate certified athletic training students from the University of Toledo. This group served as the entry level certified athletic trainers group, who have recently obtained a certification and/or licensure to practice athletic training. The inclusion criteria for this group were (1) obtained an undergraduate degree in athletic training at an accredited university, (2) possession of an athletic training certification from the Board of Certifications (BOC), (3) are in good standing with the BOC, (4) have not been practicing as a certified/licensed athletic trainer for longer than 4 years, (5) currently employed as an athletic trainer through the University of Toledo athletics department or the University of Toledo Medical College as a graduate assistant Athletic Trainer, and (6) enrolled in the graduate school at the University of Toledo Exercise Science program with an emphasis in Athletic Training. The exclusion criteria for the entry level athletic trainer group were (1) not currently possessing an athletic training certification, (2) previous experience with using and scoring the FMS™, (3) working as a certified or licensed athletic trainer for five years or more, and (4) are not working as an athletic trainer or enrolled in graduate school for athletic training.

The third group of evaluators was comprised of four certified athletic trainers who were currently employed at the University of Toledo. Two of the four athletic trainers were involved in the academic aspect of sports medicine, while the remaining two were involved in the clinical setting. This group served as the experienced athletic trainers, who have been practicing athletic training for five years or longer. The inclusion criteria
for this group were (1) currently holding an athletic training certification and licensure, (2) practiced athletic training for at least three years, (3) employed at the University of Toledo, (4) posses a minimum of a master’s degree, and (5) no previous experience with FMS™ scoring. The exclusion criteria were (1) not currently a certified and licensed athletic trainer, (2) have been practicing athletic training for less than five years as a certified athletic trainer, and (3) have experience with FMS™ scoring.

The fourth group consisted of seven athletic trainers that had extensive training and experience using and scoring the FMS™. The inclusion criteria for this group were (1) possessing a certification in athletic training or physical therapy, (2) have been practicing athletic training for a minimum of 2 years, and (3) have experience using and scoring the FMS™, either as a clinician or as a researcher. A subject was excluded from this group if they have not used the FMS™ within the past two years or met all the inclusion criteria. The targeted enrollment in each defined group was based on a sample of convenience at the University of Toledo.

3.3 Instrumentation

The first piece of instrumentation that was used for this study was the FMS™ equipment. This included the Functional Movement Screen™ instructional DVD, which the subjects watched in order to learn more about FMS™ and how to score the test. The second piece of equipment was the FMS™ test kit24, which included a measuring device, hurdle, and measuring stick. A standard video recorder, DVD, and television was used to record and watch the subjects perform the tests.
3.4 Procedures

The filming of the video subjects as well as the viewing of the video by the evaluators took place in the Athletic Training Laboratory at the University of Toledo. The video subjects came to the Athletic Training Laboratory wearing comfortable clothes (tennis shoes, shorts, and a t-shirt). The investigator described and demonstrated what was expected from the subject prior to each test.

First the subject was asked to perform the Deep Squat. The subject begins by placing his /her feet shoulder-width apart and their hands on the dowel creating a 90-degree angle with the elbows. The dowel is then pressed overhead, so that the shoulders are flexed and abducted, and the elbows are in full extension. The subject is then asked to perform a deep squat, while maintaining their heels on the ground, head and chest facing forward, dowel pressed overhead, and not allowing their knees to pass their feet. If the subject is unable to perform this test without their heels maintaining contact with the floor, or if the subject cannot score 3 points for the test, they are asked to perform the test with a 2x6 FMS™ board under his/hers heels. Subjects who need the board for assistance automatically are only able to receive a high score of 2 for this test. The subject will also be instructed to report any pain with each test and will be given a score of 0 if pain is experienced. A score of 3 should be awarded to the subject if their (1) upper torso is parallel with the tibia or toward vertical, (2) their femur is below horizontal, (3) their knees are aligned over their feet, and the (4) dowel is aligned over their feet (Figure 1). The subject will be given a score of two if their (1) upper torso is parallel with the tibia or toward vertical, their (2) femur is below horizontal, their (3) knees are aligned over their feet, the (4) dowel is aligned over their feet, and the (5) 2x6 board is required
(Figure 2). A subject will receive one point if the (1) tibia and upper torso are not parallel, the (2) femur is not below horizontal, the (3) knees are not aligned over their feet, (4) lumbar flexion is noted, and the (5) 2x6 board is required under their feet (Figure 3).

Figure 1. Deep Squat Score of 3.

**Score of 3:**

- Upper torso is parallel with tibia or toward vertical
- Femur below horizontal
- Knees are aligned over feet
- Dowel aligned over feet
Figure 2. Deep Squat Score of 2.

**Score of 2:**

- Upper torso is parallel or toward vertical
- Femur is below horizontal
- Knees are aligned over feet
- Dowel is aligned over feet
- 2x6 board required under feet

Figure 3. Deep Squat Score of 1.

**Score of 1:**

- Tibia and upper torso are not parallel
- Femur is not below horizontal
- Knees are not aligned over feet
- Lumbar flexion is noted
- 2x6 board required under feet

The second test the subject performed was the Hurdle Step. The subject begins by placing his/her feet together, with their toes touching the base of the hurdle. The
investigator will then adjust the height of the hurdle based on the height of the tibial tuberosity. The investigator will align the hurdle so it is at the same height as the subject’s tibial tuberosities. The subject will be asked to place the dowel on their shoulders at the base of their neck. The subject will then beg in by stepping over the hurdle with their right leg and touching his/her heel on the ground. They should be instructed not to shift their weight onto their right leg and simply tap the floor with their heel. The stance leg should be maintained in an extended position. This task will be performed three times on each leg, so a bilateral comparison can be made. The subject should be given a score of 3 if their (1) hips, knees, and ankles remain in aligned in the sagittal plane, (2) there is minimal to no movement in the lumbar spine, and (3) the dowel and string remain parallel (Figure 4). The subject will receive a score of two if (1) the alignment is lost between the hips, knees, and ankles, (2) movement is noted in the lumbar spine, and (3) the dowel and string do not remain parallel (Figure 5). The subject will receive a score of one is (1) there is contact between the foot and the string, (2) and loss of balance is noted (Figure 6).

Figure 4. Hurdle Step Score of 3.
Score of 3:

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

Figure 5. Hurdle Step Score of 2.

Score of 2:

- Alignment is lost between hips, knees, and ankles
- Movement is noted in the lumbar spine
- Dowel and string to do remain parallel

Figure 6. Hurdle Step Score of 1.
Score of 1:

- Contact between foot and string occurs
- Loss of balance is noted

The third test the subject performed is the In-Line Lunge. The investigator uses the tibial length from the previous test to determine how far the subject will lunge. This height is measured out on the 2x6 board that was included in the FMS™ test kit. A mark is placed at this length so that the subject knows how far they are to lunge. The subject will then place the dowel behind their back, so that it is in contact with the head, thoracic spine, and sacrum. The hand that is opposite of the leg that is stepping out should be at the cervical spine, while the opposite hand gasps the dowel at the lumbar region of the back. For example, if the right leg is stepping out to the designated length, the left hand will be at the cervical spine and the right hand will be at the lumbar spine. The subject is instructed to place their heel of the foot that is stepping out at the length that it is previously measured (the length of the tibia). The subject then lowers their back leg so that their back knee touches the board in line with the heel of the front leg. This test is then performed bilaterally three times with each leg, with the test leg being the back leg. The subject will receive a score of 3 if (1) the dowel contacts remain with lumbar spine extension, (2) no torso movement is noted, (3) the dowel and the feet remain in the sagittal plane, and (4) the knee touches the board behind the heel of the front foot (Figure 7). The subject will receive a score of two if the (1) dowel contacts do not remain with lumbar spine extension, (2) movement is noted in the torso, (3) the dowel and the feet do
not remain in the sagittal plane, and (4) the knee does not touch behind the heel of the front foot (Figure 8). The subject should receive a score of one if loss of balance is noted (Figure 9).

Figure 7. In-Line Lunge Score of 3.

**Score of 3:**

- Dowel contacts remain with lumbar spine extension
- No torso movement is noted
- Dowel and feet remain in sagittal plane
- Knee touches board behind heel of front foot

Figure 8. In-Line Lunge Score of 2.
Score of 2:

- Dowel contacts do not remain with lumbar spine
- Movement is noted in torso
- Dowel and feet do not remain in sagittal plane
- Knee does not touch behind heel of front foot

Figure 9. In-Line Lunge Score of 1.

Score of 1:

- Loss of balance is noted

The fourth test is the Shoulder Mobility Screen. The investigator begins by measuring the subject’s hand length. The hand length is considered to be the length from the distal wrist crease to the tip of the third digit. The subject will then make a fist while placing their thumbs inside the fists. Then the subject will be asked to maximally adduct, extend, and internally rotate one shoulder and abduct, flex, and externally rotate the other arm. The fists should be placed on their back in one smooth motion without “inching” the fists together. The subject should also be instructed to maintain their hands in the fist...
position while the investigator measures the distance between the fists. The distance is measured between the two closest points of the two fists. This test will be performed three times bilaterally for each subject. The subject should receive a score of 3 if the fists are within one hand length. If the fists are within one and half of the measured hand length, the subject should receive a score of two. If the subject has anything greater than one and half of their measured hand length, then they should receive a score of one \( ^8 \) (Figure 10).

![Figure 1. Shoulder Mobility III](image1.png) ![Figure 2. Shoulder Mobility II](image2.png) ![Figure 3. Shoulder Mobility I](image3.png)

Figure 10. Shoulder Mobility Scores.

The fifth test is the Active Straight Leg Raise. The subject will be lying supine with the FMS\(^\text{TM}\) board under his/her knees, with both legs fully extended. The investigator will then locate the anterior superior iliac spine (ASIS) and the midpoint of the patella on the same leg. The midpoint of the leg is considered to be the point between these two landmarks. The investigator will place the dowel perpendicular to the ground at the midpoint of the leg. The subject will then maintain an extended knee and dorsiflexed ankle while lifting their test leg as far as possible. The knee of the non-test leg must also stay extended during the test with their toes pointed upwards. The subject’s head should
also stay flat on the floor. The straight leg raise will be performed three times bilaterally. A score of 3 will be given if the ankle/dowel is located between the mid-thigh and the ASIS (Figure 11). If the ankle/dowel is located between the mid-thigh and mid-patella, the subject will receive a two (Figure 12). A score of one will be given if the ankle/dowel is located below the mid-patella (Figure 13).

Figure 11. Active Straight Leg Raise Score of 3.

Score of 3:

- Subject’s lateral malleolous passes dowel

Figure 12. Active Straight Leg Raise Score of 2.

Score of 2:

- Lateral malleolus fails to pass bar
Score of 1:

- Lateral malleolus fails to pass 60 degrees

The sixth test is a Trunk Stability Push-Up. The subject will assume a prone position, with knees fully extended, ankles dorsiflexed, and hands shoulder-width apart. If the subjects are females, their hands should be placed in the same line as their chin. If the subjects are males, then the hands would be placed parallel with the forehead. If they are able to perform the test with their hands in this position, they will receive a score of three (Figure 14). If the subjects are unable to perform the test, then the females will place their thumbs in line with their clavicle and males with their chins. This position would award the subject a score of two (Figure 15). If the subjects are unable to perform a push in this position, then they are given a score of one (Figure 16). This test will be performed three times.
Score of 3:

- Males perform one repetition with thumbs aligned with the top of the forehead
- Females perform one repetition with thumbs aligned with chin

Score of 2:

- Males perform one repetition with thumbs aligned with chin
- Females perform one repetition with thumbs aligned with clavicle
Figure 16. Trunk Stability Score of 1.

**Score of 1:**

- Males are unable to perform one repetition with hands aligned with chin
- Females are unable to perform one repetition with thumbs aligned with clavicle

The seventh test is the Rotary Stability test. The subject will begin the test in the quadruped position with the shoulders and hips at 90 degrees. The FMS™ board will be placed between the subject’s knees and hands. During the test, the subject’s knees should maintain contact with the board. The athlete will then be instructed to flex one shoulder and extended the same side hip and knee six inches off the ground. The elbow and knee are then flexed so that they touch. The subject will then return back to the neutral quadruped position. If the subject is able to perform this test, they are given a score of three (Figure 17). If the subject is unable to perform the test, then they will flex one shoulder and extend the opposite knee, the elbow and knee will then be flexed so that they touch. If they are now able to complete the test with the modified version, they are given a score of two (Figure 18). If the subject cannot perform the diagonal repetition, then they will receive a score of one (Figure 19). This will be repeated three times bilaterally.8
Figure 17. Rotary Stability Score of 3.

**Score of 3:**

- Performs one correct unilateral repetition while keeping spine parallel to surface.
- Knee and elbow touch.

Figure 18. Rotary Stability Score of 2.

**Score of 2:**

- Performs one correct diagonal repetition while keeping spine parallel to surface.
- Knee and elbow touch.
Figure 19. Rotary Stability Score of 1.

**Score of 1:**

- Inability to perform diagonal repetitions.

A powerpoint presentation was created depicting each video subject performing the tasks described above in the order described above. The evaluators watched the video clips of each participant performing the FMS™. The investigator randomized the order in which the evaluators viewed the three subjects by selecting the video subject performances from the powerpoint. The evaluators were asked to grade the performance of each participant during each of the tests described above. The evaluators returned one week later to view each video subject again. Like the previous week, the video subject’s performances were viewed in a random order and graded again.

3.5 Statistical Analysis

**Independent Variables:**

--Group (Experienced FMS™ Group, Certified Athletic Trainers, Post-certified Athletic Training Students, Senior Athletic Training Students)

--Time (Week 1 vs. Week 2)
To determine group by time differences, the means and standard deviations from each group at the first and second viewing day were used to run two-way repeated measures analysis of variance (ANOVA’s). Tukey’s post hoc testing was used in the event of a significant interaction. Additionally, intraclass correlation coefficients (ICC) will also be calculated to account for the sources of variability between the test and the retest. This analysis was performed for all assessors combined, and then separately for each of the four groups to determine which type of assessor displayed the greatest intra-rater reliability. All statistical tests were performed using SPSS 17.0 (SPSS, Inc, Chicago, IL). An alpha level of 0.5 was used for all ANOVA’s.
Chapter 4

Results

4.1 Results

A significant Group by Time interaction was observed ($F_{3,33} = 3.67; p = .022$).

Means and standard deviations are presented in Table 1.

Table 1. Group Means and Standard Deviations from Day 1 and Day 2.

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<thead>
<tr>
<th>Descriptive Statistics FMS1</th>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
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<tbody>
<tr>
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<td>14.2657</td>
<td>1.0525</td>
<td>10</td>
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<tr>
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<td>0.7694</td>
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<td></td>
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<td>ATC</td>
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<td></td>
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<tr>
<td>Expert</td>
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<td>0.76162</td>
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</tbody>
</table>

<table>
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</table>

Tukey’s post-hoc testing revealed that on Day 1 and Day 2, the FMS™ scores evaluated by the GA group was significantly higher than the other three groups (Figure 20). Additionally on Day 2, the ATC group scored the videos higher than the ATS group. Finally, for the ATC group, the Day 2 FMS™ evaluation scores were higher than Day 1.
Figure 20. Group Main Effects on Day 1 and Day 2 of Testing.

Supporting this interaction was a significant main effect for Group (F\(_{3,33}=9.29; p<.001\)). Similar to the interaction, the GA group evaluated the FMS\(^TM\) score higher (14.55± 1.05) than the ATS (13.29±0.63), ATC (13.38±0.29), and Expert (13.24±0.64) groups.

The main effect for Time also was significant (F\(_{1,33}=4.55; p=0.041\)). Overall, the raters scored the video-subjects higher on Day 2 (13.77±0.98) than they did on Day 1 (13.46±0.92).

Inter-class coefficients (ICC 2,k) were performed to calculate the intra-rater reliabilities of scoring the FMS\(^TM\) for all raters, as well as for each group. The ICC values for all raters was strong (ICC = .723). As hypothesized, the senior athletic training
students had the lowest ICC values at .372. The graduate assistant athletic trainers, who also have no FMS™ experience, had the second lowest ICC values (ICC = .626). The certified athletic trainers, who have no FMS™ experience, but have a minimum of three years of clinical experience, had the second highest reliability rates (ICC = .914). As hypothesized, the individuals who were classified as being FMS™ experts had the highest rate of reliability (ICC = .946).
Chapter 5

Discussion

5.1 Discussion

The results of this study demonstrate that the reliability of the Functional Movement Screen™ is higher for raters that have experience using the FMS™ and those who have clinical experience, regardless of FMS™ experience. Specifically, those who have more experience using FMS™ had the strongest intra-rater reliability (ICC = .946), followed by those who have at least three years of clinical experience without having experience using the FMS™ (ICC = .914). Clinical experience appears to have an influence on the reliability of the measures as the graduate assistants had stronger reliability rates (ICC=.626) than the student athletic trainers (ICC=.372) who had the least amount of clinical experience. The results confirm the hypothesis that the FMS™ experts have higher reliability, followed by the experienced clinical athletic trainers who have no FMS™ experience, followed by the graduate assistant athletic trainers, who were all found to have strong intra-rater reliability rates than the athletic training students. Also, the results indicate that poorer performance on the FMS™ itself is more obvious and easier to score than someone who performs average on the test. In conclusion,
reliability of using the FMS\textsuperscript{TM} increases as clinical and FMS\textsuperscript{TM} experience increases. These results indicate that the FMS\textsuperscript{TM} has high reliability and can be confidently used by trained individuals.

The results are in agreement with a previous study conducted Minick et al\textsuperscript{6}, who found that the FMS\textsuperscript{TM} can be confidently applied by trained individuals as a way of assessing functional movement patterns. Their study compared people who were experienced using the FMS\textsuperscript{TM} (experts) with those who had just seen a video on how the FMS\textsuperscript{TM} (novice) should be scored. Neither set of raters in that study fell below a moderate level of agreement according to the Portney and Watkins\textsuperscript{25}. However, they did report significant differences between the 2 sets of raters and between different tests. They noted that the novice raters had excellent agreement with the expert raters on 14 of the 17 tests. Their conclusions supported our results that the FMS\textsuperscript{TM} is a reliable means of assessing movement patterns if conducted by a trained individual.

The reliability of the FMS\textsuperscript{TM} is comparable to the reliability of many other functional movement screening tools. The Star Excursion Balance Test (SEBT) is another tool that is used to quantify the dynamic balance of physically active individuals. A study conducted by Kinzey et al\textsuperscript{26} investigated the reliability of this screening tool using twenty healthy subjects. The SEBT requires the subject to balance on one leg and reach with the other leg in four different directions. This study required the subjects to complete two testing sessions during which they performed the test five times in each direction. The reliability estimates for this test were found to be similar to the interclass correlation coefficients that the FMS\textsuperscript{TM} study demonstrated (ranged from 0.67 to 0.87). This study
also agreed with the FMS™ reliability study in that subjects who have previous experience with the SEBT produced higher rates of reliability.

The Balance Error Scoring System (BESS) is a tool developed to assess an individual’s postural control. This test is commonly used as a way to assess and manage individuals who have suffered a concussion. The test requires subjects to close their eyes, place their hands on their hips, and stand in three different positions, first on a firm surface and then on an unstable surface. The three different positions are: (1) single leg stance, (2) feet together, and a (3) tandem stance. A study by Finnoff et al. investigated the reliability of the BESS exam using a similar methodology that was used in our FMS™ study. The investigators videotaped 30 individuals performing the BESS exam and had three raters watch the video and score each video-subject. The raters then watched the same video a week later in order to determine the intrarater reliability. The ICC values for the intrarater and the intrarater reliability for the total BESS scores were 0.57 and 0.74 respectively. The investigators concluded that certain subcategories of the BESS exam had sufficient reliability, but other aspects of the test had poor reliability.

The Four Square Step Test (FSST) is a functional test that is used to help identify those with multidirectional instability. This assessment tool is commonly used with individuals who suffer from poor balance and/or those with a vestibular dysfunction. The test requires subjects to step forward, backwards, and side-to-side quickly. A study by Whitney et al., used 32 subjects that had balance deficits and were currently enrolled in physical therapy for these deficits. To determine the validity and reliability of this functional movement assessment tool, they compared the results of the FSST to methods that have already been found to be reliable and valid. These tests include the Time Up
and Go (TUG) test, Dynamics Gait Index (DGI), the Dizziness Handicap Inventory (DHI), and the Activities-Specific Balance Confidence (ABC) Scale. The results demonstrated that the FSST had strong reliability (ICC = .86 - .96) and had good correlations with other gait measures (TUG, DGI, and gait speed). The FSST had a poor correlation with the DHI and ABC tests. The investigators concluded that the FSST is a reliable and valid tool for assessing functional multidirectional movements in those with balance deficits.

There were several limitations to this study. The first limitation is that there is variance in the rater’s level of experience and the numbers of years practicing as a clinician within each group. The study attempted to control for this by having each rater indicate the number of years they have been working as a licensed/certified athletic trainer and to describe the type of FMS experience they have been exposed to. Also the “most experienced group” was comprised of Certified Athletic Trainers, the number of years of clinical experience as Certified Athletic Trainer ranged from 2 to 14 years, and some were currently in clinical practice while others were in academic positions. The study also has to assume that raters will not introduce any personal biases and will be honest in their answers. However, we do not believe that the limitations have compromised the results of this study.

The clinical implications for this study are that the FMS can be used as a reliable screening tool if the tester is experienced using the tool to assess muscular flexibility and imbalances. Future studies could evaluate at what point someone is considered to be an FMS expert. This information could be used to help design classes or instructional videos on how to grade the FMS. Futures studies could also
investigate the reliability of the FMS\textsuperscript{TM} as it occurs in real time instead of the rater’s assessing subjects in 2-dimensional video.
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