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The Interrater and Intrarater Reliability of the Functional Movement Screen

By

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Accepted in Partial Completion
of the Requirements for the Degree
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The Interrater and Intrarater Reliability of the Functional Movement Screen

A Thesis
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the Faculty of
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of the Requirements for the Degree
Master of Science

By
Jason Dudley
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Abstract

The purpose of this study was to determine the interrater and intrarater reliability of the Functional Movement Screen (FMS). Forty-Four Western Washington University athletes from various athletic teams volunteered. Twenty-one of the athletes tested volunteered to participate in a second testing session. Each athlete performed the seven components of the FMS while being evaluated by two separate testing teams. Each testing team was comprised of two members, with one member assigned to assess the sagittal plane, and the other, the frontal plane. The scores of the two members of each testing team were combined to form the total score given by each respective team. An intraclass correlation coefficient was used to determine the strength of association between the scores given by Team 1 and Team 2 during the 1st test, and the strength of association between the scores given by Team 1 during the 1st and 2nd test. The results show 0.763 for the interrater reliability (ICC 3, 1, $p < 0.001$) and 0.731 for the intrarater reliability (ICC 3, 1, $p < 0.001$) of the FMS. However, the strength of association for intrarater reliability was diminished by the lack of a definition of pain prior to the testing. When the limitation of the pain score is removed, the intrarater reliability shows 0.818 (ICC 3, 1, $p < 0.001$). Despite this finding, both the interrater and intrarater reliability of the FMS needs to be improved in order to use the system to track changes in athlete's movement patterns over time. The sagittal plane showed a higher correlation than the frontal plane during both interrater (ICC 3, 1 sagittal was 0.801 and frontal was 0.752) and intrarater testing (ICC 3, 1 sagittal was 0.762 and frontal was 0.713). Improving the correlation in the frontal plane scoring criteria would increase both the interrater and intrarater reliability of the total FMS score to help track changes in athlete's movement over time.

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Chapter One

The Problem and Its Scope

Introduction

It is estimated that over 70,000 non-contact anterior cruciate ligament injuries occur each year in the United States, with the majority of these injuries being suffered by young athletes involved in sports that require quick changes in direction and jumping (Griffin et al., 2000). Seventy percent of the ACL injuries suffered by athletes in the United States each year are non-contact injuries (Griffin et al., 2000). ACL injuries are only one example of the various non-contact injuries suffered by athletes. A non-contact injury is defined as an injury suffered in the absence of contact from another athlete or external object (Cook, 2005). In an effort to minimize the number of athletes who suffer a non-contact injury, field tests have been developed to attempt to predict athletes who are at an increased risk of suffering a non-contact injury. The Functional Movement Screening (FMS) system is one such field test that was developed in an effort to identify athletes who have limited or altered movement patterns that may increase their chances of suffering a non-contact injury (Cook, 2005). Functional Movement Screening consists of seven movement tests that are scored on a scale from 0 to 3.

Functional Movement Screening (FMS) has gained widespread use in athletics and other high risk work environments as a field test to identify athletes and high risk workers with an increased risk of suffering a non-contact injury. Jon Torine , the head strength coach of the Indianapolis Colts said this about the FMS system "We now use this program with every player as a pretest and evaluation tool before we even begin to train them" (Cook, 2005). The little research that has been done on FMS indicates it may be a valid test for predicting, and potentially decreasing, non-contact injury risk in athletes and high risk workers (Peate, Bates, Lunda, Francis, & Bellamy, 2007; Kiesel, Plisky, & Patrick, 2008).

The field tests included in the FMS system have been successful in predicting athletes at increased risk of injury (Cholewicki et al., 2005; McHugh, Tyler, Tetro, Mullaney, & Nicholas, 2006; Plisky, Rauh, Kaminski, & Underwood, 2006; Trojian & McKeag 2006; Wang, Chen, Shiang, Jan, & Lin, 2006), however little research has been done with the FMS system itself to determine if it predicts athletes who are at an increased risk of sustaining a non-contact injury. In order to determine if this is a valid field test to predict non-contact injury among athletes, further research is needed. Before any such research is done, the interrater and intrarater reliability of the scoring system and training process should be evaluated. Interrater reliability needs to be established to ensure results from future studies can be applied by other evaluators. Interrater reliability demonstrates scoring differences seen after an intervention are due to the intervention. Intrarater reliability needs to be established to ensure any scoring differences seen after an intervention are due to the intervention alone (Portney & Watkins, 2009).

Purpose of the Study

The purpose of this study was to determine the interrater and intrarater reliability of the Functional Movement Screen scoring system. The results of this study were to clarify if past and future pre and post test scores, performed around an intervention focused on correcting movement pattern dysfunctions, can be linked to the intervention due to the high reliability of the test instrument. The results of this study also ascertain if scoring standards established in past and future research can be applied to athletes who are screened by a separate evaluator.

Null Hypothesis

There will be no relationship between the total score given by the two testing groups for each athlete. There will also be no relationship between the total scores given during two separate tests performed by a single team of evaluators. The independent variable is the evaluation team (team 1 or team 2) administering the Functional Movement Screen and the dependent variable is the score provided, for the seven test screening process, by the administering evaluation team.

Significance of the Study

To date, no research has been obtained using the Functional Movement Screen to determine the interrater and intrarater reliability of the system. The results of this study will establish the interrater and intrarater reliability of the system and aid further research to determine the overall reliability of the system as an injury identification and prevention system.

Limitations of the Study

1. Evaluators were only trained using the training materials provided and did not attend a certification seminar, as the training video suggests.
2. The scoring of each test was based on specific criteria, but the way the criteria was interpreted and applied was subjective and may have been influenced by the evaluators' experience and/or opinion. Prior to any testing, the evaluators were trained as a group using the training materials provided.
3. Other than verbal instruction read by the head evaluator, the subjects had no motivation to perform the test properly. Additionally, there was no compensation for performing the test, so the athletes did not have any external motivation.
4. During the training process, the evaluators were instructed to provide a score of "0" for any movement when the athlete reported pain or if they reported pain when asked "did you experience any pain with that movement". This was consistent with the training materials provided with the Functional Movement Screen. All evaluators were clear that pain during any movement would result in a score of "0" for that movement; however pain was not well defined in the training materials.

Definition of Terms

Abduction: A movement away from the midline of the body (Hamill & Knutzen, 2009).

Adduction: A movement toward the midline of the body (Hamill & Knutzen, 2009).

Anterior: A position in front of a designated reference point (Hamill & Knutzen, 2009).

Asymmetry: A difference in the movement patterns between the left and right side of the body (Cook, 2005).

Concentric: Muscle action in which tension causes visible shortening in the length of the muscle; positive work is performed (Hamill & Knutzen, 2009).

Core stability: The ability to stabilize the hip and trunk (Leetun, Ireland, Wilson, Ballantyne, & Davis, 2004). Ability to stabilize the spine before movement of the extremities to provide a stable base for motion and muscular activation, reducing the chance of injury in the extremity (Jensen, Laursen, & Syogaard, 2000).

Dorsiflexion: The motion in which the relative angle between the foot and the leg decreases (Hamill & Knutzen, 2009).

Eversion: The movement in which the lateral border of the foot lifts so that the sole of the foot faces away from the midline of the body (Hamill & Knutzen, 2009).

Extension: The action in which the relative angle between two adjacent segments gets larger (Hamill & Knutzen, 2009).

Flexion: The action in which the relative angle between two adjacent segments gets smaller (Hamill & Knutzen, 2009).

Functional Movement Screening (FMS): Field test developed to identify athletes who have altered and/or limited movement patterns that may predispose them to suffer a non-contact injury (Cook, 2005).

Frontal Plane: The plane that bisects the body into front and back halves (Hamill & Knutzen, 2009).

Function (applied to movement): The ability to explore a full range of movement, demonstrating body control and movement awareness throughout numerous positions (Cook, 2005).

Imbalance: The muscular forces about a certain joint or body segment are not equal, thus creating joint stress and reduced control (Cook, 2005).

Inversion: The movement in which the medial border of the foot lifts so that the sole of the foot faces away from the midline of the body (Hamill & Knutzen, 2009).

Isokinetic exercise: An exercise in which concentric muscle action is generated to move a limb against a device that is speed controlled. Individuals attempt to develop maximum tension through the full range of motion at the specified speed of movement (Hamill & Knutzen, 2009).

Lateral: A position relatively far from the midline of the body (Hamill & Knutzen, 2009).

Medial: A position relatively closer to the midline of the body (Hamill & Knutzen, 2009).

Mobility: The combination of muscle flexibility, joint range of motion and a body segment's freedom of movement (Cook, 2005).

Non-contact injury: An injury suffered in the absence of contact from another athlete (Cook, 2005).

Posterior: A position behind a designated reference point (Hamill & Knutzen, 2009).

Rotation: A movement about an axis of rotation in which no every point of the segment or body covers the same distance in the same time (Hamill & Knutzen, 2009).

Sagittal Plane: The plane that bisects the body into right and left halves. Sagittal plane movements are typically flexions or extensions (Hamill & Knutzen, 2009).

Stability: Is the ability to maintain posture and/or control motion (Cook, 2005).

Valgus: Segment angle bowed medially; medial force (Hamill & Knutzen, 2009).

Varus: Segment angle bowed laterally; lateral force (Hamill & Knutzen, 2009).

Chapter Two

Review of Literature

Introduction

The purpose of this study was to assess the interrater reliability and the intrarater reliability of the functional movement screen system (FMS). While the FMS system has gained widespread popularity among collegiate and professional athletic teams, to date, no research has been done on the interrater reliability or the intrarater reliability of the FMS. This literature review examines risk factors for injury that the FMS is designed to identify, previous field tests used to identify injury risk in athletes, and the ability of the FMS to predict injury in previous studies.

Risk Factors for Injury

Knee injuries are a common source of non-contact injuries among athletes and are a result of the forces acting at the knee. Hewett et al. (2005) examined neuromuscular control factors, such as joint angles and joint forces during a jump-landing, in athletes who suffered an ACL rupture. Two hundred five female athletes involved in high risk sports (basketball, soccer and volleyball) were pre-tested prior to the 2002-2003 season to determine joint angles in the lower extremity upon landing, along with the forces experienced at each joint. During the 2002-2003 season, nine athletes suffered ACL ruptures. The nine female athletes who suffered an ACL rupture during the season experienced 8 % greater knee abduction angles, had a two a half times greater knee abduction moment, experienced 20% greater ground reaction forces and had a 16 % shorter stance time during the pre-season testing. During a jump landing athletes who experience a subsequent ACL rupture show greater knee angels upon landing and experience greater ground reaction forces in less time than athletes who do not suffer a subsequent ACL rupture. These findings suggest there may be preexisting neuromuscular differences in athletes who are at an increased risk of suffering an ACL rupture.

Soderman, Alfredson, Pietila, and Werner (2001) examined potential risk factors that may contribute to lower extremity injuries in female soccer players. Risk factors examined for the 146 female soccer players were age, anatomical alignment, generalized joint laxity, thigh muscle torque, muscle flexibility, ligamentous laxity of the knee and ankle joints, recent injuries, and duration of soccer exposure. A total of 61 traumatic injuries (an injury resulting in at least one practice or game missed) were suffered by 50 athletes. Of the 61 traumatic injuries five were ACL injuries and these five were analyzed in regards to the focus of the study. Generalized joint laxity, low postural sway of the legs, hyperextension of the knee joint and a low hamstring-to-quadriceps ratio during concentric action all significantly increased the risk of traumatic leg injuries. These findings suggest athletes at risk for a traumatic injury to the lower extremity exhibit common risk factors which can be identified prior to injury.

Orchard, Seward, McGivern, and Hood (2001) examined the effect of intrinsic (player related) and extrinsic (environment related) risk factors involved in non-contact ACL ruptures. One hundred thousand eight hundred twenty Australian football player-match exposures were evaluated and 63 non-contact ACL injuries occurred. Previous ACL reconstruction, increased age, weight and BMI were all significantly associated with non-contact ACL injuries. Previous

ACL reconstruction was the strongest intrinsic risk factors associated with a non-contact ACL injury.

Faude, Junge, Kindermann and Dvorak (2006) examined the risk factors for injuries among elite female soccer players. The medical histories of 143 elite female soccer players were collected prior to the season and then the players were tracked to record any injuries suffered during the following season. Athletes who suffered an ACL rupture prior to the season were at a significantly increased risk of suffering a second ACL rupture. Previous ankle and knee sprains did not increase the likelihood of a subsequent injury. Regardless of previous injuries the dominant leg was significantly more likely to sustain an injury. While a previous ACL rupture has been significantly associated with a subsequent injury, both previous ankle and knee sprains do not increase the likelihood of a subsequent injury.

Ferber, Davis, and Williams (2003) examined the differences in knee and hip kinematics and kinetics between male and female recreational runners. Gait analysis was performed on 40 runners, 20 female and 20 male. Three dimensional joint angles in the hip and knee were compared between males and females as well as negative work during the stance phase. Females demonstrated significantly greater peak hip adduction (females = 9.19 ± 6.64°, males = 5.59 ± 4.67°; p=0.05), hip internal rotation (females = 11.17 ± 4.92°, males = 7.02 ± 5.11°; p=0.01) and knee abduction (females = -6.44 ± 2.06°, males = -4.58 ± 2.51°; p=0.04) compared to males in this study. Females also demonstrated significantly more negative work in the frontal and transverse planes than males. No athletes were injured during the study because it was a cross-sectional study, but it has been well established that female athletes suffer more injuries than male athletes (Orchard et al., 2001). These kinematic and kinetic differences in the hip and knee may help explain differences in injury rates between males and females, and provide risk factors that can be prescreened prior to injury.

Leetun et al. (2004) examined core stability measures between the sexes and between athletes who suffered an injury during the season and athletes who did not suffer an injury during the season. Prior to the season 80 female and 60 male collegiate athletes were evaluated to determine hip abduction and hip external rotation strength, abdominal muscle function, back extensor endurance and quadratus lumborum endurance. Athletes who did not suffer an injury in the following season were significantly stronger in hip abduction (uninjured = 31.6 ± 7.1% BW, injured = 28.6 ± 5.5% BW) and external rotation (uninjured = 20.6 ± 4.2% BW, injured = 17.9 ± 4.4% BW). Male athletes demonstrated greater hip abduction (males = 32.6 ± 7.3 % body weight, females = 29.2 ± 6.1 % body weight), hip external rotation (males = 21.6 ± 4.3% BW, females = 18.4 ± 4.1% BW) and quadratus lumborum strength (males = 84.3 ± 32.5 seconds, females = 58.9 ± 26.0 seconds) than females. Decreased hip abduction and hip external rotation strength appear to be preexisting risk factors for injury. These results suggest testing athletes prior to competition to identify athletes who are at an increased risk of suffering a lower extremity injury during the season. The results suggest that core stability strength differences between males and females may explain the difference in injury rates between male and female athletes.

Cholewicki et al. (2005) examined reflex responses to sudden trunk loading to determine if delayed reflex responses are a result of a low back injury or a preexisting risk factor for low back injury. Two hundred ninety two athletes (148 male, 144 female) were tested for reflex responses to quick force release in trunk flexion, extension and lateral bending. Athletes were monitored for three years and post tested with the same measures. During the three years, 31 athletes sustained a low back injury. On average, athletes who suffered a low back injury had a 14 millisecond slower reflex response than athletes who did not suffer a low back injury. Those who suffered a low back injury were 2.8 times more likely to suffer a second low back injury. Delayed reflex response to an unexpected external force appears to be a preexisting risk factor for low back injury and a not a result of the low back injury.

Hodges and Richardson (1996) examined the contribution of the transversus abdominis to spinal stabilization during movement of the extremities in subjects with low back pain and subjects without low back pain. Thirty subjects (15 with low back pain and 15 without low back pain) performed rapid shoulder flexion, abduction, and extension in response to a visual stimulus. Subjects without low back pain showed activity in the transversus abdominis first regardless of the movement direction. Contraction of the transversus abdominis was significantly delayed in subjects with low back pain in all movement directions. This delay in the transversus abdominis prevents the reactive forces from being optimally controlled by the trunk muscles and increases the likelihood of further injury to the lumbar spine and lower extremities.

Cholewicki, Panjabi, and Khachatryan (1997) examined the coactivation of trunk extensors and trunk flexors in subjects without low back pain. Ten subjects performed slow trunk flexion-extension tasks while six muscles on the right side were monitored with surface electromyography. The muscles monitored were the external oblique, internal oblique, rectus abdominis, multifidus, lumbar erector spinae, and thoracic erector spinae. The analysis of the EMG signal showed that antagonistic trunk flexor and extensor muscle coactivation was present in subjects without lower back pain. The results also show that the coactivation increased with increased torso mass. This coactivation may play a key role in preventing injuries in the lower extremity.

Hodges and Richardson (1997) explored the relationship between the response of the lumbar multifidus and transversus abdominis to leg movement. Electromyography was used to record the activity of selected trunk muscles and the prime movers for hip flexion, abduction, and extension during hip movements in 15 subjects with no history of low back pain. The transversus abdominis was the first muscle active during all lower limb movements. These results suggest that the central nervous system deals with stabilization of the spine by contraction of the transversus abdominis and multifidus muscles in anticipation of reactive forces produced by limb movement in healthy individuals.

Zazulak, Hewett, Reeves, Goldberg, and Cholewicki (2007) also examined trunk displacement after sudden force release as a predictor of lower extremity injury in collegiate athletes. Two hundred seventy seven collegiate athletes (140 male and 137 female) were tested for trunk displacement and then followed for the next three seasons. Twenty five athletes suffered a knee injury (11 female and 14 male) over the next three seasons. Trunk displacement during pretesting was greater in athletes who suffered an injury than those who did not (Trunk displacement < 10° non-injured and >11° injured athletes). Lateral displacement was the strongest indicator of a subsequent ligament injury to the knee. Lack of core strength, especially lateral core strength, appears to be a strong indicator of a future knee injury.

Turbeville, Cowan, Owen, Asal, and Anderson (2003) examined player characteristics such as: playing experience, position, injury history and physical parameters as risk factors for injury. The physical parameters examined where: BMI, weight, height and grip. Seven hundred seventeen high school football players were evaluated in the preseason and then tracked the following year. None of the physical parameters were associated with an increased chance of injury. Both increased playing experience (Beta = .27 ± .07) and a previous injury (Beta = .61 ± .26) were significantly related to an increased risk of injury during the current season.

Emery and Meeuwisse (2006) also examined playing experience and the age of the athlete as potential risk factors for injury. Seventy one youth hockey teams were followed over a season and any time loss injury during practice or competition was examined. The athletes followed were in four different age groups, with three different skill levels in each age group. One hundred fifty six of the 296 injuries suffered were among the oldest age group studied. One hundred sixty four of the 296 injuries were suffered by athletes in the high skill level for their age. Both the athlete's age and skill level were significantly associated with an increased chance of injury. Further studies should be done to determine if the increased rate of injury with increases in sport specific skills are due to asymmetries and if the increased injury rates associated with increased playing experience is due to increased previous injuries.

Quarrie et al. (2001) examined playing experience, injury history, training patterns, anthropometric characteristics and performance on a battery of fitness tests as potential indicators of future injury. Two hundred fifty-eight rugby players were examined in the preseason and followed throughout the next full season to monitor injury rate. Previous injury was the most significant risk factor for a subsequent injury (RR = 2.41; 95% CI = 1.34 to 4.32).

McHugh et al. (2006) examined previous ankle injuries as a risk factor for subsequent ankle injuries among 169 high school athletes from various sports (basketball, football, soccer and gymnastics). Athletes with a previous ankle sprain were significantly more likely to sustain a subsequent ankle sprain than athletes with no previous injuries (1.12 vs 0.26 per 1000 respectively, $P < .05$). Mckay, Goldie, Payne, and Oakes (2001) also examined ankle sprains among 10,393 recreational basketball players. This study found previous ankle injury increased the chance of a subsequent injury by five times. The increased risk of injury associated with a previous injury may be due to imbalances in the athlete after the injury and/or altered or impaired movement patterns following the injury. A possible explanation suggested for the increased injury rates among these athletes, with a previous injury, is strength and stability differences between the injured and uninjured limb following the injury.

Turbeville et al. 2003 examined previous ankle injuries and a single leg balance test as possible indicators of a subsequent ankle injury. Two hundred thirty athletes (football, soccer and volleyball) were evaluated based on previous ankle injuries and their ability to complete a single leg balance test. The single leg balance test consisted of standing barefoot on one leg with the non-weight bearing leg bent at 90 degrees and not touching the stance leg. Athletes closed their eyes and attempted to hold their balance for 10 seconds. A loss of balance was reported as a positive test. A positive straight leg balance test was linked to an increased chance of suffering a subsequent ankle injury, while a history of previous ankle injuries was not associated with an increased chance of a subsequent ankle injury. This lends evidence to the belief that previous injuries contribute to the risk of subsequent injuries only if the underlying movement patterns are compromised and/or altered. If an athlete is able to restore proper movement patterns and muscular stabilization of the injured area prior to returning to play, the increased risk of a subsequent injury may be eliminated.

A number of risk factors such as: increased knee and hip angles upon landing, joint laxity, low postural sway of the legs, hyperextension of the knee, low hamstring to quadriceps strength ratio, previous injury, age, BMI, weight, core stability strength, core muscular reflex responses, and strength and movement imbalances have been suggested as preexisting risk factors for injury. All of these risk factors can be predetermined in athletes and may help identify athletes who are at an increased level of risk of suffering an injury. In an effort to identify athletes who are at an increased risk of injury a number of field tests have been evaluated.

Field Tests

A number of field tests have been researched in an effort to identify athletes who are at an increased risk of injury during competition and practice. The vast majority of these tests were targeted at indentifying a specific injury or injury to a specific area of the body

Wang et al. (2006) examined the use of postural sway, ankle strength and flexibility as field test to predict ankle injuries in basketball players. Forty two high school basketball players, without an ankle injury in the previous 6 month or significant malalignment in the lower extremities, were evaluated using isokinetic ankle strength, 1-leg postural sway, and ankle dorsiflexion flexibility prior to the season. Athletes were tracked throughout the following season for ankle injuries. Eighteen ankle injuries occurred over the following season and there was a significantly higher postural sway in both anteroposterior and mediolateral directions. All other variables tested were not related to increased risk of injury. The 1-leg postural sway field tests appear to be an accurate predictor of athletes who are at an increased risk of suffering a subsequent ankle injury.

McGuine, Greene, Best, and Leverson (2000) examined if a preseason unilateral balance test was an accurate field test to predict ankle injuries in high school basketball players. Two hundred ten high school basketball players (119 male and 91 female) without an ankle or knee injury in the previous 12 months and who did not use any type of ankle or knee bracing or taping were evaluated using a unilateral balance test prior to the season. Each athlete stood on one leg for 3 trials of 10 seconds for each leg and postural sway was calculated as the average degrees of postural sway per second for the trials. High postural sway during the unilateral balance test was significantly related to the occurrence of a subsequent ankle injury ($p = 0.001$). Athletes with poor balance test scores were seven times more likely to sustain an ankle injury during the following season. The unilateral balance test appears to be an accurate field test to help predict athletes were maybe at an increased risk of suffering an ankle injury.

Reinking and Hayes (2006) examined structural factors between cross-country runners with and without exercise related leg pain (ERLP). Sixty three cross-country runners (30 male and 33 female) were examined prior to the cross-country season. Examinations of the athletes included self-report of ERLP history, active ankle dorsiflexion with knee extended and flexed, navicular drop (ND), and 1st ray length (measurement between the navicular tuberosity and the joint line of the first metatarsophalangeal joint). Athletes were tracked over the following cross-country season to identify the occurrence of exercise related leg pain. No structural differences were found between athletes who suffered exercise related leg pain and those who did not. Active ankle dorsiflexion with knee extended and flexed, navicular drop (ND), and 1st ray length do not appear to be accurate field tests to indentify athletes who are more likely to experience exercise related leg pain.

Trojian and McKeag (2006) examined the use of a 1-leg balance test as a potential field test to identify athletes who are at an increased risk of suffering an ankle injury. Two hundred thirty athletes (football, soccer and volleyball) were evaluated using a positive/negative 1-leg balance test prior to the season. This test requires athletes to stand barefoot on one leg with their eyes closed for ten seconds. A loss of balance during the ten second time period is deemed a positive test and maintaining balance during the full ten seconds is deemed a negative test. Athletes with a positive test on the 1-leg balance test were six times more likely to suffer an ankle injury. The positive/negative single leg balance appears to be an accurate predictor of athletes at an increased risk of suffering an ankle injury.

McHugh et al. (2006) examined one leg balance on a tilt board, hip flexion, and abduction and adduction strength as potential field tests to identify athletes who are at an increased risk of suffering a non-contact ankle sprain. One hundred sixty nine athletes (101 male and 68 female) from football, basketball, soccer and gymnastics were evaluated in the preseason and track for the following two seasons for non-contact ankle sprains. Twenty non-contact injuries occurred over the next two seasons. None of the measures taken in the preseason were significant risk factors for non-contact ankle sprains. Performance on a single leg balance test using a tilt board does not appear to show any relation to an increased risk of suffering a non-contact ankle sprain.

Leetun et al. (2004) examined core stability endurance tests as a possible field test to identify athletes who are at an increased risk of suffering a non-contact lower extremity injury. One hundred forty collegiate basketball players and track athletes (80 females and 60 males) were examined prior to the season using core stability endurance tests such as the side bridge test, abdominal flexor and extensor tests. These tests are completed by having the athlete hold the position for as long as possible while being timed; the total time held for each position is used as the score. Athletes with below average times on the core stability test (standard scores and ratios are listed below in Table 1) and/or athletes who had a below average lateral to flexion ratio were at an increased risk of suffering a lower extremity injury. Core stability deficiencies reduce the ability to stabilize the hip and trunk which can result in back and lower extremity injuries. Timed core stability tests are valid to evaluate athletes who are at a greater risk of suffering a non-contact lower extremity injury (McGill, Childs, & Liebenson, 1999). Core musculature stabilizes the spine before movement of the extremities to provide a stable base for motion and muscular activation, reducing the chance of injury in the extremity (Jensen et al., 2000; Evans, Refshauge, & Adams, 2007). Increasing the rigidity of the trunk increases the stability of the spine and decreases the chance of injury by reducing the load on the spine (Hodges, 2003).

Table 1

Timed Core Stability Tests: Means and Ratios (McGill, Childs, & Leibenson, 1999).

	Males		Females	
Task	Mean	Extensor Ratio	Mean	Extensor Ratio
Extensor	146 sec	1	189 sec	1
Front Bridge	144	.99	149	.79
Side bridge R	94	.64	72	.38
Side Bridge L	97	.66	77	.40

Plisky et al. (2006) examined the star excursion balance test as a field test to identify athletes at increased risk for injuries of the lower extremity. The star excursion balance test measures the athlete's anterior, posteromedial, and posterolateral reach distances and limb lengths. Two hundred thirty five high school basketball players were evaluated using the star excursion test and followed the following season to track injuries to the lower extremity. Athletes with an anterior right/left reach distance difference greater than 4 cm were 2.5 times more likely to sustain a lower extremity injury. Female athletes with a composite reach distance less than 94% of their limb length were 6.5 times more likely to have a lower extremity injury. The anterior right/left reach distance and the composite reach distance components of the star excursion balance test are effective field tests in predicting lower extremity injuries in athletes.

Functional Movement Screen Score

The Functional Movement Screen (FMS) system was designed in an effort to combine the aspect of the previously mentioned field tests into one system which would be able to estimate an athlete's or high risk worker's overall risk of injury. Peate et al. (2007) used functional movement screening to test 433 active duty firefighters in an effort to indentify firefighters who were at an increased risk for injury. Once at risk firefighters were identified, a training program was implemented in an effort to reduce the amount of time loss due to injury amongst these firefighters. Each firefighter performed the seven-test (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability) functional movement screening process and was scored on the 21 point scoring system. Each firefighter was given a specific exercise program based on performance during the test and tracked over the following year. Compared to a historical control group (no description or information was provided in regards to the historical control group), loss time injuries were decreased by 62% and total injuries were decreased by 44%. Significant reductions were noted in both lower back and upper extremity injuries. This study indicates that functional movement screening and subsequent training exercises are effective in reducing injury rates in high risk workers.

Kiesel et al. (2008) examined Functional Movement Screening as a field test to test professional football players in the pre-season to indentify players at an increased risk of suffering a time loss injury. Eighty one professional football players were evaluated prior to the start of training camp using the standard seven-test functional movement screen. The total score given was the sum of scores given on the seven tests performed, while the asymmetry score was the sum of the difference between each of the four bilateral tests performed. Each athlete performed each of the seven tests three times. Players with a total score of fourteen or below were eleven times more likely to suffer an injury and players with an asymmetry score of one or more were three times more likely to sustain an injury. The results of this study indicate that functional movement screening may be a viable field test to indentify football players at an increased risk of injury. Further research is needed to determine if an intervention will modify the risk factors identified by the test and if modification will result in a decreased incidence of injury.

Summary

Athletes who are at an increased risk of suffering a non-contact injury demonstrate different physical traits, than their fellow athletes, which can be tested prior to competition. The Functional Movement Screen is a potential field test to identify athletes at an increased risk of injury. Additional research is needed to add to the body of evidence that the Functional Movement Screening system may be a viable field test and to determine if exercise intervention can modify risk factors identified by the screening process. Before further research is done to determine the validity of the system, the inter-rater and intra-rater reliability of the screening process needs to be determined. Inter-rater and Intra-rater reliability will allow future studies to confidently use and apply the Functional Movement Screen.

Chapter Three

Methods and Procedures

Introduction

The purpose of this study was to assess the interrater and intrarater reliability of the functional movement screen process when used to test college athletes by inexperienced, trained evaluators. The total score given by each of the two testing teams, for each athlete tested, was analyzed to determine the interrater reliability and intrarater reliability of the Functional Movement Screen. Interrater and intrarater reliability of the system was determined so that scores from previous and future studies could be applied to other populations accurately. Interrater and Intrarater reliability was also established so changes in pre-test and post-test scores following an intervention could be accurately assessed in future studies.

Description of Study Population

Forty-four collegiate athletes (24 male, 20 female) were recruited from the Western Washington University varsity athletic teams. All subjects were recruited on a volunteer basis with no form of compensation offered. Informed consent (Appendix A) was obtained prior to any testing following Western Washington University guidelines, along with permission from the varsity coaches.

Design of Study

This study was designed to determine interrater and intrarater reliability of the functional movement screen using intraclass correlation coefficients (ICC). A model three (two-way mixed model) ICC for the between-raters effect (ICC 3, 1) was used because each subject was assessed by the same set of raters. The independent variables were two evaluation teams and the dependent variable was the total FMS score for athlete.

Instrumentation

All testing was performed using the Functional Movement Screen system. This system includes the equipment needed to perform all seven tests (1-2”x6” board, 2-24’ dowels, 1- 48.5’ dowel and 2-31’ elastic rubber straps used to construct the hurdle).

All training for the evaluators was completed using only the standard videos included with the Functional Movement Screen system and the manual provided. All evaluators viewed the training video and reviewed the manual as a group during a two hour training session. Each evaluator then reviewed the training videos on their own time for an additional two hours. Each testing team performed ten training tests before testing any athletes. The training tests were done with a volunteer completing each of the seven tests with the evaluators scoring each test. While each individual test was being performed by the volunteer, the same test on the training video was being displayed on a projection screen. Each evaluator scored the volunteers in the same plane they were assigned for the testing of the athletes. During the training process, evaluators discussed how each test should be scored as it was taking place and were permitted to ask questions. Volunteers completed each test numerous times until the evaluators felt comfortable with the score that was agreed upon by the entire group of evaluators.

Scoring Sheet

The same standardized scoring sheet, developed based on the training video recommendations, was used by all evaluators for all tests. The FMS consists of seven tests (Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and Rotary Stability) and three clearing exams (linked to the Shoulder Mobility, Trunk Stability Push-up and Rotary Stability test) and the scoring ranges from 0 to 3 for each test. A score of 0 is only given if pain is experienced by the athlete during the test.

Deep Squat. The athlete holds a dowel in both hands and presses it overhead. Then with their feet approximately shoulder width apart, the athlete descends into a deep squat in order for their thighs to break parallel with the floor. The criteria being scored are: the upper torso is parallel with the tibia or toward vertical, femur is below horizontal, knees are aligned over feet, and the dowel is aligned over the feet.

Hurdle Step. The athlete places the dowel across their shoulders and stands with their feet together, at the base of the hurdle. The athlete then steps over the hurdle, with one leg, touches their heel to the floor and returns to the starting position. The criteria being scored are: hips, knees and ankles remain aligned in the sagittal plane, minimal to no movement is noted in lumbar spine and the dowel and hurdle remain parallel.

In-Line Lunge. The athlete holds the dowel vertically along the spine and stands atop the 2 x 6 board. The athlete then descends into a lunge, touching their knee behind their heel on their lead foot and returns to the starting position. The criteria being scored are: the dowel remains in contact with the L-spine extension, no torso movement is noted, dowel and feet remain in sagittal plane, and knee touches board behind heel of front foot.

Shoulder Mobility. In a single motion the athlete places one arm over their head and the other behind their back in an attempt to touch their fists behind their back. The distance between the athlete's fists is then measured. The criteria being scored are: the distance between the athletes' fists. A clearing test is also performed once this test is complete. The athlete places their hand flat on their opposite shoulder and then points their elbow vertically. If any pain is experienced during the clearing exam, a score of 0 is given for the shoulder mobility test.

Active Straight Leg Raise. The athletes lays supine on the floor, with their arms at their side. With their legs remaining straight the athlete then lifts one leg as high as possible and the distance they are able to raise their leg is measured. The criteria being scored are: the distance the athlete is able to raise their leg.

Trunk Stability Push-up. The athlete lies prone on the floor with their hands shoulder width apart. Male athletes position their thumbs in line with the forehead and female athletes position their thumbs in line with the chin. The athlete then raises themselves into a push-up position. The criteria being scored are: if the athlete can perform the movement. A clearing exam is also performed once the test is completed. The athlete places their hands beneath their shoulders and presses their chest of the floor, arching their back as much as possible, and keeping their hips in contact with the floor. If any pain is experienced during the clearing exam, a score of 0 is given for the Trunk Stability Push-up.

Rotary Stability. The athlete positions themselves on their hands and knees with both their shoulders and hips at 90 degrees. The athlete then lifts both their right arm and right leg off the ground and extends both their arm and their leg. Next the athlete will touch their elbow to their knee, return to the extended position and then back to the starting position. The criteria being scored are: keeping the spine parallel to the floor and the knee and elbow touch in-line. A clearing exam is performed after the Rotary Stability test is completed. The athlete assumes a quadruped position and then rocks back and touches their buttocks to their heels and their chest to their thighs. If any pain is experienced during the clearing exam, a score of 0 is given for the Rotary Stability Test.

Data Collection Procedures

This study was approved by the Human Subjects Committee at Western Washington University (Appendix A). All testing took place in either the Biomechanics Laboratory or Physiology Laboratory at Western Washington University. Each testing session took approximately 30 minutes per athlete. Each athlete signed-up for a testing time on a sign-up sheet which was posted outside of the Physiology Laboratory. The order in which each athlete was tested was pre-determined based on the time slot the athlete signed-up for. Each subject was given a subject number based on when they would report to the Biomechanics or Physiology Laboratory. All athletes were asked to wear form fitting clothing, as suggested in the FMS training video, to help insure the visibility of each body movement being evaluated. Upon arrival in the Biomechanics or Physiology laboratory, each athlete completed the informed consent form with the lead researcher, which included an explanation of the procedures, benefits and risks to participation, and the purpose of the study. The athlete then completed a short interview process to determine his/her age, sport, position played, previous injuries, dominant leg and dominant arm. The athlete's dominant arm was identified as the arm they would throw a ball with and their dominant leg was identified as the leg they would kick a ball with.

Once the interview was complete, each athlete was given a brief explanation of the testing process and introduced to the testing team. All verbal instructions were given by the team leader and were communicated for each test exactly as they were written in the FMS manual (Appendix B). The scoring criteria and description of each test are also listed in Appendix B. The tests were completed in the following order: deep squat, hurdle step, in-line lunge, shoulder mobility, shoulder clearing exam, active straight leg raise, trunk stability push-up, trunk clearing exam, rotary stability, and rotary clearing exam. The athlete performed three attempts at each test and was scored according to the scoring criteria provided in the training video and detailed in Appendix B.

This study had two evaluation teams, each consisting of two evaluators. All evaluators were trained on the Functional Movement Screen using the training materials provided with the instrument. The evaluators scored each athlete for all seven tests associated with the Functional Movement Screen. A member of each testing team was assigned to either a frontal plane or a sagittal plane viewing position. One member of each team was assigned to only one plane due to the fact that many of the scoring factors can only be seen from one plane and having one evaluator in each plane is common based on prior field experience using the FMS system to test Division 1 athletes. Most of the seven tests require the movement to be evaluated in two planes simultaneously, which is why one member of each team was assigned to only one plane. Each athlete was evaluated simultaneously by both evaluation teams. No communication regarding scoring occurred between either of the two testing teams or between the two members of each team.

Each team member scored the test on their own individual scoring sheet for each athlete. Each individual evaluator recorded the highest score for the three attempts performed by the athlete as their final score. Each evaluator was provided with a specific scoring sheet with the variables being tested in each test and the scoring criteria. Once the test was complete and all evaluators had completed their individual scoring sheets, the scores of the two evaluators on the same evaluation team were combined. In order to combine the final scores of the two individual evaluators on the same evaluation team, the lowest final score given by either evaluator was taken as the team's final score for that test. At no time during the testing process or upon completion of the test were the athletes told their performance scores on any of the tests. Once all seven tests were completed, the scoring sheets were collected by the lead researcher and filed for future analysis. Each evaluation team's scores for each athlete were kept confidential from the other evaluation team until all data was collected. The athlete was then asked if they would be willing to come back in two weeks to be retested by one of the testing teams.

Two weeks after the original testing process 21 athletes were retested by one of the testing teams, following the same procedures previously described. These tests were conducted to provide data for intrarater reliability.

Data Analysis

The total score given by each testing team, for each athlete, was analyzed to determine the interrater reliability of the Functional Movement Screen process and training system using an intraclass correlation coefficient (ICC). A model three (two-way mixed model) ICC for the between-raters effect (ICC 3, 1) was used because each subject was assessed by the same set of raters. The two scores given by team 1 for the 21 athletes who were brought back in for a second test were also analyzed to determine the intrarater reliability of the FMS system using an ICC (3, 1). The ICC (3, 1) ranges from 0.00 to 1.00, with higher values representing stronger reliability. There are no standard values for acceptable reliability using the ICC (3, 1), therefore the general guideline of values above 0.75 indicating good reliability and those below 0.75 representing poor to moderate reliability were used (Portney & Watkins, 2009). For measurements tools used to track changes over time a reliability exceeding 0.90 is recommend to ensure validity (Portney & Watkins, 2009). A significance level of $p < 0.05$ was acceptable for all correlations.

Chapter Four

Results, Discussion and Summary

Introduction

The purpose of this study was to assess the interrater and intrarater reliability of the Functional Movement Screen process when used to test college athletes by inexperienced, trained evaluators. The subject characteristics and Intra class correlation values for both interrater reliability and intrarater reliability are presented in this chapter.

Results

Subject characteristics.

The entire subject sample, tested for interrater reliability, consisted of 24 male and 20 female volunteer athletes from various Western Washington University athletic teams. The physical characteristics of the total subject sample, as well as the sports the subjects played, are listed in Table 2. The sub-group of athletes, tested twice by Team 1 for intrarater reliability, consisted of 14 male and 7 female volunteer athletes. The physical characteristics of the sub-group, as well as the teams the subjects played for, are listed in Table 3.

Table 2

Subject Characteristics

Interrater group	Total Subjects	Male Subjects	Female Subjects	Mean age (yrs)	Age SD	Mean Height (cm)	Height SD	Mean Weight (kg)	Weight SD
	44	24	20	21	2.5	174.4	8.61	71.28	13.07
Sports: Baseball (1), Cross Country (3), Cycling (2), Football (4), Rubgy (1), Soccer (4), Softball (7), Track & Field (20), Tri-athlete (1), Volleyball (1)									

Table 3

Subject Characteristics

Intrarater group	Total Subjects	Male Subjects	Female Subjects	Mean age (yrs)	Age SD	Mean Height (cm)	Height SD	Mean Weight (kg)	Weight SD
	21	14	7	21.62	3.15	175.26	7.45	74.85	13.77
Sports: Baseball (1), Cross Country (3), Cycling (2), Football (3), Soccer (1), Softball (2), Track & Field (8), Tri-athlete (1)									

Total Functional Movement Screen Score.

The total score given by Team 1 and Team 2 for each subject tested for interrater reliability is presented in Table 4. The mean total scores of team 1 and team 2 during the interrater reliability tests were 12.89 ± 1.92 and 13.02 ± 2.14, respectively. The total score given by Team 1 and Team 2 for each subject tested, who did not report pain during testing for interrater reliability is presented in Table 5. The mean total scores of team 1 and team 2 during the interrater reliability tests, for athletes who did not report pain, were 13.28 ± 1.75 and 13.44 ± 1.92. The scores given by each team, for each plane (frontal and sagittal), during interrater testing are presented in Table 6. The mean scores of team 1 and team 2 in the frontal plane during the interrater reliability tests were 14.20 ± 2.27 and 14.07 ± 2.19. The mean scores of team 1 and team 2 in the sagittal plane during the interrater reliability tests were 14.43 ± 2.07 and 14.57 ± 2.10.

Both of the total scores given by Team 1 for the subjects tested for intrarater reliability are presented in Table 7. The mean total scores of Team 1 during the first and second test for intrarater reliability were 13.63 ± 1.8 and 13.19 ± 1.89, respectively. Both of the total scores given by Team 1 for the subjects tested, who did not report pain during their first or second test, for intrarater reliability are presented in Table 8. The mean total scores of Team 1 during the first and second test for intrarater reliability, of athletes who did not report pain during their first or second test, were 13.81 ± 2.01 and 13.69 ± 1.70. The scores given by team 1, for each plane (frontal and sagittal), during intrarater testing are presented in Table 9. The mean scores of test 1 and test 2 in the frontal plane during the intrarater reliability tests were 14.95 ± 2.13 and 14.76 ± 2.12. The mean scores of test 1 and test 2 in the sagittal plane during the intrarater reliability tests were 14.81 ± 1.99 and 14.57 ± 1.86.

Table 4

Total Functional Movement Screen Scores Given by Team 1 and Team2

Subject	Team 1	Team 2
1	17	17
2	14	12
3	14	14
4	13	14
5	9	9
6	16	16
7	10	10
8	15	15
9	13	12
10	10	12
11	15	15
12	11	12
13	12	13
14	13	13
15	13	13
16	13	14
17	14	15
19	15	15
20	13	12
21	14	14
22	13	13
23	11	13
24	12	13
25	11	10
26	14	16
27	16	16
28	13	14
29	15	14
30	12	15
31	13	13
32	15	15
33	16	15
34	11	9
35	13	12
36	13	12
37	11	12
38	14	15
39	11	15
40	14	12
41	12	12
42	10	12
43	12	12
44	9	8
45	12	8

Team 1 Mean Score: 12.89 ± 1.92
Team 2 Mean Score: 13.02 ± 2.14

Table 5

Total Functional Movement Screen Scores Given by Team 1 and Team 2 (No Pain)

Subject	Team 1	Team 2
1	17	17
2	14	12
3	14	14
4	13	14
6	16	16
8	15	15
9	13	12
10	10	12
11	15	15
13	12	13
17	14	15
19	15	15
20	13	12
21	14	14
22	13	13
23	11	13
24	12	13
26	14	16
27	16	16
28	13	14
29	15	14
30	12	15
31	13	13
32	15	15
33	16	15
34	11	9
35	13	12
36	13	12
37	11	12
38	14	15
39	11	15
40	14	12
41	12	12
42	10	12
43	12	12
45	12	8

Team 1 Mean Score: 13.28 ± 1.75
Team 2 Mean Score: 13.44 ± 1.92

Table 6

FMS Scores Given by Team 1 and Team 2 in Frontal and Sagittal Planes

	Frontal Plane		Sagital Plane	
Subject #	Team 1	Team 2	Team 1	Team 2
1	18	17	18	17
2	18	15	14	12
3	14	16	17	15
4	14	15	15	16
5	10	9	9	10
6	18	16	16	17
7	11	10	11	11
8	17	16	16	16
9	14	14	14	15
10	10	14	16	15
11	17	16	16	17
12	14	15	14	12
13	13	13	14	15
14	14	14	14	14
15	13	13	14	14
16	13	15	16	14
17	14	15	15	16
19	17	17	15	17
20	14	13	16	15
21	17	15	15	17
22	15	16	14	14
23	12	15	12	13
24	14	15	12	13
25	12	11	15	14
26	15	17	16	17
27	17	17	17	16
28	13	14	16	14
29	16	15	15	16
30	13	15	15	17
31	15	15	15	14
32	16	15	18	20
33	18	17	18	17
34	12	10	14	13
35	14	12	14	14
36	14	13	15	15
37	12	13	13	13
38	16	15	15	16
39	14	16	13	16
40	14	12	15	13
41	15	13	12	13
42	11	12	11	13
43	13	13	13	13
44	9	8	9	10
45	15	12	13	12
Mean	14.20	14.07	14.43	14.57
SD	2.27	2.19	2.07	2.10

Table 7

Total FMS Scores Given by Team 1 for Sub-Group during 1st and 2nd Test

Subject	1st Test	2nd Test
1	17	18
2	14	13
4	13	13
8	15	13
9	13	14
11	15	15
14	13	13
15	13	13
16	13	12
17	14	11
19	15	14
24	12	13
27	16	14
29	15	14
30	12	13
32	15	15
33	16	15
37	11	13
41	12	12
42	10	10
43	12	9

1st Test Mean Score: 13.62 ± 1.80
2nd Test Mean Score: 13.19 ± 1.89

Table 8

Total FMS Scores Given by Team 1 for Sub-Group, no pain, during 1st and 2nd Test

Subject	1st Test	2nd Test
1	17	18
2	14	13
4	13	13
8	15	13
9	13	14
11	15	15
19	15	14
24	12	13
27	16	14
29	15	14
30	12	13
32	15	15
33	16	15
37	11	13
41	12	12
42	10	10

1st Test Mean Score: 13.81 ± 2.01
2nd Test Mean Score: 13.69 ± 1.70

Table 9

FMS Scores Given by Team 1 in Frontal and Sagittal Planes during Intrarater Testing

	Frontal Plane		Sagital Plane	
Subject #	Test 1	Test 2	Test 1	Test 2
1	18	19	18	19
2	18	15	14	16
4	14	14	15	14
8	17	15	16	15
9	14	16	14	17
11	17	15	16	16
14	14	15	14	14
15	13	14	14	14
16	13	14	16	14
17	14	13	15	13
19	17	17	15	14
24	14	15	12	13
27	17	15	17	16
29	16	15	15	14
30	13	16	15	14
32	16	15	18	17
33	18	19	18	16
37	12	13	13	14
41	15	14	12	13
42	11	11	11	11
43	13	10	13	12
Mean	14.95	14.76	14.81	14.57
SD	2.13	2.12	1.99	1.86

Table 10

ICC (3, 1) Values and Significance Values for all Data

	ICC (3, 1) Values	Sig (p)
Interrater Reliablity	0.763	< 0.001
Interrater Reliablity- Without Pain	0.661	< 0.001
Interrater Reliablity - Frontal Plane	0.752	< 0.001
Interrater Reliablity - Sagittal Plane	0.801	< 0.001
Intrarater Reliablity	0.731	< 0.001
Intrarater Reliablity - Without Pain	0.818	< 0.001
Intrarater Reliablity -Frontal Plane	0.713	< 0.001
intrarater Reliablity - Sagittal Plane	0.762	< 0.001

All eight ICC (3, 1) values have a $p < 0.001$ below the threshold of 0.05 and are therefore accepted as being significant. There are no standard values for acceptable reliability using the ICC (3, 1), therefore the general guideline of values above 0.75 indicating good reliability and those below 0.75 representing poor to moderate reliability were used (Portney & Watkins, 2009). The ICC (3,1) values of the interrater reliability, interrater reliability – frontal plane, interrater reliability – sagittal plane, intrarater reliability – without pain, and intrarater reliability - sagittal plane are all above 0.75 which indicates a good strength of association. The ICC (3, 1) values of the interrater reliability – without pain, intrarater reliability, and intrarater reliability – frontal plane are below 0.75 indicating a poor to moderate strength of association (Portney & Watkins, 2009).

Discussion

The ICC (3, 1) values of 0.763 ($p < 0.001$) and 0.731 ($p < 0.001$) suggest a good and poor to moderate strength of association for interrater and intrarater reliability, respectively (Portney & Watkins, 2009). Both of these ICC (3, 1) values are significant ($p < 0.001$) therefore the null hypothesis which states "There will be no relationship between the total score given by the two testing groups for each athlete. There will also be no relationship between the total scores given during two separate tests performed by a single team of evaluators" is rejected. These results suggest the scores given by teams 1 and 2 during interrater reliability testing are well correlated and scores given by two different testing teams can be compared with some confidence (Portney & Watkins, 2009). These results further suggest the scores given by team 1 during the first and second tests for intrarater reliability are poor to moderately correlated and evaluating an athlete's progress using pre- and post- scores can only be done with moderate confidence (Portney & Watkins, 2009).

Upon examination of Table 4, the total scores given to each athlete by team 1 and team 2 during interrater reliability testing reveals 70% of the scores were identical or within one score of each other (17/44 scores= identical; 17/44 scores = within one of each other). Seven of the scores given by teams 1 and 2 during interrater reliability testing differed by 2, and three scores had a difference of 3 or greater, with the maximum difference being a 4. While the ICC (3, 1) value of 0.763 for interrater reliability suggests a good correlation based on the general guidelines used in this study, it should be noted an instrument used for tracking changes over time should show an ICC (3, 1) value of 0.9 or greater (Portney & Watkins, 2009). This indicates the interrater reliability of the FMS needs to be improved before scores between evaluators can be compared with confidence. Improving the quality and clarity of the instructions may help increase the interrater reliability of the FMS. Evaluators expressed confusion and different interpretations of what was being said in the instructions during the training process. Upon completion of the study, evaluators also expressed their interpretation of the manual and scoring criteria changed throughout the course of the study. The training materials provided leave the interpretation up to the evaluator and clearer training materials or the certification suggested in the training video may be needed to increase the interrater reliability to a more acceptable level. There have been no prior studies performed on the interrater reliability of the Functional Movement Screen, so no comparisons can be made between previous studies and the finding in this study.

The scores given in the frontal and sagittal planes during interrater reliability testing by team 1 and team 2 are displayed in Table 6. The ICC (3, 1) values of 0.752 in the frontal plane and 0.801 in the sagittal plane show a good correlation for interrater reliability of the FMS in both planes (Portney & Watkins, 2009). The ICC (3, 1) of 0.801 in the sagittal plane shows a higher correlation between evaluators using the sagittal plane scoring criteria than those using the frontal plane scoring criteria. Examination of the scores given in the frontal and sagittal planes during intrarater reliability in Table 9 reveals the same trend. The ICC (3, 1) was .0713 in the frontal plane and 0.762 in the sagittal plane. These results reveal a higher correlation in the sagittal plane than the frontal plane for both interrater and intrarater reliability. Improving the correlation of the scoring criteria used in the frontal plane would help improve both the interrater and intrarater reliability for the total FMS score.

Upon inspection of Table 7, the total scores given by team 1 during the first and second test for intrarater reliability, shows 69% of the athletes tested twice received the same score or a score within one (7/21=same score; 9/21=score differed by one). Three of the 21 athletes tested twice were given scores that differed by two and only two were given scores with a difference of three. Further investigation of the scoring sheets revealed that both athletes given a score which differed by three, reported pain during one of the testing sessions, but did not report any pain during the other testing session. Both scores which differed by three, show a difference of one or zero in total score between the first and second testing session, when the score given prior to pain being reported is used. The possible causes for the difference in pain being reported by the athletes during the two different testing sessions were a lack of a definition of what pain is and using athletes who were involved in competition or heavy off-season training between testing sessions. These limitations had an effect on the intrarater reliability reported in this study and should be taken in consideration when interpreting the results.

To determine the effect reported pain had on the results, athletes who reported pain during one of the testing sessions were removed and an ICC (3, 1) was done only on the athletes who did not report pain in either testing session. The ICC (3, 1) for intrarater reliability – without pain was 0.818 ($p < 0.001$). These results confirm the pain reported by the athletes during one testing session, but not the other, decreased the intrarater reliability of the FMS. These results suggest pre- and post- test scores from a healthy athlete are correlated and can be compared with confidence (Portney & Watkins, 2009).

The fact that the subjects were not taken through a standardized warm-up prior to testing may have had an impact on the intrarater reliability of the FMS. The athletes in this study were not taken through any standardized warm-up before beginning the test and began the test in the state of physical readiness they report to the lab. During intrarater testing, some athletes ran or biked to the laboratory during one testing session and walked during the other. This difference in activity level may have affected the intrarater reliability of the FMS. The relatively small scoring scale (0-3) may have also impacted the statistics of this study.

The present study is the only known study investigating the interrater and intrarater reliability of the Functional Movement Screen. The results of the present study indicate a good ICC (3, 1) value for interrater reliability and a poor to moderate ICC (3, 1) value for intrarater reliability (Portney and Watkins, 2009). However, when the limitation of pain being reported during only one of the two test sessions is removed, the intrarater reliability ICC (3, 1) value shows a better reliability. The limitations during the present study had an impact on intrarater reliability and should be taken into account when evaluating the results.

Further investigation of both the interrater and intrarater reliability of the Functional Movement Screen is necessary to determine the effect the limitations had on the present study and for a complete understanding of the interrater and intrarater reliability of the total Functional Movement Screen score given to college athletes during testing.

Chapter Five

Summary, Conclusions and Recommendations

Summary

Two testing teams consisting of two members each, one member observing only the frontal plane and the other observing on the sagittal plane, evaluated 44 division 2 college athletes using the Functional Movement Screen. All 44 athletes underwent the first testing session and were evaluated by both testing teams to determine the interrater reliability of the Functional Movement Screen. Twenty-one of the athletes were tested a second time by Team 1 to determine the intrarater reliability of the Functional Movement Screen. The total Functional Movement Screen score given during the testing process for each subject was analyzed using an ICC (3, 1).

The results of this study indicate an ICC (3, 1) value of 0.763 for the interrater reliability of the Functional Movement Screen and an ICC (3, 1) value of 0.731 for intrarater reliability. Upon examination of the total scores given and the testing sheets used by each evaluator, the pain reported by the athletes during intrarater reliability testing reduced the intrarater reliability of the FMS. The fact that all of the athletes tested were either in season or involved in heavy off-season training affected the strength of association for the intrarater reliability. When the athletes who reported pain during one testing session for intrarater reliability were removed, the ICC (3, 1) was 0.818 for intrarater reliability. These results suggest that the training and competition status of the athletes may have an effect on the athlete's ability to perform the test and this should be taken into account when evaluating the athletes FMS score.

These results also suggest the training materials Included with the Functional Movement Screen are sufficient enough to result in a good correlation for both interrater and intrarater reliability from an evaluator with no experience, but the training materials need to be improved to achieve a ICC (3, 1) of 0.9 or greater, which is suggested for instruments used to measure changes over time (Portney & Watkins, 2009). The sagittal plane showed a higher correlation than the frontal plane during both interrater (ICC 3, 1 sagittal was 0.801 and frontal was 0.752) and intrarater testing (ICC 3, 1 sagittal was 0.762 and frontal was 0.713). Improving the correlation in the frontal plane scoring criteria would increase both the interrater and intrarater reliability of the total FMS score to help track changes in athlete's movement over time.

Conclusions

The major findings in this investigation were providing the first reported interrater and intrarater reliability, respectively, for the Functional Movement Screen when administered by inexperienced, trained evaluators. However, the strength of association for intrarater reliability was diminished by the lack of a definition of pain prior to the testing and testing athletes who were involved in competition or heavy off-season training between tests. When the limitation of pain is removed, the intrarater reliability shows a good strength of association. The sagittal plane also showed a higher correlation than the frontal plane during both interrater and intrarater testing. Improving the correlation in the frontal plane scoring criteria would increase both the interrater and intrarater reliability of the total FMS score. Despite these findings, both the interrater and intrarater reliability of the FMS needs to be improved in order to use the system to track changes in athlete's movement patterns over time.

The scores given by the two testing teams for the majority of the subjects tested, 34 of 44, showed a difference of only one or less in total score across evaluation teams. Similarly, 16 of the 21 subjects' two scores differed by one or less across testing days, as assessed by the same evaluators. While the ICC (3, 1) values originally revealed a good and poor to moderate association for interrater and intrarater reliability respectively, the examination of the limitations present in this study indicate the association was stronger than reported if the limitations were eliminated or minimized. Providing a clear definition of what is considered pain to both the evaluators and the athletes would increase the intrarater reliability of the measurement. The lack of research to determine the interrater and intrarater reliability of the Functional Movement Screen, as well as the limited research using the FMS to identify and potentially minimize the risk factors of non-contact injuries in athletes, indicates a need for further investigation using the Functional Movement Screen.

Recommendations

The following recommendations are suggested for future investigations:

1. Use a standardized warm-up for athletes prior to administering the FMS to insure the athlete is in the same physical condition before each testing session.
2. Conduct more studies using athletes to establish the interrater and intrarater reliability of the Functional Movement Screen. Such studies should eliminate or minimize the subjective interpretation of the scoring criteria, a lack of a definition of pain prior to testing, and using athletes who are in season to determine a more accurate reliability standard. In order to eliminate subjective interpretation of the scoring criteria, more

specific criteria need to be established for each test. This would add evidence to the reliability of the Functional Movement Screen and provide reliability standards for using the Functional Movement Screen in research to identify and minimize risk factors for non-contact injuries.

3. Repeat the present study using athletes from only one sport. This would help determine if there are different reliability measures when testing athletes of different sports, possibly due to variations in training practices and training status.
4. Repeat the present study, using one testing team that uses only the training provided with the Functional Movement Screen and another team which goes through the certification process. This would help determine if there is a different level of reliability depending on the training method used for the evaluator and if more advanced training is necessary to increase the reliability of the testing process.
5. Conduct studies examining the relationship between the score given in preseason Functional Movement Screen testing and the number of non-contact injuries during the season. Such studies may test athletes prior to the season and then track the number of non-contact injuries that result in time lost from practice or play through observation by the athletic training staff. Results from such studies would provide evidence of any association between the Functional Movement Screen score and the likelihood of sustaining a non-contact injury which results in loss time during the season. This line of research may evaluate the efficacy of the use of the FMS in identifying athletes who are at an increased risk of sustaining a non-contact, so individualized prevention strategies may be implemented.

6. Conduct studies to examine the effect of the corrective exercises provided with the Functional Movement Screen suggested to improve the athlete's score and reduce the likelihood of suffering a non-contact injury. Such studies could test the athlete in the off-season and then prescribe the appropriate corrective exercises, based on the outcome of the off-season Functional Movement Screen test, and retest the athlete at the end of the off-season. Such testing would help determine the effectiveness of the corrective exercises provided with the Functional Movement Screen and help determine if these exercises may potentially decrease the athlete's risk of suffering a non-contact injury in the upcoming season.

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Appendix A

Consent Form

Purpose and Benefit:

Functional Movement Screening (FMS) is a method of determining athletes who may be at an increased risk of suffering a non-contact injury. FMS is performed based on the training materials provided with the system and athletes are scored on a scale of 0 to 3 for each test. The purpose of this experiment is to examine the consistency between scores performed by two separate teams of evaluators on the same athlete. The difference between scores collected by the same team in two different sessions will also be compared. The results of this study will help determine if FMS scores, obtained by different evaluators, can be compared and applied in further research and athletics. The potential benefits for you are possibly uncovering a movement pattern that may lead to a possible injury in the future.

I understand that:

1. This experiment will involve completion of one or two testing sessions (your choice) that will involve filling out a questionnaire and participating in 7 movement tests designed to identify underlying movement patterns which may lead to non-contact injuries. My participation will involve approximately 30 minutes to one hour depending on if I volunteer for the second testing sessions two weeks later. The tests performed during the screening process are: Deep Squat (squatting past parallel), Hurdle Step (Stepping over a knee high hurdle with one leg), In-Line Lunge (A single leg lunge to touch your knee to the floor), Shoulder Mobility (Placing arms behind your back), Active Straight-Leg Raise (Raising one leg off the floor as far as possible while lying on your back), Trunk Stability Push-up (performing a push-up with hands slightly higher than shoulders) and a Rotary Stability Test (while on hands and knees touch one elbow to your knee).
2. There are no anticipated risks associated with participation. No previous injuries have been reported during FMS screening. You will be asked during every test if you feel any pain or discomfort. Slight discomfort and/or pain may be revealed during the movement screens in which case the test will be stopped and the discomfort or pain noted on the scoring sheet.
3. My participation is voluntary. I may choose **not** to answer certain questions or to complete any and all tests. I may withdraw from participation at any time without penalty.
4. All information is confidential. My signed consent form will be kept in a locked cabinet separate from the questionnaires and scoring sheets. Only the evaluators who perform my screen and the primary researcher will see my scoring sheet. I will be assigned a number by the primary researcher and only this number will appear on my scoring sheet. My name will not be associated with my scoring sheet.
5. My signature on this form does not waive my legal rights of protection.
6. I am at least 18 years old.
7. This experiment is conducted by Jason Dudley. Any questions that you have about the experiment or your participation may be directed to him at 425-306-1007 dudleyj2@cc.wwu.edu or Lorrie Brilla 360-650-3056 Lorrie.Brilla@wwu.edu. If you have any questions about your participation or your rights as a research participant, you can contact Geri Walker, WWU Human Protections Administrator (HPA), (360) 650-3220, geri.walker@wwu.edu. If during or after participation in this study you suffer from any adverse effects as a result of participation, please notify the researcher directing the study or the WWU Human Protections Administrator.

I have read the above description and agree to participate in this study.

Participant's Signature ____________________ Date ____________

____

Participant's PRINTED NAME

NOTE: Please sign both copies of the form and **retain the copy marked "Participant."**

Appendix B

Verbal Instructions and Scoring Criteria for Each Test (Included Exactly as it Appears in the Training Manual)

The same verbal instructions and scoring criteria were used for each testing team and they were taken directly from the training manual (Cook 2005).

Deep Squat (Cook 2005)

Verbal Instructions:

"Hold the dowel with both hands over your head in order for both your shoulders and elbows to maintain a 90 degree angle. Now, press the dowel over your head and hold it there."

"Place your feet in a comfortable position, approximately shoulder width or slightly greater than shoulder width apart. Point your toes forward and keep them pointing forward."

"While maintaining an upright posture, the dowel over your head, and your heels on the floor, descend into a deep squat in order for your thighs to break parallel with the floor." (Score the subject)

"Return to the starting position." (Repeat 3 times if necessary)

Repeat the instructions as stated above using a 2 x 6 board beneath the subject's heels if necessary.

Scoring Criteria:

To obtain a 3:

- Upper torso is parallel with tibia or toward vertical
- Femur below horizontal

- Knees are aligned over feet

- Dowel aligned over feet

To obtain a 2: (2x6 board is placed below the subject’s heels)

- Upper torso is parallel with tibia or toward vertical

- Femur is below horizontal

- Knees are aligned over feet

- Dowel is aligned over feet

To obtain a 1:

- Tibia and upper torso are not parallel

- Femur is not below horizontal

- Knees are not aligned over feet

- Lumbar flexion is noted

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

Hurdle Step (Cook 2005)

Verbal Instructions:

"Place the Dowel across your shoulders. Now, stand comfortably with your feet together and your toes against the base of the Hurdle."

"While maintaining an upright posture, step over the hurdle without touching the string."

"Touch the floor with your heel and return to the starting position."

Repeat instructions 2 and 3 for the left foot. (Score the subject)

Repeat 3 times per side if necessary.

Scoring Criteria:

To obtain a 3: (scored for leg stepping over hurdle)

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

To obtain a 2:

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

To obtain a 1:

- Contact between foot and hurdle

- Loss of balance is noted

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

<u>In-Line Lunge (Cook 2005)</u>

<u>Verbal Instruction</u>:

“Hold the dowel with both hands and position it along your spine with your right hand against the back of your neck and your left hand against your low back.”

“Step onto the 2 x 6 with your right foot along the back edge and place your left foot with the heel just past (length of the tibia) the black line (or mark). Point your toes forward and keep them pointing forward.”

“While maintaining an upright posture, descend into a lunge, touching your right knee along the black line (or mark) behind your left heel. Maintain contact with the dowel against the head, thoracic spine and sacrum.”

“Return to the starting position, making sure to place the right heel flat on the board.”

Repeat instructions 1 through 4 with the left side. (Score the subject)

Repeat 3 times per side if necessary

<u>Scoring Criteria</u>:

<u>To obtain a 3</u>:

- Dowel contacts remain with L-spine extension

- No torso movement is noted

- Dowel and feet remain in sagittal plane

- Knee touches board behind heel of front foot

To obtain a 2:

- Dowel contacts do not remain with L-spine extension

- Movement is noted in torso

- Dowel and feet do not remain in sagittal plane

- Knee does not touch behind heel of front foot

To obtain a 1:

- Loss of balance is noted

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

Shoulder Mobility (Cook 2005)

Verbal Instruction:

While in a comfortable standing position, instruct the subject to:

"Make a fist with the thumbs tucked in the fist."

“In a single motion, place your right fist over your head on to your back and your left fist behind your back, attempting to touch the fists.”

“Do not move your hands closer after their initial placement.” (Measure the distance between the fists. The closest proximity for each)

Repeat instruction 2 with the opposite hand placement. (Score the subject)

<u>Active Shoulder Stability Verbal Instruction:</u>

“Place your right hand on your left shoulder.”

“While maintaining that hand placement, raise your right elbow toward your forehead.”

Ask the subject: “Do you feel any pain?”

Repeat instructions 1 through 3 with the left side. (Score the subject)

<u>Scoring Criteria</u>:

<u>To obtain a 3</u>:

- Fists are within one hand length

<u>To obtain a 2</u>:

- Fists are within one and a half hand lengths

<u>To obtain a 1</u>:

- Fists are not within one and half hand lengths

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

Clearing test:

Have the subject place his/her hand on the opposite shoulder and then attempt to point the elbow upward. If there is pain associated with this movement, a score of zero is given for the shoulder mobility test.

Active Straight Leg Raise (Cook 2005)

Verbal Instruction:

"Lay on your back with the back of your knees against the 2 x 6, arms at your side, palms facing up, and toes pointing up."

"Lift the toes of your right foot toward your shin. With your legs remaining straight and toes pointing toward the ceiling/sky, raise your right leg as high as possible, without any movement occurring in left leg." (Measure lift in relation to opposite leg)

Repeat instruction 2 with the left side. (Score the subject)

Scoring Criteria:

To obtain a 3:

- Ankle/Dowel resides between mid-thigh and ASIS

To obtain a 2:

- Ankle/Dowel resides between mid-thigh

and midpatella/joint line

To obtain a 1:

- Ankle/Dowel resides below midpatella/joint line

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

Trunk Stability Push-up (Cook 2005)

Verbal Instruction:

“Lay on your stomach with your hands positioned shoulder width apart (appropriate hand placement).”

- Males: Thumbs in line with the forehead

- Females: Thumbs in line with the chin.

“Raise your toes toward your shin and place them on the ground. Extend your knees off of the ground.”

“Maintain a rigid torso; raise yourself as one unit with no lag in the low back into a push-up position.”

Repeat 3 times if necessary.

Repeat instructions 1 through 3 with appropriate hand placement if necessary. (Score the subject)

Prone Press-up Verbal Instruction:

While lying on their stomach, instruct the subject to:

“Place both hands (palms down) beneath your shoulders.”

“Press your chest off of the floor by extending your elbows, arching your back as much as possible, keeping your hips in contact with the floor.”

Ask the subject: “Do you feel any pain?” (Score the subject)

Scoring Criteria:

To obtain a 3:

- Males perform 1 repetition with thumbs aligned with the top of the forehead

- Females perform 1 repetition with thumbs aligned with chin

To obtain a 2:

- Males perform 1 repetition with thumbs aligned with chin

- Females perform 1 repetition with thumbs aligned with clavicle

To obtain 1:

- Males are unable to perform 1 repetition with hands aligned with chin

- Females are unable to perform 1 repetition with thumbs aligned with clavicle

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

Clearing Exam:

Spinal extension can be cleared by performing a press-up in the push-up position. If there is pain associated with this motion, a zero is given and a more thorough evaluation should be performed.

Rotary Stability (Cook 2005)

Verbal Instruction:

In a hands and knees position, instruct the subject to:

"Position your shoulders and hips at 90 degrees with your thumbs and knees touching the sides of the 2 x 6."

"Lift both your right arm and leg off of the ground, pointing the arm forward and leg backward. Next, touch your right elbow and knee over the board. Again, return to the extended position. Perform this movement keeping your back as flat as possible."

"Return to the starting position." Repeat instructions 2 and 3 with the left side. If necessary, instruct the subject to use a diagonal pattern of right arm and left leg. Repeat diagonal pattern with left arm and right leg. (Score the subject)

Passive Spinal Flexion Verbal Instruction:

While in a hands and knee position, instruct the subject to:

“While maintaining contact with your hands on the floor, rock back to your heels.”

“Now, lower your chest to your knees, reaching your arms in front of you on the floor.”

Ask the subject “Do you feel any pain?” (Score the subject)

<u>Scoring Criteria</u>:

<u>To obtain a 3</u>:

- Performs 1 correct unilateral repetition while keeping spine parallel to board
- Knee and elbow touch in line over the board

<u>To obtain a 2</u>:

- Performs 1 correct diagonal repetition while keeping spine parallel to board
- Knee and elbow touch in line over the board

<u>To obtain a 1</u>:

- Inability to perform diagonal repetitions

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

Clearing Exam:

Spinal flexion can be cleared by first assuming a quadruped position and then rocking back and touching the buttocks to the heels and the chest to the highs. The hands should remain in front of the body reaching out as far as possible. If there is pain associated with this motion a zero is given.

Functional Movement Screen (Scoring Sheet)

Subject Number____________________________________ _________Date:____________________________

Age___________Height_______________Weight__________________ Male Female

Address:______________________Phone:_______________City:_____________State:______Zip:__________

Sport:____Position:______________________________________

Hand dominance: L R Leg dominance: L R Eye dominance: L R

Previous Injuries:____

____

____

____

Test Score Comments

Deep Squat 3 2 1 0 _________________________________ ______________ Final Score:___

Hurdle Step R 3 2 1 0____

L 3 2 1 0__________________________Asym. Score__________Final Score:___

In-Line Lunge R 3 2 1 0____

L 3 2 1 0_________________________ Asym. Score_________ Final Score:___

Shoulder mobility R 3 2 1 0____

L 3 2 1 0__________________________ Asym. Score_________ Final Score:___

Clearing Exam R: Pass Fail Clearing Exam L: Pass Fail

Active S. Leg raise R 3 2 1 0____

L 3 2 1 0__________________________ Asym. Score_________ Final Score:___

Trunk stability push-up 3 2 1 0____ Final Score:___

Clearing Exam: Pass Fail

Rotary stability R 3 2 1 0____

L 3 2 1 0_________________________ Asym. Score_________ Final Score:___

Clearing Exam: Pass Fail

Total Score:___________ Asymmetry Score:__________ Evaluator:________________________________

Appendix C

Table 4

Total Functional Movement Screen Scores Given by Team 1 and Team2

Subject	Team 1	Team 2
1	17	17
2	14	12
3	14	14
4	13	14
5	9	9
6	16	16
7	10	10
8	15	15
9	13	12
10	10	12
11	15	15
12	11	12
13	12	13
14	13	13
15	13	13
16	13	14
17	14	15
19	15	15
20	13	12
21	14	14
22	13	13
23	11	13
24	12	13
25	11	10
26	14	16
27	16	16
28	13	14
29	15	14
30	12	15
31	13	13
32	15	15
33	16	15
34	11	9
35	13	12
36	13	12
37	11	12
38	14	15
39	11	15
40	14	12
41	12	12
42	10	12
43	12	12
44	9	8
45	12	8

Team 1 Mean Score: 12.89 ± 1.92
Team 2 Mean Score: 13.02 ± 2.14

Table 5

Total Functional Movement Screen Scores Given by Team 1 and Team2 (No Pain)

Subject	Team 1	Team 2
1	17	17
2	14	12
3	14	14
4	13	14
6	16	16
8	15	15
9	13	12
10	10	12
11	15	15
13	12	13
17	14	15
19	15	15
20	13	12
21	14	14
22	13	13
23	11	13
24	12	13
26	14	16
27	16	16
28	13	14
29	15	14
30	12	15
31	13	13
32	15	15
33	16	15
34	11	9
35	13	12
36	13	12
37	11	12
38	14	15
39	11	15
40	14	12
41	12	12
42	10	12
43	12	12
45	12	8

Team 1 Mean Score: 13.28 ± 1.75
Team 2 Mean Score: 13.44 ± 1.92

Table 6

Total FMS Scores Given by Team 1 and Team 2 in Frontal and Sagittal Planes

	Frontal Plane		Sagital Plane	
Subject #	Team 1	Team 2	Team 1	Team 2
1	18	17	18	17
2	18	15	14	12
3	14	16	17	15
4	14	15	15	16
5	10	9	9	10
6	18	16	16	17
7	11	10	11	11
8	17	16	16	16
9	14	14	14	15
10	10	14	16	15
11	17	16	16	17
12	14	15	14	12
13	13	13	14	15
14	14	14	14	14
15	13	13	14	14
16	13	15	16	14
17	14	15	15	16
19	17	17	15	17
20	14	13	16	15
21	17	15	15	17
22	15	16	14	14
23	12	15	12	13
24	14	15	12	13
25	12	11	15	14
26	15	17	16	17
27	17	17	17	16
28	13	14	16	14
29	16	15	15	16
30	13	15	15	17
31	15	15	15	14
32	16	15	18	20
33	18	17	18	17
34	12	10	14	13
35	14	12	14	14
36	14	13	15	15
37	12	13	13	13
38	16	15	15	16
39	14	16	13	16
40	14	12	15	13
41	15	13	12	13
42	11	12	11	13
43	13	13	13	13
44	9	8	9	10
45	15	12	13	12
Mean	14.20	14.07	14.43	14.57
SD	2.27	2.19	2.07	2.10

Table 7

Total FMS Scores Given by Team 1 for Sub-Group during 1st and 2nd Test

Subject	1st Test	2nd Test
1	17	18
2	14	13
4	13	13
8	15	13
9	13	14
11	15	15
14	13	13
15	13	13
16	13	12
17	14	11
19	15	14
24	12	13
27	16	14
29	15	14
30	12	13
32	15	15
33	16	15
37	11	13
41	12	12
42	10	10
43	12	9

1st Test Mean Score: 13.62 ± 1.80
2nd Test Mean Score: 13.19 ± 1.89

Table 8

Total FMS Scores Given by Team 1 for Sub-Group, no pain, during 1st and 2nd Test.

Subject	1st Test	2nd Test
1	17	18
2	14	13
4	13	13
8	15	13
9	13	14
11	15	15
19	15	14
24	12	13
27	16	14
29	15	14
30	12	13
32	15	15
33	16	15
37	11	13
41	12	12
42	10	10

1st Test Mean Score: 13.81 ± 2.01
2nd Test Mean Score: 13.69 ± 1.70

Table 9

Total FMS Scores Given by Team 1 in Frontal and Sagittal Planes during Intrarater Testing

	Frontal Plane		Sagital Plane	
Subject #	Test 1	Test 2	Test 1	Test 2
1	18	19	18	19
2	18	15	14	16
4	14	14	15	14
8	17	15	16	15
9	14	16	14	17
11	17	15	16	16
14	14	15	14	14
15	13	14	14	14
16	13	14	16	14
17	14	13	15	13
19	17	17	15	14
24	14	15	12	13
27	17	15	17	16
29	16	15	15	14
30	13	16	15	14
32	16	15	18	17
33	18	19	18	16
37	12	13	13	14
41	15	14	12	13
42	11	11	11	11
43	13	10	13	12
Mean	14.95	14.76	14.81	14.57
SD	2.13	2.12	1.99	1.86

Interrater Reliability- ICC- Total Scores

Total Scores	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.763**	0.605	0.863	7.345	43	43	0.000
Average Measures	0.865	0.754	0.927	7.345	43	43	0.000

Interrater Reliability- ICC- Total Scores With No Pain

Total Scores	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.661**	0.428	0.811	4.830	35	35	0.000
Average Measures	0.796	0.599	0.896	4.830	35	35	0.000

Interrater Reliability- ICC- Frontal Plane Team 1 and Team 2

Total Scores	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.752**	0.589	0.857	6.986	43	43	0.000
Average Measures	0.859	0.741	0.923	6.986	43	43	0.000

Interrater Reliability- ICC- Sagittal Plane Team 1 and Team 2

Total Scores	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.801**	0.663	0.886	8.938	43	43	0.000
Average Measures	0.889	0.798	0.94	8.938	43	43	0.000

Intrarater Reliability- ICC -Total Scores

Total Scores	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.731**	0.454	0.881	6.751	20	20	0.000
Average Measures	0.845	0.624	0.937	6.751	20	20	0.000

Intrarater Reliability- ICC -Total Scores With No Pain							
		95% Confidence Interval		F Test with True Value 0			
Total Scores	Intraclass Correlation	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.818**	0.554	0.932	9.519	15	15	0.000
Average Measures	0.900	0.713	0.965	9.519	15	15	0.000

Intrarater Reliability- ICC -Frontal Plane Test 1 and Test 2							
		95% Confidence Interval		F Test with True Value 0			
Total Scores	Intraclass Correlation	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.713**	0.414	0.873	5.791	20	20	0.000
Average Measures	0.832	0.586	0.932	5.791	20	20	0.000

Intrarater Reliability- ICC -Sagittal Plane Test 1 and Test 2							
		95% Confidence Interval		F Test with True Value 0			
Total Scores	Intraclass Correlation	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	**0.762**	0.504	0.895	7.287	20	20	0.000
Average Measures	0.865	0.670	0.945	7.287	20	20	0.000