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The Capability of the Functional Movement Screen to Predict Injury in Division I Male and Female Track and Field Athletes

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THE CAPABILITY OF THE FUNCTIONAL MOVEMENT SCREEN TO PREDICT INJURY IN DIVISION I MALE AND FEMALE TRACK AND FIELD ATHLETES

by

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Introduction

Track and field, formally know as athletics, formed part of the first Olympics in 776 BC and was included in the first modern Olympic Games in 1896 (Quercetany, 2000). Ever since the creation of this sport, sport related injury has followed. The inevitability of musculoskeletal injury associated with sports in general is well known amongst its participants, and the people who research it. According to the NCAA Injury Surveillance System, a sixteen year sampling period (1988 through 2004), recorded 182,000 injuries (Hootman, Dick, & Agel, 2007). Despite the risk for injury, people continue to participate in track and field. During that 16 year sampling period, participation has increased among both sexes: (80% increase in females and 20% increase in males) in all NCAA championship sports (Hootman, Dick, & Agel, 2007).

Sports medicine professionals provide preventive, curative, and rehabilitative health care services to sport participants. Over the past few decades, as technology and medical knowledge advances, curative and rehabilitative medicine techniques and strategies have improved the abilities of the medical professional to diagnose and treat a sport injury. Preventative medicine and strategies are lagging behind. Injury prevention is, or at least should be, the number one goal of any sports medicine professional.

Currently many different strategies are employed to reduce the likelihood or degree of sport related injury. For instance, prophylactic taping and bracing; there have been many improvements in athletic protective equipment and shoe wear, including the use of custom orthotics. Changes have also been made by the NCAA and other governing bodies on specific sports rules that are aimed at keeping athletes healthy. These changes include regulating the amount of practice exposures. Another preventative measure is to improve an athlete's performance capabilities (strength, power, endurance) through resistance training. A heavy emphasis has been placed on pre and post practice stretching. The use of soft tissue mobilization techniques have become popular with foam rolling, active release techniques, and other trigger point devices. Many athletic training rooms and sports medicine clinics invest large sums of money into cold plunges for post practice icing in an effort to reduce injuries.

For some of these strategies research has shown a positive effect in preventing injury. For example a randomized study by Sitler & Hopkinson (1990) found that a prophylactic knee brace reduced knee injuries among defensive players in American football. Similarly, ankle stabilizers have been shown to prevent recurrent ankle sprains in soccer players (Surve, Schwellnus, & Noakes, 1994). In Parkkari, Kujala, & Kannus' (2001) review article on prevention strategies they found five randomized trails that have provided evidence that the use of shock-absorbing insoles in footwear reduces the incidence of stress fractures in athletes. Yet, some strategies have conflicting findings within the research community and are inconclusive. Two randomized studies failed to show any positive effect of stretching on individual injury risk (Parkkari et al. 2001). Stretching still remains a common practice in the sports medicine realm. The aim of a study by Goodall & Howatson (2008) was to elucidate the efficacy of repeated cold water immersions in the recovery of exercise induced muscle damage. Their results suggest that repeated cold water immersion do not enhance recovery from a bout of damaging eccentric muscle contractions. Despite the researched bases evidence, athletes swear by it and cold plunges continue to gain popularity.

More recently, sport medicine professionals are focused on improving balance and proprioception capabilities. Much more emphasis has been placed on motor learning and the interaction between motor neurons and the muscle it innervates. Core stability and spinal segmental control is of more importance than ever. There has been a shift in focus from exercising and rehabilitating a single isolated joint or injury, to a more holistic approach. Sport medicine professionals are taking into consideration the entire kinetic chain and acknowledging the fact that one joint affects another in a positive or negative way. An athlete's dysfunction in one region of the body may present pain, tightness, or weakness in another region.

Health care providers who only make an attempt to cover up or block a pain response are doing their athletes a disservice. Unmanaged problems force the neuromuscular system to compensate in the presence of both pain and dysfunction. This compensation often hides the primary problem and creates secondary problems (Cook, 2010). Thus, compounding the situation, prolonging activity limitations, and exposing the athlete to further tissue damage.

This leads to the following questions regarding how one should evaluate their patients in a holistic manner: How would sports medicine professionals evaluate how one joint is affecting another? How do they recognize the movement dysfunctions involved? How would they know what is considered normal versus abnormal? Most importantly, how can sports medicine professionals use functional movement patterns to provide early detection of possible injury predispositions?

A physical therapist, Gray Cook, has proposed to address those questions. He and a number of his colleagues set out to develop a screening tool that assesses fundamental movement pattern quality. Cook states that the assessment of fundamental movements is an attempt to pinpoint deficient areas related to proprioception, mobility, and stability that may be overlooked in the asymptomatic population (Cook, Burton, & Hoogenboom, 2006b). He speaks about the importance of inspecting and understanding common fundamental aspects of human movement because very similar movements occur throughout many athletic activities (Cook, Burton, & Hoogenboom, 2006a). These basic functional movements ultimately form the foundation for more complex, sport specific movements. When the foundation is dysfunctional, training more complex movements predispose the athlete to a more heightened risk for injury.

The Functional Movement Screen (FMS) is comprised of seven fundamental movement patterns, or tests, that place the individual in extreme positions where weaknesses and imbalances become noticeable when appropriate stability and mobility is not utilized (Cook, Burton, & Hoogenboom, 2006a). Athletes that have mobility and/or stability issues typically have developed compensational movement patterns in order to still perform at a high level. If compensations continue, poor movement patterns are reinforced, leading to poor biomechanics and ultimately the potential of micro- or macro-traumatic injury (Cook, Burton, & Hoogenboom, 2006a). After the seven tests are completed, evaluated, and scored independently, a composite score is generated to represent the individual's total FMS score.

Cook's proposal is simply this: screen movement patterns before you train the athlete because training poor movement patterns reinforce poor quality and creates greater risk of injury (Cook, 2010). Once the dysfunctional movement pattern is identified, the sports medicine professional may work with the athlete to correct it. By rescreening the individual they will be able to asses whether or not the corrective strategy was effective.

There have been several studies that have investigated the FMS's validity as a predictor of injury. Kiesel, Plisky, and Voight (2007) examined the relationship between professional football players' scores on the FMS, and the likelihood of a player suffering a serious injury over the course of one competitive season. They determined that professional football players with a composite score of 14 or less on the FMS had a greater chance of suffering a serious injury over the course of one season.

As a follow up to Kiesel et al (2007) Chorba, Chorba, Bouillon, Overmyer, & Landis (2010) conducted a study to determine if compensatory movement patterns predispose female collegiate athletes to injury, and if the FMS could be used to predict injury in this population over the course of one competitive season. To maintain consistency with Kiesel et al (2007), the researchers used 14 as the cut off score on the FMS to determine relationships between FMS scores and injury during their data analysis. What these researchers reported was that a lower score on the FMS was significantly associated with injury, with 69% of those scoring 14 or less sustaining an injury, and experiencing a 4-fold increase in injury risk. They concluded that compensatory fundamental movement patterns will increase the risk of injury in female collegiate athletes, and can be identified by using the FMS (Chorba et al, 2010).

These two studies speak to the validity of the FMS as a predictor of injury. A score of 14 or less on the FMS is considered an increased risk factor and predisposes athletes to a higher chance of sustaining an injury. The first study researched professional football players and the second study researched women's soccer, volleyball, and basketball collegiate athletes. Despite the differences in subjects (gender and level of experience) both studies found a score of ≤14 a good indicator of potential injury.

Problem Statement

To date there has not been any research conducted on the capability of the FMS in predicting injury rates of athletes who participate in noncontact sports. Gradual onset to injury is predominate for these athletes. Also, the relationship between track and field athletes and FMS scores as a predictor of injury has not been previously researched.

Purpose Statement

The purpose of this study is to investigate the capability of the FMS to predict injury rates for division I male and female track and field athletes. This study will test whether or not a composite score of ≤14 is an appropriate indicator of increased injury risk for this population. In addition, this study will evaluate the differences between FMS composite score and specific track and field events, scholarship vs. non-scholarship athletes, and level of athletic eligibility (freshman, sophomore, junior, and senior).

Research Hypotheses

Hypothesis 1: There will be a significant difference between injured and non-injured FMS composite scores.

Hypothesis 2: Track and field athletes will require a higher cut off score than ≤14 as a predictor of increased injury risk.

Hypothesis 3: Distance runners will experience the most incidences of injury and have the lowest average FMS scores compared to the other track and field events.

Hypothesis 4: Juniors and seniors will have higher FMS composite scores compared with the freshman and sophomores and will have less incidences of injury.

Hypothesis 5: Non-Scholarship athletes will have a lower FMS composite score than scholarship athletes. Scholarship in this case is defined as an athlete receiving any sum of money from the athletic department no matter how large or small.

Literature Review

Preventing athletic injuries first requires the recognition of the injury problem or morbidity. Secondly the risk factors, etiologies, and exact mechanisms of injuries that predispose athletes to injury must be identified. Only after these first two steps can a preventative measure, the third step, be created and implemented. The fourth step would be to evaluate the effectiveness of the preventive action taken.

During the 1989-1990 track and field season, D'Souza (1994) conducted a survey to study the incidence, severity, and types of injuries suffered by 147 United Kingdom (UK) track and field athletes. The participant's age ranged from 14 to 32 years with the mean and standard deviation being 18, and ± 2.5. Their levels of completion ranged from "competitive spectators" to UK internationals. The level of competition was determined by comparing the participant's season best records to UK records for each individual event, according to their age and sex. Of the 147 athletes who took part in the study, 90 (61.2%) suffered an injury of some kind during the season (D'Souza, 1994). Sprints and hurdles were the most common events in which injuries occurred (67.2%) while the endurance events (58.1%) had the next highest prevalence of injury. The jumpers and throwers had the lowest injury incidence (57.5%). Overall the shin (17.8%) was the most common injury site, followed by the back (14.4%), ankles (13.6%) and knees (11.0%) (D'Souza, 1994).

Bennell and Crossley (1996) evaluated the incidence, distribution, and type and severity of musculoskeletal injuries sustained by track and field athletes in a 12 month period. They also assessed selected training parameters, anthropometric, menstrual, and clinical biomechanical risk factors for injury. 49 male and 46 female track and field athletes ranging in age from 17-26 years volunteered for this study. An injury was defined as any musculoskeletal pain or injury which resulted from athletics training and which was sufficient to cause alteration of normal training in any way for a period of one week or more (Bennell & Crossley 1996). Anthropometric characteristics including height, weight, sum of eight skinfolds, and girth measurements were obtained by a physiotherapist. The same physiotherapist performed the biomechanical assessment which involved: sit-and-reach, passive rang of motion of hip internal and external rotation, structural leg length, rang of ankle dorsiflexion in a weight-bearing position, and calf flexibility. The alignment of the lower extremity was classified as being varus, straight, or valgus. The foot type was determined in weight-bearing and classified as cavus, planus, or neutral. For each subject the researchers created a flexibility index by adding the z-scores for the sit-and-reach, hip rotation, calf flexibility, and ankle dorsiflexion measurements. Menstrual history was obtained via a questionnaire prior to the start of the study.

Bennell & Crossley (1996) found an injury incidence rate of 75.8% (72 athlete's sustained 130 injuries). The most common site of injury was the leg (27.7%), followed by the thigh (21.5%), knee (16.2%), foot (14.6%) back/pelvis/hip (13.0%), and ankle (7.3%). No injuries were found to occur in the upper limb. This was probably due to the fact that this study did not include throwers or pole vaulters. Of the injured athletes, 98% sought the attention of a health care professional, and the most common diagnosis was stress fracture (20.5%) with the majority of these occurring in the tibia (45.0%). Hamstring strains were the second most prevalent at 14.2% followed by overuse knee injuries at 12.6%.

There was no significant difference in injury rate and event group (sprint/hurdles, middle distance, distance, and jump/multi). However, they did find that sprint/hurdles and jumps/multi event athletes sustained more acute lower extremity injures, compared with the middle distance and distance athletes who sustained more overuse lower extremity injuries.

There was no significant difference when comparing men and women to injury incidence. There was no association between age, and the risk of developing an injury. According to these researchers training and competitive level, anthropometric and biomechanical measurements did not influence injury risk. However, an interesting finding was those athletes who sustained an injury had a significantly higher flexibility index. This indicates that the more flexible athletes sustained more injuries than less flexible athletes. The odds of an injury for those who were most flexible was 5.3 times that of those who were least flexible (Bennell & Crossley 1996). Females in this study with a history of menstrual disturbance had an increased risk of multiple musculoskeletal injuries. Bennell & Crossley (1996) concluded that the results of their study showed that track and field athletes are at a high risk for musculoskeletal injury.

A more recent injury surveillance study was conducted during the 2007 International Association of Athletics Federations (IAAF) World Athletics Championships. The aim of the study was to record and analyze all sports injuries incurred in competition and/or training during the 2007 IAAF World Championships. Team physicians were asked to fill out a daily standardized injury report form indicating any newly incurred injuries, or the non-occurrence of injuries during the duration of the championships. If team physicians were unavailable the team physiotherapist took on the responsibility. The following additional information was requested: sport/discipline, round/heat/training, date and time of injury, injured body part, type and cause of injury, and estimated time loss from competition and/or training.

Of the registered athletes, 1,660 (84%) of the 1,980 were reported in the study. Of these athletes, 192 (10%) incurred an injury during the nine days of the championships. The incidence was 97.0 injuries per 1,000 registered athletes, or 53.0 time-loss injuries per 1,000 athletes. An interesting, yet not surprising finding was that almost 80% (n = 153) of the injuries were located in the lower extremity (Alonso et al. 2009).

Overuse was reported to cause 43.5% of the injury cases. Most injuries were reported in marathon (n = 22) with 12% of the male runners incurring a time-loss injury. This was followed by heptathlon, and 1500 m and 3000 m steeplechase, each with 14 injured athletes. In this study

10 athletes incurred an injury in both the 800 m and 10,000 m. The most frequently injured location was the lower leg (24.5%), followed by the thigh (21.9%), and the knee (9.4%). The most prevalent diagnosis was a thigh strain (n = 30) which also happened to be the most prevalent time-loss injury (n = 27) (Alonso et al. 2009).

There are only a few studies that exist when it comes to evaluating track and field injuries. The studies that have been conducted have substantial differences in research design, methods, injury definition, and population making it difficult to compare and analyze these studies results (Alonso et al. 2009).

For instance, in the study conducted by D'Souza (1994), the definition of injury was left to the subjective interpretation of the athlete. Bennell & Crossley (1996) and Alonso et al. (2009) both had studies with team physicians and/or physiotherapists evaluating athletes with newly incurred musculoskeletal injuries. The evaluation dictated whether or not the injury was recorded for analysis. It is difficult to relate the injury prevalence rates of the 2007 IAAF World championships to previous findings, because no other publication on injuries during a major event in track and field could be found in the literature (Alonso et al. 2009).

Additional epidemiological research is needed to better guide injury prevention efforts made for track and field athletes. Future studies should include a standardized definition of injury and its severity, as well as a systematic method of collecting data on the injuries incurred. Also, researchers should strive to be more consistent with their sample populations and injury exposure time frames. Despite these studies short comings, the extent of the injury problem becomes evident when 61% of the track and field athletes suffered an injury during the course of one season, 76 % over 12 months, and 10% of the athletes competing over the course of nine days in the IAAF World Championships.

Walking alone creates increases in vertical ground-reaction forces 70% to 80% of body weight. Running can reach levels of 275% to 300% of body weight (Korpelainen, Orava, Karpakka, Siira, & Hulkko, 2001). Most of the track and field athletes are subjected to a large volume of running. Subsequently, injuries frequently occur as a result of running. Some of the more common injuries often associated with running include patellofemoral knee pain, shin splints or lower leg pain, achilles tendinopathy, iliotibial band tendinopathy, plantar fasciitis, and metatarsal and tibial stress fractures (van Mechelen, 1992). Understanding the cause of each running injury could greatly enhance prevention strategies. Unfortunately, risk factors for individual running conditions as well as for running injuries in general are poorly defined; very few well-controlled studies exist in the literature. Most of the purported risk factors are based on opinion, case series, and uncontrolled studies (Wen, 2007).

In general the risk factors that athletes face on a daily bases can be categorized as extrinsic and intrinsic. Extrinsic risk factors are those risks that take place outside of the body, where as intrinsic risk factors take place within the body (Murphy, Connolly, & Beynnon, 2003). Please refer to table 1 for examples of extrinsic and intrinsic risk factors for sports injuries in general, and table 2 for injury risk factors that have been indicated for runners and more specifically for stress fractures.

Table 1: Extrinsic and Intrinsic Risk Factors for Sports Injuries (Parkkari et al. 2001)

Extrinsic risk factors	Intrinsic Risk Factors
Exposure	**Physical characteristics**
Type of sports	Age
Exposure time	Gender
Position on the team	Somatotype
Level of competition	Previous injury
	Physical fitness
Training	Joint mobility
Type	Muscle tightness, weakness
Amount	Ligamentous instability
Frequency	Anatomic abnormalities (malalignments)
Intensity	Motor abilities
	Sport-specific skills

Environment Type of playing surface Indoor vs. outdoor Weather conditions Time of season Human factors (team mates, opponent, referee, coach, spectators) **Equipment** Protective equipment Playing equipment (racket, stick, bat, etc.) Footwear, clothing	**Psychological profile** Motivation Risk taking Stress coping

Table 2: Potential risk factors for stress facture (Bennell et al. 1999)

Intrinsic mechanical factors
Bone mineral density
Bone geometry
Skeletal alignment
Body size and composition
Physiological factors
Bone turnover
Muscle flexibility and joint rang of motion
Muscular strength and endurance
Nutritional factors
Calcium intake
Caloric intake/eating disorders
Nutrient deficiencies
Hormonal factors
Sex hormones
Menarcheal age
Other hormones
Physical training
Physical fitness
Volume of training
Pace of training
Intensity of training
Recovery periods
Extrinsic mechanical factors
Surface
Footwear/insoles/orthotics
External loading
Others
Genetic predisposition
Psychological traits

In a literature review of risk factors for overuse injuries in runners, Wen (2007), states that despite the amount of speculation and opinion regarding a variety of proposed risk factors for running-related overuse injuries, the available studies in the literature do not allow any firm conclusions to be made. Murphy, Connolly, & Beynnon's (2003) literature review of risk factors for the lower extremity also found little agreement between researchers. The general consensus was that the incidence of injury is greater in competition than in training sessions, that injury risk is greater on artificial turf than grass or gravel, that previous injury, when couple with inadequate rehabilitation, is a risk factor for subsequent injury, and finally a reduced femoral intercondylar notch width is a risk factor for anterior cruciate ligament injury. Wen (2007) found the most consistently implicated risk factors cited in epidemiological studies were training volume and previous injury. Wen's (2007) theory is that risk factors for running injuries are multifactorial, with some underlying risk associated with various anatomic factors, but with the need for certain training factors, such as high volume, to manifest that underlying risk.

Let's shift the focus to the Functional Movement Screen. As alluded to previously, the FMS is designed to identify individuals who have developed compensatory movement patterns in the kinetic chain (Cook et al. 2006). The kinetic chain refers to a linked system where movement at one joint produces predictable movement at all other joints (Prentice, 2004). The ankle, knee, and hip joints make up the kinetic chain of the lower extremity. Cook et al. (2006) suggest that this identification process is accomplished by observing right and left side imbalances and mobility and stability weaknesses that have developed over time. Once an inefficient movement pattern has been isolated by the FMS, functional prevention strategies can be implemented to avoid problems such as imbalance, micro-traumatic breakdown, and injury (Cook et al. 2006).

The validity of the FMS as a predictor of sport injury has also previously been discussed, but warrants a little more attention. The study by Kiesel et al. (2007) tested the relationship between FMS score and injury risk in professional football players over the course of one season. The sample included the 46 football players who were on the active roster at the start of the competitive season. An injury was defined as and recorded when a player was out of action for at least 3 weeks and placed on the injured reserve. An athlete would have to incur a fairly significant or serious injury to be considered under this injury definition. A dependent t-test was performed to determine if a significant difference existed in FMS scores between injured and non-injured players. A receiver-operator characteristic (ROC) curve was created to determine a cut-off score on the FMS that maximized specificity and sensitivity. In the case of the FMS the sensitivity is the probability that the FMs will correctly identify individuals at risk of injury who in fact suffered an injury during the season. Specificity on the other hand is the probability that the FMS will correctly identify individuals with out a heightened risk of injury and in fact stayed injury free. Ideally, a test should have high sensitivity and specificity, but false positives and false negative can still occur. ROC curves are useful for assessing the accuracy of predictions. An ROC curve is a plot of the sensitivity (true positives) versus 1-specificity (false positives) of a screening test (Kiesel, Plisky, & Voight, 2007). The cut-off score is the FMS composite score which maximizes both true positives and controls for false positives (Kiesel, Plisky, & Voight, 2007). Once the researchers identified the cut-off score they created a 2x2 contingency table dichotomizing those who suffered an injury, those who did not, and those above and below the cut-off score on the FMS. They estimated how much an individuals FMS score influenced the probability of suffering an injury by calculating post-test odds and post-test probabilities.

The mean FMS score for all subjects was 16.9 ± 3.0. The mean score for those who suffered an injury was 14.3 ± 2.3, and the average was 17.4 ± 3.1 for those who were not injured. A Significant difference was found between the mean scores of the injured verses non-injured football players ($df = 44$; $t = 5.62$; $p < 0.05$) (Kiesel et al. 2007). The ROC curve produced a FMS cut-off score of 14. The odds ratio was found to be 11.67, which suggests a player who scores a 14 or less on the FMS has an eleven-fold increase in the chance of injury compared to a player who scored higher than 14. From these findings Kiesel and colleges suggest that athletes with dysfunctional fundamental movement patterns, as measured by lower scores on the FMS, are more likely to suffer a time-loss injury.

The study by Chorba et al. (2010) evaluated the Functional Movement Screen to determine injury risk in female collegiate athletes. They chose 38 volunteer female student-athletes participating in NCAA division II women's collegiate soccer, volleyball, and basketball for the study. Injuries sustained by each subject during the 2007-2008 season were collected by the certified athletic trainers responsible for those sports. An injury was defined as a musculoskeletal injury that occurred as a result of participation in an organized intercollegiate practice or competition setting, and the injury required medical attention or the athlete sought advice from a certified athletic trainer, athletic training student, or physician.

The researchers chose to maintain consistency with Keisel et al. (2007) and use a FMS score of 14 as their cut-off. The mean FMS Score for all subjects was 14.3 ± 1.8. Of the athletes who sustained an injury, the mean FMS score was 13.9 ± 2.1, while those who did not sustain an injury had a mean score of 14.7± 1.3. In addition, 81.8% of the subjects scoring ≤13 on the FMS incurred an injury during the season, where as 48.3% of the subjects scoring ≤15 sustained and injury. Of those scoring ≤14, 69% sustained an injury, experiencing a 4-fold increase in injury risk. They concluded that compensatory fundamental movement patterns will increase the risk of injury in female collegiate athletes, and can be identified by using the FMS (Chorba et al, 2010).

O'Conner, Deusten, Davis, Pappas, & Knapik (2011) investigated the validity of the FMS in predicting injuries in Marine Corps officer candidates. Although this sample population is not directly related to collegiate athletics, officer candidates are more likely to be affected by overuse injuries similar to the current population of track and field athletes. The researchers also examined the relationships among FMS scores, physical fitness scores, and injury.

A total of 874 male candidates aged 18-30 years participated in this study. Two different groups were used in the analysis. 427 participants were in a 6week short-cycle (SC) group which generally consisted of collegiate ROTC students, and 447 participants were in a 10 week long-cycle (LC) group that gets direct military commissions.

The physical fitness score consisted of pull-ups to exhaustion, two minute abdominal crunch, and a three mile run for time. Points were assigned depending on the performance level of the candidate. A composite score is gained once the three events scores are summed. The maximum amount of points one candidate can earn is 300, with each test being worth 100 points.

The injury data was collected by medical professionals and recorded in an electronic data base. Depending on the descriptive information in the medical notes and by the specific diagnosis, injuries were categorized into four different groups: overuse, traumatic, any, and serious injury. “Any injury” was considered a combination of overuse and trauma. The definition of injury was a subject who sustained physical damage to the body secondary to physical training and sought medical care one or more times during the study period.

The mean FMS score among all candidates was 16.6 ± 1.7 with a range of 6-21. The mean LC and SC was 16.5 ± 1.5 and 16.7 ± 1.9. The LC group had 8.4% score ≤14 and 25.3% score ≥18. The SC group had 12.8% score ≤14 and 36.7% score ≥18. When the LC and SC groups were combined, the relative risk was 1.5 times greater for the “any” injury category with a FMS score ≤14. 45.8% of persons with scores ≤14 suffered and injury compared with 30.6% of candidates with scores >14. Interestingly the researchers didn’t find a significant difference in FMS scores and incidence of overuse injury in the candidates. Persons with scores ≤14 had 12.5% of overuse injuries compared with 10.6% with scores >14.

In the previous two studies the researchers dichotomized the FMS/injury data but this group of researcher's chose to examine the LC and SC groups according to FMS categories of ≤14, 15-17, and ≥18. This decision was based from the observation of FMS scores. If their score was 18 they had a higher injury incidence compared with FMS scores of 17 (LC = 46.7%, SC =32.2% compared with LC = 27.6%, SC = 18.1%). By using 15-17 as the reference, the risk of injury was significantly higher in the ≤14 as reported by other studies, but also significantly higher for the ≥18 category for the LC group only. Additionally, no ROC curves provided a point that maximized specificity and sensitivity addressed to overuse, serious, and any injury categories.

The researchers reported the physical fitness scores were significantly associated with injury. The candidates with lower fitness scores were more likely to suffer overuse or serious injuries compared with those who had high fitness scores. Candidates with fitness scores of <280 were 2.2 times more likely to have FMS scores ≤14 and significantly more likely to sustain an injury across all categories of injury (O'Conner et al 2011). The researchers concluded that although the sensitivity was low FMS scores of ≤14 were associated with increased injury risk and that further investigations are warranted.

The work done by Schneiders, Davidsson, Horman, & Sullivan (2011) provides normative values on a large general cohort of a young, active population. Their secondary aims were to examine the relationship between males and females and their respected FMS performance. 108 physically active/injury free females (mean age 21.2) and 101 males (mean age 22.7) participated in this study.

There was no significant difference found between male and female FMS composite scores. The mean female composite score was 15.6 and for the males 15.8. This indicates that the

FMS can be used to compare individuals in mixed populations (Schneiders et al. 2011). The researchers did find a gender specific significant difference between four of the FMS tests. Males on average performed better on the trunk stability push-up and the rotary stability tests, and females were better on the active straight leg raise and the shoulder mobility tests. The mean and standard deviation for the combined composite score was 15.7 ± 1.9. Twenty nine males and thirty six females (31%) had composite score of ≤14. Schneiders et al (2011) concluded that the normative data can act as a reference standard for sports physical therapist's, athletic trainers, and coaches in order to allow meaningful comparisons between sport and exercise participants.

After reviewing the literature evaluating the validity of the FMS, the consensus is that the FMS was able to predict injury in their sample populations. The FMS can indicate individuals who are more likely to incur an injury while participating in physical activity and/or sport activities with a cut off score being 14 or below. As with any screening tool or assessment, the validity is critical for its practical use in the field. An integral part of validity is reliability, which pertains to the consistency, or repeatability, of a measure (Thomas, Nelson, & Silverman, 2005). The FMS cannot be considered valid if it is not reliable. Interrater reliability becomes of importance when the FMS is primarily made up of subjective assessments for each of the movement patterns tested. Interrater reliability is defined as the degree to which different testers can obtain the same scores on the same participants (Thomas, Nelson, & Silverman, 2005).

The overall goal of Minick et al's (2010) study was to establish the interrater reliability of the FMS by comparing individuals with different levels of training on the FMS. Their study used 39 healthy, college age (mean 20.8 years), varsity athletes were videotaped from both anterior and lateral views performing each of the seven FMS tests. To determine the interrater reliability of the FMS, four raters each independently scored the subjects performing each test of the FMS via the video recordings.

The raters consisted of two expert and two novices. An expert is defined as an individual who was instrumental in the development of the FMS. Novice individuals were defined as having taken the standardized introductory training course and have used the FMS less then a year. The FMS scores were compared between the two experts, the two novices, and then between the expert and novice raters (Minick et al 2010). Kappa values were calculated for both the individual right and left sides and composite score for each of the seven tests.

The two novice raters demonstrated excellent agreement on 6 of the 17 test components (deep squat, shoulder mobility, parts of the trunk stability push-up and active straight leg raise). Substantial agreement was evident on 8 of the 17 test components. Moderate agreement was found on the left and right components of the lunge and the final component of the rotary stability test.

When comparing the expert rater's to one another, there was less agreement than the novice raters. They had excellent agreement in 4 of the 17 test components with substantial agreement in 9 of the 17 components. Two components of both the lunge and rotary stability test demonstrated moderate agreement.

The expert pair compared to the novice pair was evaluated last. 14 of the 17 test components produced excellent agreement. Substantial agreement was evident in one part of the rotary stability test and two components of the in-line lunge (Minick et al 2010).

The results from Minick et al. (2010) study indicate that he FMS has high interrater reliability and can confidently be executed by trained individuals when the standard procedure is used. Schneiders et al. (2011) also evaluated the inter-rater reliability between two separate raters but rather then using filmed subjects they tested in real-time. These researches got similar results as Minick et al (2010). The interrater reliability of the composite score for both evaluators was 0.971 which indicates excellent reliability.

Now that the validity and reliability have been established in the FMS, it leads to the question whether or not an athletes composite FMS can be improved through therapeutic intervention. The injury predictive capability of the FMS would be rendered useless if an athlete was unable to alter the outcome of his or her performance. Limited research is available in the literature dealing with this question.

A study conducted by Kiesel, Plisky, & Butler (2011) examined if an offseason intervention program is effective in improving FMS scores in professional American Football players. This study used 62 healthy football players from the same organization to participate in an individualized intervention program in conjunction to the usual offseason strength and conditioning program. The intervention program was based on the individual's performance on the FMS and designed to correct the identified movement deficits. The program consisted of: self and partner stretching and self-administered trigger point treatment, and individual corrective exercises. The team's strength and conditioning staff provided instruction and supervision as needed. The athletes were required to participate in the seven week program which included supervised sessions four day per week and two optional sessions per week. Post-test FMS scores were obtained at the completion of the seven weeks. For analysis the subjects were grouped by position with lineman and linebackers (lineman, $n = 32$) in one group and all other positions in another group (non-lineman, $n = 30$).

The mean pre-test score for the lineman was 11.8 ± 1.8 and 13.3 ± 1.9 for the non-lineman. The mean post-test score for the lineman was 14.8 ± 2.4 and 16.3 ± 2.4 for the non-lineman. Thus, at the pre-test only 11% of the players earned a score >14 compared to 63% of the players exhibiting a score >14 at the post-test (Kiesel et al. 2011). However, its important to note that 20 subjects failed to improve their score above a 14 and the answer as to why was left undetermined. In regards to changes in symmetry 50% of the players demonstrated asymmetrical movement at pre-test. At post-test this number was decreased to 32%. The results of this study support that an off-season training program can significantly improve scores on the FMS. The researchers concluded that movement can improve with an individualized exercise program (Kiesel et al. 2011).

It is important to point out that there was some research design flaws that could have either influenced the results, or if corrected, for made the results more powerful. A large limitation to this study was not having a control group, which makes it difficult to establish a true cause and effect relationship. For instance there is a chance that the football players may have improved their post-test score by having an increased familiarity with the FMS testing procedure. Also, the researchers did not control for co-interventions, meaning some subjects could have received addition medical treatment whereas some did not. For example, an athlete may be involved with physical therapy, chiropractic care, or massage therapy. Much needed research is needed using random controlled studies to better evaluate the performance changes or lack there of seen in the FMS as a result from a therapeutic intervention.

Methodology

Experimental design

Utilizing a prospective cohort study design, pre-indoor track season FMS scores were obtained from the Utah State University male and female track and field teams. During the indoor track and field season, daily exposure rates for practices and competitions were recorded as well as any incidences of injury. In this case, an injury is defined as: the inability of an athlete to participate in practice or competition for at least four days after the initial onset. Also, the sustained injury must occur as a result of participation in an organized intercollegiate practice or competition. Each athlete can be only be recorded once for a single injury incidence and first evaluated by a Certified Athletic Trainer and/or physician.

The number of exposures (practices and competitions) was tallied for the 2012 indoor track and field season. Any incidences of injury were discussed and recorded at the end of each athletic exposure by the three Certified Athlete Trainers assigned with the track and field team. The FMS composite scores were compared with the injury data at the end of the indoor track season and statistical analysis was rendered.

Subjects

57 Utah State University track and field athletes (26 men, 31 women) volunteered for this study. One participant was excluded from the study due to having a current injury prior to testing and another for choosing to not be apart of the USU track and field team any longer.

Table 3: Participant Demographics

USU Track and Field	**Age (years)**	**Height (cm)**	**Weight (kg)**
All Participants Mean ± SD	19.9 ± 1.92	175.8 ± 10.2	70.8 ± 13.5

USU Track and Field	**Age (years)**	**Height (cm)**	**Weight (kg)**
Women Mean ± SD	19.6 ± 1.5	171.5 ± 6.2	68.4 ± 15.0

USU Track and Field	**Age (years)**	**Height (cm)**	**Weight (Kg)**
Men Mean ± SD	20.4 ± 2.3	182.6 ± 6.2	74.4 ± 11.5

Independent Variables

- Track and field events: running events and/or field events
- Scholarship status: scholarship or non-scholarship
- Level of eligibility: freshmen, sophomore, junior, or senior

Table 4: Participants Track and Field Event

Event	**Male**	**Female**	**Total**
Distance	12	7	19
Sprint	2	3	5
Middle Distance	1	4	5
Hurdle	3	3	6
Jumps	0	2	2
Multi	3	2	5
Pole Vault	4	4	8
Throws	1	6	7

Table 5: Combined Track and Field Events

Combined Events	**Male**	**Female**	**Total**
Sprint & Hurdle	5	6	11
Distance & Middle Distance	13	11	24

Multi & Throws	4	8	12
Jumps & Pole Vault	4	6	10

Table 6: Participant Eligibility Status

Level of eligibility	**Male**	**Female**	**Total**
Senior	8	4	13
Junior	2	8	10
Sophomore	3	4	7
Freshman	13	15	27

Table 7: Participant Scholarship Status

Scholarship Status	**Male**	**Female**	**Total**
Yes	15	16	31
No	11	15	26
Total	26	31	57

Table 8: Participant Surgical Status

Previous Injury Requiring Surgery	**Yes**	**No**
	7	50

Dependent Variables

- Functional Movement Screen composite score

Instrumentation

Three Functional Movement Screen™ kit replicas: each including a two-by-six box, two dowel rods, a small-capped piece, and four-foot dowel rod. Other equipment used included two two-by-six wooden boards, one elastic string, and a tap measure. Also, a tap measure was used to measure height and tibial length and a scale (Tanita BWB-800, Tanita Corporation, Japan) was used to measure weight.

Procedures

Each subject was asked to fill out a history questionnaire about their current athletic year of eligibility, scholarship status, track and field events they participate in, any previous or current injuries, and any past surgeries (refer to Appendix B). An athlete who has or is receiving treatment for an injury at the time of screening was excluded from this study.

Each subject's functional movement will be individually evaluated using the FMS. The FMS has a total of seven functional movement tests: deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability push up, and rotary stability tests. The FMS is scored by three ability levels, but has four different scoring options (zero to three with three being the best possible score). A score of three is given when the movement pattern is completed correctly without any compensation. A score of two is given when the athlete is able to complete the movement pattern but has observable compensation, faulty form, or loss of alignment. A score of one is given when the athlete is unable to complete the movement pattern or is unable to assume the position to perform the movement. A zero is given if pain is experienced with the movement pattern anywhere in the body regardless of movement competency. Five of the seven FMS test (hurdle step, lunge, shoulder mobility, active straight leg raise, and rotary stability) are performed and scored for right and left sides of the body. The lesser of the two scores is calculated into the final composite score.

There are three additional clearing tests associated with the shoulder mobility, trunk stability pushup, and rotary stability tests. The shoulder pain provocation, trunk stability press-up extension, and rotary stability posterior rocking tests are not scored numerically but as positive or negative. A positive test would be indicative of pain with the movement where as a negative test would be pain free. If pain is experienced with any of the clearing test, a zero is recorded for the corresponding test regardless of the score previously attained specifically for that test.

Experimental Setup and Data Collection

There were a total of nine stations. The first station was designated for the participants to fill out the history questionnaire. The participant's height, weight, and tibia length was recorded at the second station. The remaining seven stations were comprised of each FMS test. There was one evaluator assigned for each FMS test station. That evaluator stayed at that test station for the remainder of the data collection period to help increase interrater reliability. The FMS test evaluators embodied a group of certified athletic trainers, physical therapists, physical therapist assistants, and an exercises physiologist who all have had previous experience with the FMS testing and evaluation procedures.

The seven evaluators participated in a short pilot study a two weeks before the actual data collection. This pilot study was designed to help determine the most efficient and practical testing setup as well as to review all the testing, evaluating, and scoring procedures involved with the FMS. Once the evaluators felt comfortable with the procedures, seven volunteers completed all stations. This was for practice but also to get an estimated time frame for how long it would take seven participants to complete all seven FMS tests plus the three clearing tests.

The evaluator responsible for the shoulder mobility test was also responsible for evaluating and recording the outcomes of the three clearing tests. This was done to help speed up the testing process and keep the participants moving smoothly from one test to the next. Both the history questionnaire and the FMS scoring sheet were collected once the participant had completed all FMS tests. The participants were split up into their respected track and field event groups and given a specific time to show up to the athletic training room for testing to begin (refer to Appendix A for a diagram of the study's layout).

Statistical Analysis

Statistical significance was set at $p<0.05$ for all of the above tests. SPSS 20.0 (IBM, Inc.; Chicago, IL) was used to perform the statistical analyses. Each participant's FMS composite score was used in the statistical analysis.

Hypothesis 1: independent t-tests were performed to determine if a statistical difference was present between injured and non-injured athletes. Hypothesis 2: A receiver operator characteristic (ROC) curve analyses was used along with calculation of a likelihood ratio and an odds ratio to determine a FMS cut-off score more suited for track and field athletes. Hypothesis 3 and 4: Two separate one-way ANOVA models were used to determine if there was a statistical difference in FMS score and specific track and field events and also for athletic year of eligibility. Note, each event was paired with another event to increase the sample size to better aid the statistical analysis. Hypothesis 5: independent t-tests were performed to determine if a statistical difference was present between FMS scores and scholarship and non-scholarship athletes.

Results

Of the 57 participants, 9 (15.8%) suffered a recorded injury that resulted in the inability to participate in practice or competition for at least four days after the initial onset. There was no statistical significant difference between pre-indoor track season FMS composite scores of the injured and non-injured groups (Table 9) nor was there a gender difference (Table 10).
There was no statistical significant difference between FMS composite scores and scholarship and non-scholarship groups (Table 11). There was no statistical significant difference between different track and field events groups and FMS composite score (Table12 & 13). Finally, there was no statistical significant difference between level of eligibility and FMS composite score (Table 14 & 15).

Since the FMS scores were similar between injured and non-injured groups an ROC curve was utilized to determine a cut-off score specific to this study's sample population. No specific point on the ROC curve could be identified as an ideal cut-off score that discriminated between injured and non-injured subjects. Using the example provided by Kiesel et al. (2007) we selected a point on the ROC curve between 12.5 and 13.5. This point maximized sensitivity (.889) and specificity (.708) (refer to Appendix C for ROC curve graph and coordinates).These findings resulted in a positive likelihood ratio (sensitivity/1-specificity) of 3.04 and a negative likelihood ratio (1-sensitivity/specificity) of 0.15. An odds ratio was calculated at 0.48.

A group of 2x2 contingency tables were constructed at cut-off scores of ≤ 13 (Table 17), ≤ 18 (Table 18), and the previously established score of ≤14 (Table 16) (Kiesel et al. 2007). These three tables display athletes who scored above and below the specified cut-off, and those athletes who suffered an injury and those who did not.

	Significance		
Event	**Distance & Middle Distance**	**Multi & Throws**	**Jumps & Pole Vault**
Sprint & Hurdle	0.50	0.33	0.64
Distance & Middle		0.95	1.0

Table 9: Injured/Non-injured vs. FMS Score

Injured	**N**	**Mean ± SD**	**F**	**Significance**
Yes	9	15.9 ± 1.8	1.62	0.21
No	48	15.6 ± 2.7		

Table 10: Male/Female vs. FMS Score

Gender	**N**	**Mean ± SD**	**F**	**Significance**
Female	31	15.3 ± 2.6	0.02	0.89
Male	26	16.1 ± 2.5		

Table 11: Scholarship/Non-Scholarship vs. FMS Score

Scholarship	**N**	**Mean ± SD**	**F**	**Significance**
Yes	30	16.1 ± 2.6	0.05	0.83
No	27	15.2 ± 2.5		

Table 12: Track and Field Event vs. FMS Score

Event	**N**	**Mean ± SD**	**F**	**Significance**
Sprint & Hurdle	11	16.8 ± 1.6	1.06	0.37
Distance & Middle Distance	24	15.5 ± 2.7		
Multi & Throws	12	15.0 ± 2.8		
Jumps & Pole Vault	10	15.5 ± 2.7		

Distance & Middle Distance		0.95	1.0
Multi & Throws			0.97

Table 13: Event Groups Compared vs. FMS Score

Table14: Year of Eligibility vs. FMS Score

Year	N	Mean ± SD	F	Significance
Senior	13	16.2 ± 3.0	0.68	0.57
Junior	10	16.2 ± 2.8		
Sophomore	7	14.7 ± 3.0		
Freshman	27	15.4 ± 2.2		

	Significance		
Year	**Junior**	**Sophomore**	**Freshman**
Senior	1.0	0.64	0.85
Junior		0.65	0.86
Sophomore			0.91
Freshman			

Table15: Year of Eligibility Compared vs. FMS Score

Table 16: 2x2 Contingency Table FMS Cut-off of ≤ 14

	Incurred an Injury	
	Yes	**No**
FMS Score ≤ 14	2	14
FMS Score ≥14	7	34

Table 17: 2x2 Contingency Table FMS Cut-off ≤ 13

	Incurred an Injury	
	Yes	**No**
FMS Score ≤ 13	1	10
FMS Score ≥13	8	38

Table 18: 2x2 Contingency Table FMS Cut-off of ≤ 18

	Incurred an Injury	
	Yes	**No**
FMS Score ≤ 18	9	41
FMS Score ≥18	0	7

Discussion

The primary purpose of this research study was to establish the efficacy of the FMS test to predict injury in collegiate track and field athletes. This analysis relied on the composite score of ≤14 as reported by Kiesel et al. (2007) and validated by Chorba et al. (2010) as an appropriate indicator of increased injury risk for an athletic population. In addition, this study evaluated the differences between FMS composite score and specific track and field events, scholarship vs. non-scholarship athletes, and level of athletic eligibility.

Hypothesis 1: There will be a significant difference between injured and non-injured athletes based on FMS composite scores. This hypothesis was rejected as there was no significant difference between non-injured (15.6 ± 2.7) and injured (15.9 ± 1.8) FMS scores.

Hypothesis 2: Track and field athletes will require a higher cut off score than ≤14 as a predictor of increased injury risk. The ROC curve constructed provided little insight into an appropriate cut-off score for this study's sample population. Based on the ROC curve, no clear cut-off score was evident, with the best estimate of 13 should have maximized sensitivity and specificity. However, at that cut-off, the FMS only captured one injury out of the nine injured athletes. There were ten athletes who where considered at risk (scored less then 13) and stayed injury free. From this information an odds ratio was calculated at 0.48. Essentially an athlete with an FMS score lower than 13 should have only ½ the risk of becoming injured compared to the rest of the subjects in this study. The ROC analysis also suggested the FMS is no greater of a predictor of injury than would be a flip of a coin (~50-50). Therefore it appears that Kiesel's original cut-off score of 14 may not be as discriminatory toward predicting injury as previously reported.

An examination of the subjects who experienced an injury and their subsequent FMS score suggested a more sensitive FMS score of 18. Using this cut-off the FMS was quite sensitive as it captured all nine injuries. However, specificity became extremely poor. 50 athletes were indicated at risk but only 9 athletes actually were injured. There were 41 false positives compared to only 9 true positives. With these numbers at these odds, it would be overwhelmingly difficult to justify the time and effort required to, first, screen 57 athletes and then treat 88% of them with a corrective exercise program, while estimating only 18% of the at risk group may actually get injured.

Hypothesis 3: Distance runners will experience the most incidences of injury and have the lowest average FMS scores compared to the other track and field events. The distance runners were the most injured group (4 injured), followed by the throwers (3 injured). However, due to the relatively large number of distance runners only 21% of the distance runners suffered an injury, while 42% of the throwers were injured. These two groups made up 78% of the injured athletes. The sprint and hurdle group (16.8 ± 1.6) had the highest mean composite FMS Score, while the multi and throwers group (15.0 ± 2.8) had the lowest mean FMS composite score.

It is conceivable that distance runners have the highest occurrence of injury because most distance track and field athletes also run cross country. This means these athletes are training all year round. They have a very small recovery period between the end of the cross country season and the start of the indoor track season. Throwers on the other hand are more at risk perhaps of the type of training required for their sport. In order to be a successful thrower you need strength, power, and technique. They work on increasing strength and power on a weekly basis with the amount of weight lifted and the types of lifts being performed. This puts these athletes at a increased risk of injury compared to some of their teammates. They improve their technique in practice, but in order to improve their technique they need to perform each repetition like they would in a competition. There is no such thing as a walk through in a colligate thrower. This also increases the chance of injury by continuously pushing your body to the maximum each repetition. This is also true for most of the track and field disciplines.

Hypothesis 4: Juniors and seniors will have higher FMS composite scores compared with the freshman and sophomores, and will have less incidences of injury. Although there was no statistical significance between eligibility statuses, seniors (16.2 ± 3.0) and juniors (16.2 ± 2.8) did have a higher mean FMS composite score than the sophomores (14.7 ± 3.0) and freshman (15.4 ± 2.2). Since the sophomores have such a small sample represented it is difficult to draw a definitive conclusion on this matter. The freshman accounted for 6 of the 9 injuries (67%) that occurred during the indoor season. Two seniors, one sophomore, and zero juniors were injured. Freshman may be more susceptible to injury because their bodies are trying to adapt to new training demands when they transition from their high school program to the college level. For most freshmen both training intensity and volume increase. They may be asked to weight train with the strength and conditioning staff or be asked to learn to perform a new event. The freshman athlete sometimes struggles to maintain healthy sleeping and eating habits once they start living away from home and are on their own. Some freshman feel they need to push themselves even harder because their new to the team, and they must prove themselves as a valuable member. Some freshman can overcome the new challenges where others find themselves spending most of their time in the athletic training room.

Hypothesis 5: Non-Scholarship athletes will have a lower FMS composite score than scholarship athletes. Although there was no statistical significance between scholarship statuses, scholarship athletes (16.1 ± 2.6) had a slightly higher mean FMS composite score than did the non-scholarship athletes (15.2 ± 2.5).

An interesting aspect of this particular sample population is that running, jumping, and throwing are basic sport skills that provide the foundation for most other sports, but they are the focus of the sport of track and field (Zemper, 2005). Although it was not strongly indicated by this study it is conceivable that track and field athletes would produce higher FMS scores compared to other sport disciplines, because these athletes running, jumping, and/or throwing form and technique are strongly emphasized in their everyday training. Arguably, track and field athletes devote more time working on mobility and stability through flexibility, and core training than most other sports do in a given practice period. This is partially due to the fact that track and field athletes do not need to consume practice time with play calling, offensive and defensive schemes, watching their opponents on film, etc.

Each track and field athlete strives to perfect the fundamental movement pattern foundation because they know the more efficiently they move, the more success they will have in their respected events. This may help explain why the current sample of track and field collegiate athletes, using only the women, had a mean FMS score of 15.2 ± 2.6 while a sample of female colligate soccer, volleyball, and basketball athletes had a mean FMS score of 14.3 ± 1.8(Chorba et al. 2010). The male track and field athletes mean FMS score (16.1 ± 2.5) was slightly lower than Kiesel et al's. (2007) sample of professional football players (16.9 ± 3.0). This higher score may be indicative of the elite athletic status the professionals have obtained.

The main goal of a track and field athlete is to maximize their physical capability through training, compete against others who have been working at the same goal, and see who has the larger physical capacity and skill acquisition. D'Souza, 1994 reported 61% of track and field athletes suffered an injury during the course of one season; Bennell & Crossley (1996) reported 76 % over 12 months. Perhaps the high incidence of injury, injuries stemming predominately from overuse and chronic mechanisms, can be attributed to the sheer nature of the sport. Individuals who are not as naturally gifted or genetically fit to meet the demands of the sport, need to bridge the gap. They bridge the gap by the only way they know how…train harder and longer. Training intensity and volume have both been indicated as risk factors for running related injuries. Wen (2007) states it best; risk factors for running injuries are multifactorial, with some underlying risk associated with various anatomic factors, but with the need for certain training factors, such as high volume, to manifest that underlying risk. Some of the bodies of the athletes that are training harder and longer to bridge the gap are able to adapt to the demands placed on it, but for others it seems injury is the end result.

This study's conflicting results to the previous body of research on the validity of the FMS may be due to the difference in injury definition. It was challenging to distinguish the definition of injury for this population since most injuries encountered are overuse conditions with micro-traumatic breakdown of tissue vs. the macro-traumatic disruption of tissue that acute injuries involve. This study recorded injuries that limited the athlete for four or more consecutive days. This allowed the distinction between people who were dealing with more soreness related issues vs. injury related. Some athletes needed two to three days to cross train on a bike or underwater treadmill, miss a day of weight training or scheduled practice, etc. before they could continue to train at their expected level. Kiesel et al. (2007) only recorded athletes as injured when the football player had a time loss of three weeks or was placed on the injured reserve. It is hard to say with-out knowing the injury diagnoses of the injured athletes, but this definition of injury is perhaps geared toward serious injuries and may miss much of the chronic overuse pathologies. Chorba et al. (2010) defined an injury when the athlete required medical attention or the athlete sought advice from a certified athletic trainer, athletic training student, or physician. If the current study replicated this injury definition a large percentage of the track and field athletes would have been recorded and considered injured, regardless if any time was lost due to the injury. Most athletic training staffs encourage the athletes to seek out advice for problems they may be having in an attempt to correct the problem before it becomes an injury. Thus another stipulation placed on whether an injury was recorded or not was based on the professional and objective opinion of the Certified Athletic Trainer and/or physician.

It is also important to outline some of the limitations that this study encountered. The statistical power would have benefited if the entire track team (~110 athletes) would have participated in the FMS screening to help increase the over all sample size. Ideally the data collection period should have been conducted over both the indoor and outdoor track and field seasons to increase the amount of exposures, thus increasing the chances of injury occurrence. Despite all the raters being sports medicine professionals and having past experience utilizing the FMS, the study's intrarater reliability possibly could have been increased if each member would have been certified in the FMS prior to the testing of our participants. FMS certification involves active participation in a certified workshop, practical application, and successful performance on a written examination administered through Functional Movement Systems (O'Connor et al. 2011). However, a recent study by Onate et al. (2012) reported the FMS to have good to strong real-time interrater and intrarater reliabilities. This is one of the first studies to investigate the interrater reliability between a noncertified novice rater and a certified FMS experienced rater. Onate et al. (2012) states that they found that the FMS certification process did not seem to have an impact on the interrater reliability scores of a real-time FMS assessment.

It is possible the FMS is a better predictor of acute injury vs. chronic injury and is more suitable for athletes playing contact sports. More research is needed using the FMS on the population of track and field to draw a stronger conclusion on this matter. Also, more research is needed on other sports that are non-contact in nature and that produce injuries predominately from an overuse mechanism. Lastly some of the studies that have shown positive results in the FMS's validity as a predictor of injury need to be replicated to increase this evidence. If indeed the FMS is found to been a valid predictor of athletes at risk for injury, the next step would be to evaluate how well athletes can improve their score through an intervention, and lastly studies should focus on whether this improvement leads to less risk or chance of injury.

Conclusion

A score of 14 or less on the Functional Movement Screen was not a good predictor of injury for track and field athletes. A more appropriate cut-off score that maximized the tests sensitivity and specificity could not be produced for this population. Perhaps the FMS is not as strong as a predictor of injury for non-contact sports that suffer predominantly from overuse and chronic pathologies. More research is needed on the use of the FMS with track and field athletes and sports that are non-contact.

References

Alonso, J., Junge, A., Renström, P., Engebretsen, L., Mountjoy, M., & Dvorak, J. (2009). Sports injuries surveillance during the 2007 IAAF world athletics Championships. *Clinical Journal of Sports Medicine*, 19: 26-32.

Bennell, K., & Crossley, K. (1996). Musculoskeletal injuries in track and field: incidence, distribution and risk factors. *The Australian Journal of Science and Medicine in Sport*, 28 (3): 69-75.

Bennell, K., Matheson, G., Meeuwisse, W., & Brukner, P. (1999). Risk factors for stress factures. *Sports Medicine*, 28 (2): 91-122.

Chorba, R., Chorba, D., Bouillon, L., Overmyer, C., & Landis, J. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy,* 5: 47-54.

Cook, G. (2010) Movement: functional movement systems: Screening, assessment, and corrective strategies. Aptos, CA: On Target Publications.

Cook, G., Burton, L., & Hoogenboom, B. (2006a). Pre-participation screening: the use of fundamental movements as an assessment of function—part 1. *North American Journal of Sports Physical Therapy*, 1: 62-71.

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

D'Souza, D. (1994). Track and field athletics injuries—a one-year survey. *British Journal of Sports Medicine*, 28: 197-202.

Goodall, S., & Howatson, G. (2008). The effects of multiple cold water immersions on indices of muscle damage. *Journal of Sports Science and Medicine*, 7: 235-241.

Hootman, J., Randall, D., & Agel, J. (2007). Epidemiology of collegiate injures for 15 sports: summary and recommendations for injury prevention initiatives. Journal of Athletic Training, 42: 311-319.

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

Kiesel, K., Plisky, J., & Voight, M. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy*, 2: 147-158.

Korpelainen, R., Orava, S., Karpakka, J., siira, P., & Hulkko, A. (2001). Risk factors for recurrent stress factures in athletes. *The American Journal of Sports Medicine*, 29: 304-310

Minick, K., Kiesel, K., Burton, L., Taylor, A., Plisky, P., & Butler, R. (2010). Interrater reliability of the functional movement screen. *Journal of Strength and Conditioning Research*, 24 (2): 479-486.

Murphy, D., Connolly, D., & Beynnon, B. (2003). Risk factors for lower extremity injury: a review of the literature. *British Journal of Sports Medicine*, 37: 13-29.

O'Connor, F., Deuster, P., Davis, J., Pappas, C., & Knapik, J. (2011). Functional Movement Screening: predicting injuries in officer candidates. *Medicine and Science in Sports and Exercise*, 43 (12): 2224-2230.

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

Parkkari, J., Kujala, U., & Kannus, P. (2001). Is it possible to prevent sports injuries? Review of controlled clinical trails and recommendations for future work. *Sports Medicine*, 31: 985-995.

Prentice, W. (2004). Rehabilitation Techniques for Sports Medicine and Athletic Training. New York, NY: McGraw-Hill,4th ed. page. 243.

Quercetany, R. (2000). The tale of track and field athletics: from prehistory to modern times. *A History of Modern Track and Field Athletics*, 11-17.

Schneiders, A., Davidsson, A., Horman, E., & Sullivan, J. (2011). Functional Movement Screen normative values in a young, active population. *The international Journal of Sports Physical Therapy*, 6 (2): 76-82.

Sitler, M., Ryan, J., & Hopkinson, W. (1990). The efficacy of prophylactic knee brace to reduce knee injuries in football. *American Journal of Sports Medicine*, 18: 310-315.

Surve, I., Schwellnus, MP., & Noakes, T. (1994). A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. *American Journal of Sports Medicine*, 22: 601-606.

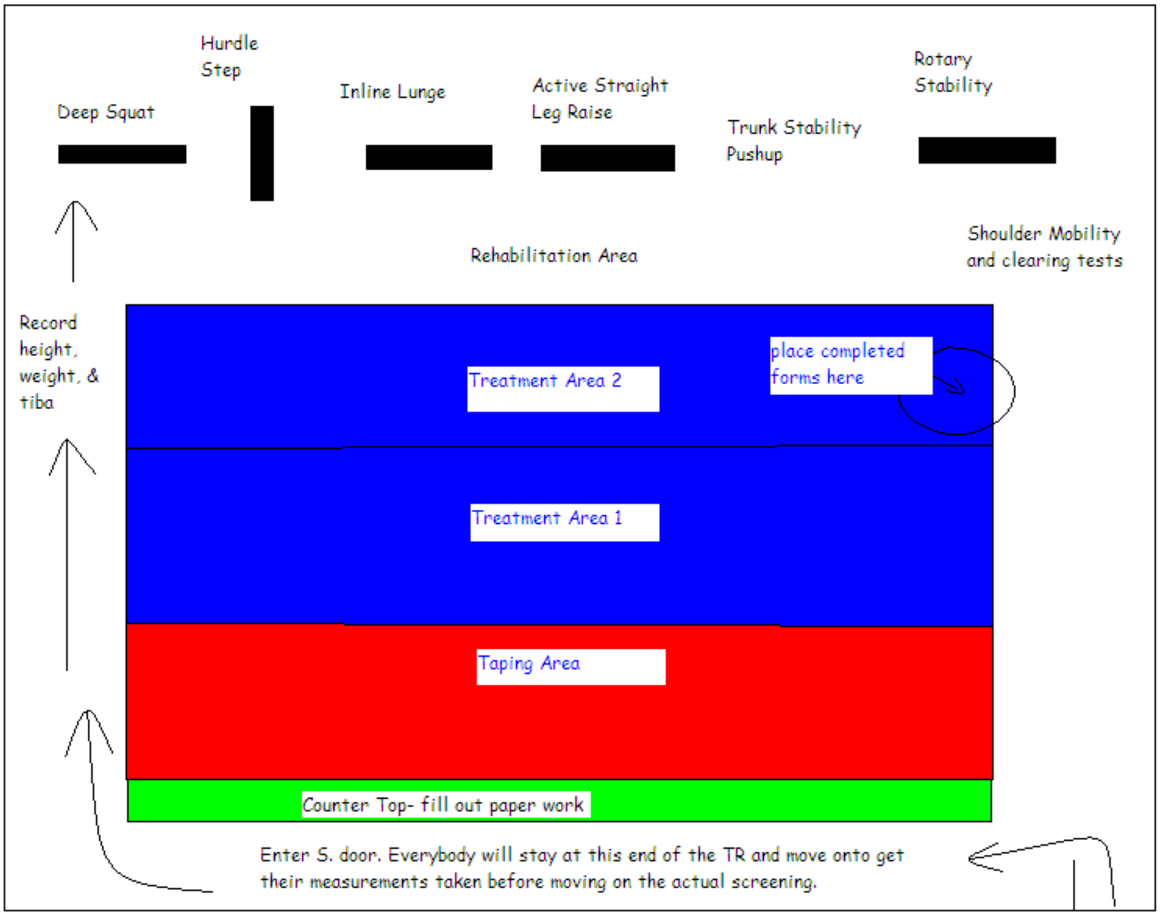
Thomas, J., Nelson, J., & Silverman, S. (2005). Research Methods in Physical Activity. Human Kinetics, Champaign, IL: 5th ed.

van Mechelen, W. (1992). Running injuries: a review of the epidemiological literature. *Sports Medicine*, 14: 320-335.

Wen, D. (2007). Risk factors for overuse injuries in runners. *Current Sports Medicine Reports*, 6: 307-313.

Zemper, E. (2005). Track and field injuries. *Individual Sports Medicine and Sports Science*, 48: 138-151.

Appendix A


Deep Squat
Hurdle Step
Inline Lunge
Active Straight Leg Raise
Trunk Stability Pushup
Rotary Stability
Shoulder Mobility and clearing tests
Rehabilitation Area
Record height, weight, & tiba
Treatment Area 2
place completed forms here
Treatment Area 1
Taping Area
Counter Top- fill out paper work
Enter S. door. Everybody will stay at this end of the TR and move onto get their measurements taken before moving on the actual screening.

Appendix B

Name: ______________________________

Age: __________

Height: __________

Weight: __________

Gender: Male Female

Track and field event: ______________________________

Level of athletic eligibility: ______________________________

On athletic scholarship: YES NO

Please list any current injuries that has keep you out for one or more days of training and are currently receiving treatment for. Circle none if applicable: NONE

____

____

____

____

____

Please list any past injuries that have kept you out for one or more days of training, circle none if applicable: NONE

____

____

____

____

____

Have any of your injuries required surgery: YES NO

If so please describe what the surgery was for:

____

____

____

____

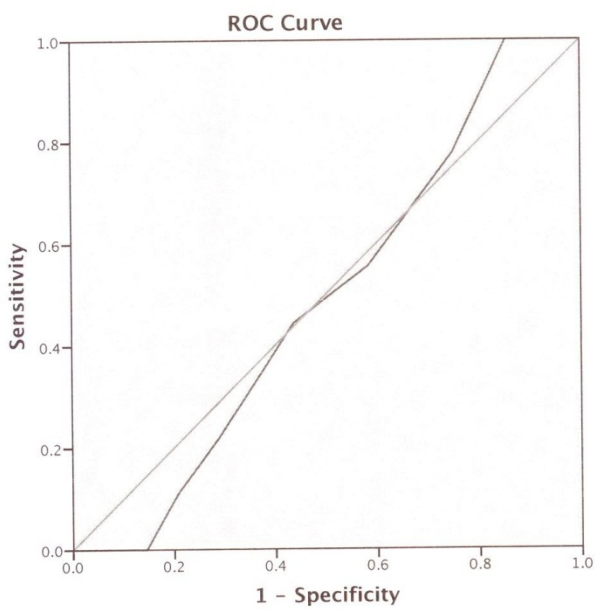
Appendix C

Case Processing Summary

Injured	Valid N (listwise)
Positive[a]	9
Negative	48
Missing	1

Smaller values of the test result variable(s) indicate stronger evidence for a positive actual state.

a. The positive actual state is 1.00.



Diagonal segments are produced by ties.

Area Under the Curve

Test Result Variable(s): FMSScore

Area
.488

Coordinates of the Curve

Test Result Variable(s): FMSScore

Positive if Less Than or Equal To[a]	Sensitivity	1 - Specificity
8.0000	.000	.000
9.5000	.000	.021
10.5000	.000	.042
11.5000	.000	.104
12.5000	.000	.146
13.5000	.111	.208
14.5000	.222	.292
15.5000	.444	.438
16.5000	.556	.583
17.5000	.778	.750
18.5000	1.000	.854
20.0000	1.000	.979
22.0000	1.000	1.000