FMS AND INJURY PREVALENCE

THE FUNCTIONAL MOVEMENT SCREEN AND INJURY PREVALENCE IN COLLEGIATE ATHLETES

An Independent Research Report

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Doctor of Physical Therapy

By
Allison Joslin
Heather Bodin

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FMS AND INJURY PREVALENCE

APPROVAL SHEET

This independent research is submitted in partial fulfillment of the requirements for the degree of

Doctor of Physical Therapy

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Allison Joslin, SPT

__________________________________________________________________

Heather Bodin, SPT

Approved: May, 2016

__________________________________________________________________

Stephen Black, DSc, PT, ATC, CSCS
Committee Chairperson

__________________________________________________________________

Verner Swanson, MSPT
Committee Member

__________________________________________________________________

Shawn Felton, EdD, ATC, LAT
Committee Member

The final copy of this independent research has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.
FMS AND INJURY PREVALENCE

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Abstract

Introduction. The Functional Movement Screen (FMS) is an evaluation tool that was created to help health care professionals assess an individual’s functional movement patterns. Research has demonstrated a cutoff FMS score associated with increased risk of injury and this finding has led to interest in utilizing the FMS for guiding preventative measures for athletes. The purpose of this study was to determine if FMS scores could predict injury occurrence in Division I collegiate female swimmers, divers, and cheerleaders during one competitive athletic season. A total of forty-eight (n=48) NCAA Division I female athletes were included in this study.

Methods. Athletes were screened at the beginning of their respective athletic seasons utilizing the standardized FMS kit, verbal instructions, and grading criteria. Injuries were recorded by the team athletic trainers over fifteen weeks. Injury data was analyzed and correlated with composite FMS scores.

Results. FMS scoring ranges from 0-21 with 21 indicating all movements were performed appropriately, without pain and no asymmetries observed. Participants in this study scored composite FMS scores ranging from 8 to 18 with a mean FMS score of 13.9 ± 2.26 for all (n=48) participants. Specifically, cheerleaders mean score was 14.4 ± 1.70 and swimmers and divers mean score was 13.6 ± 2.41 respectively. Sixteen total injuries occurred during the 15 week study. Logistic regression analysis concluded that FMS scores were not a significant predictor (p=0.927) of injury and no cutoff score signified an increased risk for injury. With a FMS score of 14, logit(p) =.335 (for sustaining an injury) which indicated that this FMS score would inaccurately predict an injury. The
calculated odds ratio (B=1.013) indicated that the odds of sustaining an injury or not sustaining an injury were equally likely.

**Conclusion.** Based on the results of this study, composite FMS scores should not be utilized to predict risk of injury in female division I collegiate swimmers, divers, and cheerleaders. However, data analysis revealed unique patterns amongst individual component scores of the FMS. Further research is needed to determine if the individualized results from component scores can be correlated with risk of injury or utilized as a framework for developing customized therapy or training.
Introduction

The Functional Movement Screen™ (FMS), developed by Gray Cook and Lee Burton, is an evaluation tool that utilizes seven complex movements to assess an individual’s functional movement pattern and accentuate asymmetries or limitations of movement. It was designed as a systematic screening guide to assist health and wellness professionals in identifying poor fundamental movement patterns in patients and clients. Although the FMS is not a diagnostic tool, research has found a cutoff score associated with increased risk of injury (Chorba et al, 2010; Kiesel, Plisky, & Voight, 2007). Knowledge of these findings led to the practitioners serving the athletic population implementing the FMS as part of pre-season physical fitness examinations. The movements of the FMS have been specifically designed to stress an individual’s functional movement limits so that one’s range of motion, dynamic stabilization, and balance deficits are exposed. The identified maladaptive movements observed with the FMS can be evaluated and correlated with outcomes. Research has demonstrated deficits in an individual’s ability to actively control and stabilize the pelvis and spine influence sport-performance outcomes (Palmer, Howell, Mattacola, & Viele 2013). Cook and Burton (2010) believed that poor movement patterns, such as poor dynamic balance and flexibility, make persons more susceptible to injury.

Evaluation tools such as the FMS have value in assisting health care professionals identify athletes who are most susceptible to injury through the identification of non-ideal movement patterns and guide the development of a proactive prevention plan. Compensations and maladaptive movement patterns place abnormal stresses on the body increasing risk of micro-trauma injuries (Cook, Burton, Kiesel, Rose, & Bryant, 2010;
Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010). Bushman et al (2015) describe that the FMS is useful in assessing neuromuscular control and natural movement patterns which reflect habitual movement patterns during daily activities. These researchers also believed that the FMS could be particularly useful in identifying risk of overuse injury by exposing maladaptive habitual movement patterns.

Analysis of fundamental movements should precede analysis of physical fitness, performance, or movement parts because high performance and fitness levels disguise underlying dysfunction. Compensatory and maladaptive movement patterns are revealed when athletes are challenged to utilize the combination of stability and mobility during the FMS. Although athletes can compete at elite levels of competition with unidentified dysfunction, abnormal stresses are placed on the musculoskeletal system and have the potential to increase risk of injury. Research has demonstrated that the FMS may play a large role in reduction of injury through the aforementioned movement assessment (Cook et al, 2010).

**Purpose/Research Question**

Based on the current research available, it was not known whether the Functional Movement Screen scores can predict increased risk of injury in female collegiate level swimming, diving, or cheerleading athletes. More research on a threshold FMS score for female endurance and non-contact sports is still needed. Sports such as swimming, diving, and cheerleading (gymnastics), where overuse injuries are more common than contact injuries need further research regarding use of the FMS (Cook et al, 2010; Butler, Contreras & Curton, 2012; Kiesel, Plisky, & Voight, 2007; O’Connor, Deuster, & Davis, 2011). Thus, the purpose of this study was to determine if FMS scores could
predict injury occurrence over one competitive athletic season in this population of athletes. Specifically, the research question asked, ‘Can FMS scores predict the occurrence of injuries in female Division I collegiate level swimming, diving, or cheerleading athletes during one competitive season?’

Review of the Literature

The Functional Movement Screen

The FMS was developed to be an objective tool used to analyze human movement patterns. It is based upon the assumption that there are ideal, fundamental human movement patterns which present themselves as a child moves through motor development. At infancy, movements are the result of reflexive actions and develop into voluntary actions in which mobile and stable segments work in coordination (Cook et al, 2010). Motor development follows the progression of mobility, stability, controlled mobility and finally functional distal control (Tecklin, J., 2015, pg 25). As a child goes through motor development a progression is made through fundamental patterns including rolling, quadruped, sitting, kneeling and eventually walking. These foundational patterns are what the movements of the FMS were derived from. They represent the foundational movements and those patterns in which the musculoskeletal system works optimally. It is important to note that environmental factors can influence learned patterns and hinder the musculoskeletal system from providing optimal stability and mobility (Cook et al, 2010).

The FMS consists of seven fundamental movement patterns that include the deep squat, the hurdle step, the in-line lunge, the shoulder mobility test, the active straight-leg raise, the trunk stability push-up, and the rotary stability tests (Cook et al, 2010). The
FMS movements can be separated into two or three groupings. The hurdle step, deep squat, and the inline lunge are considered the “big three”. These movements are complex, dynamic, and require the greatest stability and neuromuscular control to complete. The active straight leg raise, shoulder mobility, trunk stability push up, and rotary stability are considered the “little four”. These movements are considered to be fundamental tests reflecting earlier stages of motor development. Alternatively, some argue that the rotary stability test and the trunk stability push up are transitional movements. To complete appropriately, integration of core stabilization, scapular stability, and coordination between upper and lower extremities must occur (Koehle, Saffer, Sinnen, & MacInnis 2016). The seven movements of the FMS provide a comprehensive assessment of an individual’s ability to provide the necessary mobility, stability, and coordination of multiple body segments.

Each movement of the FMS is scored on a four point scale of 3, 2, 1, or 0 with a total composite score of 0 to 21 points possible (Teyhen et al., 2012). A 3 is given if the individual can complete the movement as defined by the FMS scoring criteria. A score of 2 is given if the individual can complete the motion but has compensations as defined by any movement pattern outside of the standardized criteria. A score of 1 is assigned if the individual cannot perform the movement and a 0 is given if there is pain during the movement (Cook et al, 2010). The shoulder mobility, trunk stability push-up and rotary stability assessments have clearing tests that are pass/fail. If an individual fails the clearing test they receive an overall score of 0 for that test. Five out of the 7 tests are scored independently for the right and left side. The lower score between the left and right is used towards the final composite score (Cook et al, 2010; Sprague et al, 2014).
FMS Reliability and Validity

Several studies have been done to test the reliability of the scoring system of the FMS. Research by Minick et al. (2012) assessed the inter-rater reliability of individuals with various levels of training on the FMS. The resultant data indicated that the FMS has high interrater reliability between novice and expert raters maintaining at least a moderate level (kappa 0.4-0.59) of agreement. Any disagreements were attributed to the 2-dimensional limitations of rating based on a video rather than real time. A similar study supported these findings and demonstrated good inter (ICC=0.80) and intra-rater (ICC=0.75) reliability between physical therapists (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2010). Additionally, research by Onate et al. (2012) indicated high inter-rater (ICC = 0.98) and intersession (ICC = 0.92) reliability for the composite score and 6 of the 7 component FMS scores. A study on novice examiners demonstrated moderate to good intra-rater (ICC=0.76) and inter-rater (ICC=0.74) agreement and reliability. These findings were further supported by a study by Hotta et al (2015) who determined the FMS to have excellent interrater reliability (ICC=0.928). This body of research indicated that the scoring system of the FMS is reliable for both novice and expert examiners.

Normative Data

There has been limited research on normative data for the FMS however, the information available provided insight into various FMS predictors. Perry and Koehle (2013) studied 622 adults of various athletic backgrounds. Statistical data revealed that age, Body Mass Index (BMI), and activity level had a direct correlation to FMS scores. Those who were within the 20-39 age range had the highest FMS scores whereas those age 65 and older had the lowest FMS scores on average. Hotta et al (2015) additionally
concluded that individuals over 40 years of age scored lower on the FMS than their younger counterparts. This study further concluded that higher levels of physical activity predicted higher FMS scores. Findings by Lisman et al (2013) also found a correlation between physical activity and FMS scores. They found that slower run times during a three mile run by military recruits were associated with a 1.66 times higher risk of injury. Perry and Koehle concluded that participants with a BMI >30 had much lower scores compared to those with a lower BMI. This evidence is supported by Bushman et al who found that a BMI >25 was associated with increased injury risk. Research focused on gender differentiation discovered that there was not a significant statistical difference between the composite scores of males and females. Researchers found that males scored higher on the rotary stability and trunk stability push-up whereas females scored higher on the shoulder mobility and active straight leg tests (Schneiders, Davidsson, Horman, & Sullivan, 2011). Multiple studies supported the conclusion that women scored higher than their male counterparts on the shoulder mobility and active straight leg raise movements (Hotta et al, 2015; Perry & Koehle, 2013; Schneiders et al., 2011). Further research on normative data is necessary since there are several other variables such as training age and sport that can affect the FMS score.

**FMS and Injury Prediction**

The demands of athletic competition can result in the development of specialized movement patterns. In order to excel at the respective sport, certain movement patterns develop that may improve performance but are not ideal biomechanics. These patterns can also develop as a result of pain with subsequent movement avoidance behaviors. Cook et al. (2010) explained that these specializations result in imbalances in the body
which manifest as inappropriate agonist antagonist muscle strength, inappropriate activation ratios of larger power to smaller stabilizing musculature, or muscle strength that surpasses joint integrity. Inappropriate movement specializations can lead to fatigue and/or poor muscle recruitment negatively influencing motor control, balance, and ability of the body to provide adequate stability and mobility (Cook et al, 2010).

There have been several research investigations examining the FMS and prediction of injury (Chorba et al, 2010; Kiesel, Plisky, & Voight, 2007). Despite athletic ability, even elite athletes are frequently unable to properly perform the seven movements addressed during the FMS. During the screening, compensation strategies and inefficient movement patterns are exposed and reflected by lower FMS scores. Researchers have reported that those with lower FMS scores are more likely to become injured or already have a history of injury (Onate et al., 2012). Kiesel, Plisky, and Voight (2009) studied professional football players (n=46) and found that those with a score of less than or equal to 14 had a much greater chance of serious injury during their competitive season. Serious injury was defined as an athlete being a member of the injured reserve for a minimum of three weeks. These findings were supported by a study on physically active students between ages 18-25 (n=100) that found individuals who scored below a 17 had a 4.7 times increased likelihood of sustaining a knee or ankle injury. They also found that individuals who score less than 14 had an 11.7 times greater risk of injury. This study defined an injury as any acute lower extremity injury that kept the athlete out of participation for one or more consecutive exposures (Letafatkar, Hadaneshad, Shojaedin, & Mohamadi, 2014). Research focusing on female collegiate soccer, volleyball, and basketball players (n=38) also found that a lower score on the FMS was associated with
Injury. In this study population, 69% of the injuries sustained were by participants who scored a 14 or less (R. Chorba, D. Chorba, Bouillon, Overmyer, & Landis, 2010). Additionally, a study on firefighters (n=108) found an equal determinant score of 14 or less indicating increased injury risk (Butler, Contreras, and Curton, 2012).

A cohort study of Division II soccer and volleyball athletes utilized pre and post season FMS scores to analyze changes in movement over the course of a season. The study concluded there were no statistically significant differences between composite scores, however, there was a statistically significant reduction in the total number of asymmetries. Additionally, findings demonstrated that individual movement scores both increased and decreased (Sprague, Mokha, & Gatens, 2014). This compilation of evidence supports the use of the FMS for assessing injury risk within the studied populations; however, this information cannot yet be generalized to apply to all individuals.

**FMS and Pre-participation Screening**

As sport participation has continually increased over time, the risk of incurring a musculoskeletal injury has also increased (Minick, K., Kiesel, K., & Burton, L., 2010). According to Teyhen et al., “More than 10,000 Americans seek medical treatment for sports, recreational activity, and exercise-related injuries on a daily basis” (Teyhen, D.S., Shaffer, S.W., Lorenson, C.L…Childs, J., 2012, p.530). Pre-participation screenings ensure the safety and health of the athletes for participation in competitive athletics. Professional organizations such as the National Collegiate Athletic Association (NCAA) and the National Association of Intercollegiate Athletics (NAIA) require a pre-participation evaluation for all athletes. Organizations including the Sports Physical
Therapy Section of the American Physical Therapy Association (APTA) and National Athletic Trainer’s Association (NATA) have literature supporting the use of pre-participation screening and athlete’s readiness to participate. The American Medical Association (AMA) promotes the rights of the athlete and their entitlement to appropriate health supervision (Sanders, Blackburn, & Boucher, 2013). Pre-participation screenings act as a preventative measure to assist with reducing the risks of injuries (Sanders, Blackburn, & Boucher, 2013). Screening individuals for dysfunctional patterns before pain or injuries occur, allow healthcare professionals to proactively address deficits (Frohm et al., 2010).

**Sport Specific Injuries: Swimming**

The sport of swimming is a unique overhead sport as a result of the continuous propulsive actions required primarily by the upper extremities. Swimmers can average 6,000-10,000 meter practices, 5-7 days a week, over a 10-12 month training period. This volume of training results in the shoulder producing 30,000 rotations or more per week (Heinlein, & Cosgarea, 2010). The high volume of repetitive motion predisposes the shoulder to overuse trauma. The term ‘swimmer’s shoulder’ is used in reference to an array of shoulder pathologies but most commonly supraspinatus tendinopathy or impingement (Heinlein, & Cosgarea, 2010). Swimmers develop alternative stroke biomechanics in order to avoid painful arcs in their range of motion and these compensatory movements can result in further injury (Tate, Turner, Knab, Jorgensen, Strittmatter, & Michener, 2012). It is currently unknown whether the FMS can accurately identify swimmers who are at risk of developing overuse pathologies.
Sport Specific Injuries: Cheerleading

Cheerleading routines incorporate gymnastics, tumbling, and stunts that utilize various lifts, catches, and tosses. A study analyzing 243 cheerleading teams (n=9,022) including high school, collegiate, and All Star groups, recorded a total of 567 cheerleading injuries over one year. Lower extremity and upper extremity injuries were the most common with the ankle, knee, neck, lower back, and head being those areas of the body most likely to be injured. Over half of the recorded injuries occurred while the cheerleader was attempting a stunt or tumbling maneuver. The top five injuries sustained by cheerleaders were ankle strain or sprain (15%), neck strain or sprain (7%), lower back strain or sprain (5%), knee strain or sprain (5%), and wrist strain or sprain (4%); (Shields and Smith, 2009). A different study including cheerleading teams at division IA universities found that injuries to the ankle, wrist, hand, and knee occurred most frequently. Further analysis determined that majority of these injuries occurred during stunting (Jacobson, Redus, and Palmer, 2005). Participation in cheerleading requires appropriate mobility and stability and it is advantageous to determine if the FMS can predict injury in this population.

To date, the majority of research on the FMS has included male athletes in sports that rely primarily on the lower extremity (Onate et al., 2012; Kiesel, Plisky, & Voight, 2007; Letafatkar et al., 2014; Butler et al., 2012). Further research is warranted to determine whether the FMS is a valid screening tool to use for female athletes. The information gained from this study evaluated the use of the FMS as a tool for predicting injuries in these athletic populations, and more broadly whether the FMS can be utilized
as a screening tool for sports with different gender participation and varying biomechanical demands.

Methods

Participants

A total of fifty-one NCAA Division I female athletes were screened including thirty-three swimmers, fifteen cheerleaders, and three divers. Three of the swimmers were not included in the final results due to one swimmer transferring colleges, one swimmer quitting the team, and one graduating before the completion of the study resulting in a total of forty-eight ($n=48$) athletes. To be included in this study, participants were required to be an NCAA Division I swimming, diving, or cheerleading female athletes between the ages of 18-25 years. Athletes were excluded from this study if they had sustained an injury 30 days or less prior to FMS testing that prevented participation in strength and conditioning, practice, competition, or if they had recent surgical intervention that limited their participation in sport due to physician restriction.

Data Collection

Prior to the initiation of this research, the investigation was approved by the University’s Institutional Review Board for Research with Human Subjects. At the beginning of the participant’s respective athletic seasons, functional movement patterns were evaluated by two Student Physical Therapists who were trained in using the FMS.

Prior to testing, all athletes signed the approved informed consent documentation, were educated on the purpose of the study, and informed that the results of the study would not influence their participation in athletic activities. Testing was performed in the athlete’s normal training environments. For the swimmers and divers, testing was
performed on the pool deck and for the cheerleaders, testing was performed in the university’s gymnasium. Two testing stations were set up with an FMS test kit, FMS scoring sheet, FMS scoring criteria, and one researcher at each. Athletes were screened one at a time and were provided with the same standardized FMS verbal instructions before each movement. Per FMS standards, athletes were allowed 2 attempts at each movement. Athlete’s year in school and position or specialty stroke were recorded. All athletes and coaches were blind to FMS results.

Injuries were recorded over the following fifteen weeks. During this time, athletes completed their typical practice, strength and conditioning sessions, and competition as usual. Researchers did not alter training regimes and all athletic activities continued as prescribed by the athletic staff. Team athletic trainers recorded injury occurrence, treatment, and referral to other healthcare providers using the ATS computer system. Each athlete was randomly assigned a code that kept the athlete’s identity confidential to the researchers.

For the purpose of this study the definition of an injury met the following criteria: The injury occurred as a result of participation in their collegiate sport practice or competition setting, the injury required medical attention, or the athlete received any type of assistance from a certified athletic trainer, athletic training student, physical therapist, physical therapist student, or physician. Assistance was defined as any therapeutic intervention including but not limited to modalities, exercise, taping, or any modification to usual training. This definition of injury was utilized in the research by Chorba et al. (2010). Rather than utilizing a time loss injury definition like Kiesel et al (2007); the
broader definition of an injury was utilized to ensure that all injuries regardless of severity would be included.

**Data Analysis**

All analysis was performed utilizing the IBM SPSS Statistics 24 software. Of the 48 athletes included in analysis, 16 sustained injuries (33%) over the 15 week data collection period. Descriptive statistics for FMS scores and injury occurrence (Table 1) exhibit that FMS scores ranged from 8-18 with an overall mean composite score of 13.9 ± 2.26. Specifically, cheerleaders scored a mean of 14.4 ± 1.7 and swimmers/divers scored a mean of 13.6± 2.41. Logistic regression analysis was performed and used to determine if FMS scores could predict injury risk in the population of athletes included in the study. Only two possible outcomes for injury occurrence were possible (yes or no) and thus logistic regression analysis was used. Incidence of injuries was dichotomized using the coding of 1 for “yes an injury occurred” and 0 for “no injuries occurred”. FMS scores were left unchanged. The results of the regression analysis concluded that FMS scores were not a significant predictor of injury (p=0.927) and there was no cutoff score signifying an increased risk of injury (pseudo R² = 0, Df (1), p> .05) (Table 2). When a score of 14 was put into the logistic regression equation, (logit)p=.335 (for sustaining an injury) concluding that an FMS score of 14 would inaccurately predict an injury (logit(p)<.5). The odds ratio (Exp(B)) = 1.013) concluded that the odds of sustaining an injury or not sustaining an injury were roughly equally likely. The pseudo R² value (pseudo R² = 0) determined that this model does not explain the variability of the response data around the mean.
A bivariate correlation analysis was also completed to determine if there was a relationship between injury occurrence and FMS score (Table 3). Injury occurrence was dichotomized as previously with the logistics regression analysis. FMS scores were dichotomized numerically with a 1 indicating the individual scored below a 14 and a 0 indicating the individual scored above a 14. Results of the bivariate correlation supported the logistic regression analysis findings and determined FMS composite scores were not a significant predictor of injury risk, \( r = -0.030, p > 0.05 \). The data analysis suggested that overall, in this sample of athletes, the FMS score was not a significant predictor of risk for injury and no cutoff score for injury risk was indicated.

Table 1
Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS Score</td>
<td>48</td>
<td>8</td>
<td>18</td>
<td>13.90</td>
<td>2.262</td>
<td>-0.740</td>
<td>0.343</td>
</tr>
<tr>
<td>Injury</td>
<td>48</td>
<td>0</td>
<td>1</td>
<td>0.33</td>
<td>0.476</td>
<td>0.730</td>
<td>0.343</td>
</tr>
</tbody>
</table>

Table 2
Logistic Regression Analysis
(Equation: \( \logit(p) = -0.867 + 0.013 \times (\text{FMS score}) \))

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1a</td>
<td>FMS Score</td>
<td>.013</td>
<td>.137</td>
<td>.008</td>
<td>1</td>
<td>.927</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>-.867</td>
<td>1.935</td>
<td>.201</td>
<td>1</td>
<td>.654</td>
</tr>
</tbody>
</table>
Results

Logistic regression \((p=0.927)\) and bivariate correlation \((p=0.840)\) analysis both concluded that FMS scores were not a significant predictor of injury and there was no cutoff score indicating an increased risk of injury as previous studies have found (Kiesel et al., 2007; Sprague et al., 2014).

Analysis of the component FMS scores revealed that for swimmers and divers the shoulder mobility movement was the lowest scoring item overall (mean = 1.18) followed by the push up (mean = 1.78), hurdle step (mean = 1.84), deep squat (mean = 1.90), rotary stability (mean = 2.03), and finally the inline lunge and active straight leg raise (mean = 2.45). For the cheerleaders, the lowest component score was also the shoulder mobility test (mean = 1.40) followed by the push up and hurdle step (mean = 1.8), rotary stability and deep squat (mean = 2.0), inline lunge (mean = 2.6), and the active straight leg raise (mean = 2.9).

Utilizing the previously determined score of 14 as the cutoff for injury risk, further analysis found that for swimmers and divers, the FMS would have accurately assessed injury risk for only 42% of the injuries that occurred and that 58% of those
who scored below a 14 would have been inaccurately assessed as high injury risk. Similar outcomes were found in the cheerleading population where 40% of injuries were incurred from individuals scoring above 14 and 40% of individuals scoring below a 14 were inaccurately assessed as high injury risk. Overall, between both athletic teams, 45% of the injuries that occurred were from athletes who scored above the 14 composite score cut off. Based upon the previously supported cutoff score, the low average scores of the participants would have predicted that approximately half of the athletes would have incurred an injury. However, this conclusion is not supported by these research findings.

**Discussion**

The Functional Movement Screen is an evaluation tool that has been used by health and wellness professionals to observe fundamental movement patterns and guide the identification of movement asymmetries and compensatory patterns. Studies have been performed utilizing the FMS in populations including professional football players (Kiesel et al, 2007), firefighters (Butler et al, 2012), police officers (O’Connor et al, 2011), soldiers (Bushman et al, 2015), male runners (Takayuki et al., 2015), and collegiate basketball, soccer, and volleyball players (Chorba et al, 2012). These studies established that a score of 14 or less indicated increased injury risk. Due to these findings, the FMS has become a progressively more common tool used by various professional and collegiate level sports (Sprague et al, 2014). Limited data was available to date on the use of the FMS for determining injury risk in the female population. One study performed on Division II female athletes concluded that a score of 14 or less was associated with a 4-fold increase in injury risk supporting the validity of the FMS in the female population (Chorba et al, 2012). The aim of this study was to determine if this
cutoff score applied to a population of Division I female collegiate swimmers, divers, and cheerleaders. This population of athletes had not been studied to date in relation to the FMS and a larger body of research is needed to provide more conclusive evidence on the use of the 14 cutoff score being generalized to the universal population.

The findings of this research indicated that there is no statistically significant correlation between FMS score and injury risk in Division I female collegiate swimmers, divers, or cheerleaders. These findings are consistent with other research findings which have advised against the use of a summative score for reflecting injury risk. Lack of a single factor between the components of the FMS suggests a lack of meaning of the summative score. Research on factor analysis of the FMS concluded that there was low internal consistency between the seven tasks. Using the sum score indicates that the screen is unidimensional and that the seven tasks assess for the same construct, which would result in high internal consistency rather than low. According to this study, the sum scores should not be used to indicate injury risk and suggests that the score of each task is more relevant than the composite score of the FMS (Li et al, 2015). Krause et al (2014) questioned the four point grading system of the FMS and suggested development of a new grading system where each component is weighted evenly. This research argued that the components of the FMS are not unidimensional and the total score cannot be treated as a cluster variable. Individual daily activity and athletic demands have great variation which results in a vast array of potential injuries. Thus, individuals with the same low score will not necessarily have an identical type or amount of injury risk. Frost et al (2015) also argued against the use of the composite FMS score for assessment of injury risk. This research concluded that the same score reflects a broad range of
movement patterns and scores do not necessarily reflect an individual’s task performance. It is recommended that future research regarding FMS scores focus on component scores rather than total scores to account for differences in each individual movement when summative scores are equal.

The ability of pain to assess for injury risk in relation to summative FMS score has also been researched. Previous research indicated that the FMS is useful when supported by pain assessment during movement. Bushman et al. (2015) assessed whether pain, rather than movement quality, provided more information on the risk of injury. Results indicated that pain during the hurdle step had the strongest association with injury risk finding a 3.5 times greater risk compared to no pain. This research supported the current findings concluding that the FMS cutoff score of 14 failed to identify the majority of individuals who experienced an injury. The FMS inaccurately categorized 63-72% of individuals who incurred an injury to be at low injury risk. The FMS only positively categorized 28-37% of individuals who experienced an injury to be at high injury risk. These findings indicate that the summative FMS score should not be the only tool utilized to identify injury risk in athletes (Bushman et al., 2015).

Additional factors to be considered when categorizing an individual’s risk of injury include but are not limited to: previous history of injury, age, BMI, and aerobic fitness. Frost, Beach, Callaghan, and McGill (2012) questioned the effectiveness of using the FMS to identify faulty movements. Theory suggests that daily variation influences the quality of movement and thus an individual’s composite FMS score. In order to obtain a comprehensive analysis of an individual’s risk for injury, the FMS should be used in
conjunction with other assessment tools, patient background information, and sport
specific performance measures during pre-participation assessments.

Currently the FMS verbal instructions allow the client two to three attempts for
each movement if necessary. Some discussion exists regarding whether individuals
should be allowed these practice attempts. Frost et al (2015) showed that FMS scores can
be improved within minutes. This study argued that allowing multiple attempts provided
the individual with the opportunity to alter their natural movement patterns. Further
reasoning stated that the initial movement score was more reflective of the habitual
movement pattern of the individual and was a superior indicator of injury risk (Frost,
Beach, Callaghan, & McGill 2015). However, Krause et al (2014) supported the
allowance of multiple practice attempts, suggesting that the first attempt does not
accurately reflect the individual’s neuromuscular control. Other factors have been
shown to influence FMS summative scores such as interpretation of the task, previous
experience, and motivation to perform. Palmer et al (2013) concluded that an athlete’s
dedication and focus improved likelihood of success. In this current study, it is possible
that each athlete’s performance on the FMS was affected by personal outlook.
Participants were aware that their FMS results would not influence playing time or
participation which may have impacted motivation to perform.

There are several limitations to this study that should be considered when future
research on the Functional Movement Screen is completed. This study relied on self-
report of injuries by the athletes to coaches and athletic training staff. It is possible that
athletes were hesitant to reveal an injury due to the potential of jeopardizing their ability
to participate, and thus, all injuries that occurred may not have been accounted for. This
study also had a relatively small sample size of 48 included participants. According to the power analysis, a minimum of 55 athletes should have been included for this study to have a power of 0.8. Future studies should consider a greater number of participants in order to obtain more meaningful results.

Additionally, this research study had a shorter time frame of fifteen weeks. Future studies should consider tracking injuries over a complete macrocycle of training in order to include injuries that occur during off-season and pre-season in addition to in-season training and competition. This study did not take in to consideration whether injuries took place during practice or competition and another potential covariate to be considered is hours of training and competitive participation by each athlete. Differences in training and competitive load could influence risk of injury. These factors would be valuable information to include in future studies on injury occurrence.

**Conclusion**

Based on the results of this study, composite FMS scores should not be utilized to predict risk of injury in female division I collegiate swimmers, divers, and cheerleaders. These findings add to the body of research available indicating that the summative FMS score indicating risk of injury cannot be generalized to the greater population. However, data analysis revealed unique patterns amongst individual component scores of the FMS. Further research is needed to determine if the individualized results from component scores can be correlated with risk of specific injury. The FMS was designed to identify weaknesses, compensations, asymmetries, and dysfunctional movement patterns during the completion of fundamental movements. Professional assessment of the movements
and identification of dysfunction can be utilized as a framework for developing
customized therapy or training.

Figure 1. Hurdle Step

Figure 2. Shoulder Mobility

Figure 3. Rotary Stability
Figure 4. Deep Squat

Figure 5. In Line Lunge

Figure 6. Trunk Stability Push Up
References


## Appendix A: Cheerleading Injuries

<table>
<thead>
<tr>
<th>FMS Score</th>
<th>Position</th>
<th>Type of Injury</th>
<th>&lt;= 14 cutoff score</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Flyer</td>
<td>Grade I ankle sprain</td>
<td>No</td>
</tr>
<tr>
<td>15</td>
<td>Base</td>
<td>Ankle surgery due to multiple sprains</td>
<td>No</td>
</tr>
<tr>
<td>12</td>
<td>Base</td>
<td>Tibia and talus bruising/injury</td>
<td>Yes</td>
</tr>
<tr>
<td>14</td>
<td>Flyer</td>
<td>Shoulder subluxation</td>
<td>Yes</td>
</tr>
<tr>
<td>14</td>
<td>Base</td>
<td>Knee meniscal tear</td>
<td>Yes</td>
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## Appendix B: Swimming and Diving Injuries

<table>
<thead>
<tr>
<th>FMS Score</th>
<th>Stroke</th>
<th>Type of Injury</th>
<th>&lt;= 14 cutoff score</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Breast</td>
<td>-Low back pain</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Grade I oblique strain</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Fly</td>
<td>Inflammation/pain of supraspinatus</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>Breast</td>
<td>Grade I Sartorius strain</td>
<td>Yes</td>
</tr>
<tr>
<td>14</td>
<td>Fly</td>
<td>Grade I Supraspinatus strain</td>
<td>Yes</td>
</tr>
<tr>
<td>15</td>
<td>IM</td>
<td>-Grade II Supraspinatus strain</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>-Grade I subscapularis strain</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>-Frayed labrum</td>
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<tr>
<td>12</td>
<td>Free/back</td>
<td>Grade I Sartorius strain</td>
<td>Yes</td>
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<tr>
<td>10</td>
<td>Free</td>
<td>Low back strain</td>
<td>Yes</td>
</tr>
<tr>
<td>16</td>
<td>Free</td>
<td>Bilateral shoulder pain; supraspinatus strain</td>
<td>No</td>
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<tr>
<td>15</td>
<td>Free/back</td>
<td>Rotator cuff instability and nerve entrapment</td>
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</tr>
<tr>
<td>16</td>
<td>Free/back</td>
<td>Grade I supraspinatus strain</td>
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<tr>
<td>14</td>
<td>Diver</td>
<td>Wrist pain and inflammation</td>
<td>Yes</td>
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</table>
Appendix C: FMS Scoring Sheet

THE FUNCTIONAL MOVEMENT SCREEN

SCORING SHEET

<table>
<thead>
<tr>
<th>NAME</th>
<th>DATE</th>
<th>DOB</th>
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<table>
<thead>
<tr>
<th>PRIMARY SPORT</th>
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<table>
<thead>
<tr>
<th>HAND/LEG DOMINANCE</th>
<th>PREVIOUS TEST SCORE</th>
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<table>
<thead>
<tr>
<th>TEST</th>
<th>RAW SCORE</th>
<th>FINAL SCORE</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td>DEEP SQUAT</td>
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</tr>
<tr>
<td>HURDLE STEP</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INLINE LUNGE</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHOULDER MOBILITY</td>
<td>L</td>
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<td>R</td>
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<tr>
<td>IMPELLEMENT CLEARING TEST</td>
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<td>R</td>
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<td>R</td>
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<tr>
<td>TRUNK STABILITY PUSHUP</td>
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<tr>
<td>PRESS-UP CLEARING TEST</td>
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<td>ROTARY STABILITY</td>
<td>L</td>
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</tr>
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<td>R</td>
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<tr>
<td>TOTAL</td>
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<td></td>
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</tbody>
</table>

**Raw Score:** This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

**Final Score:** This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.