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A Mixed-Methods Investigation of FMS Shoulder Mobility and Reported Upper Body Injury in Collegiate Football Athletes at a Division II Midwestern University

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A Dissertation submitted to the Education Faculty of Lindenwood University

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Dr. Robyne Elder, Committee Member	9/1/17 Date
Dr. Kevin Winslow, Committee Member	9/1/17 Date
Dr. Beth Kania-Gosche, Committee Member	9/1/17 Date

Declaration of Originality

I do hereby declare and attest to the fact that this is an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

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Abstract

Since the introduction of the Functional Movement Screen (FMS), researchers explored how resulting scores related to injury incidence, often by utilizing the sum score of all seven patterns. This study isolated the shoulder mobility screen and upper body injury incidence for collegiate Division II football athletes at a private Midwestern university. The researcher was interested in determining if pain on the screen indicated by a score of 0, too much or too little mobility, left to right asymmetry, and general score of the screen were related to upper body and/or shoulder injuries for football athletes during the 2014-2015 and 2015-2016 academic years. Injuries were classified as all reported and recorded and as injuries resulting in three or more days lost from practices or games. Additionally, the head football strength and conditioning coaches and head football athletic trainer were interviewed to provide information related to perceptions of effectiveness of the FMS in identification of injury and barriers to implementation of FMS results. Many significant conditions were identified in the 2014-2015 cohort related to shoulder mobility score and injury likelihood, while only one condition was identified in the 2015-2016 cohort. This lack of transferability from one academic year to the next, in conjunction with the limitations of time and resources identified by the strength and conditioning and athletic training staff, led the researcher to express concern in the utilization of the FMS shoulder mobility screen as a consistent primary tool in the identification of potential injury of the upper body and prescription of individual corrective exercise for this population.

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Chapter One: Introduction

Purpose of the Dissertation

The fields of physical education, strength and conditioning, exercise science, and athletic training have become increasingly data driven and the Functional Movement Screen (FMS) was one of the many assessments available for educators in these areas. However, with numerous assessments in the field and limited resources (time, money, personnel), educators needed to choose effective and impactful assessments that were not a drain on resources. As this screen continued to grow in popularity, the use of data-driven decisions regarding the ability of the FMS to offer meaningful insight to educators was especially pertinent.

This research was connected to the field of educational leadership because the FMS assessment was utilized in educational settings — from K-12 physical educators; to collegiate educators in the health sciences and physical education settings; to educators outside of the classroom, such as coaches, strength and conditioning professionals, and athletic trainers. This study was necessary because of the cost and the time investments to implement this assessment. If the FMS was measuring something meaningful to educators, then using the FMS would be worth the educators' time, effort, and funds; however, if the FMS was not measuring something physical educators were highly invested in (i.e. injury likelihood), then the FMS was not an effective tool in the education realm. This study was necessary because the results could allow educators to use data-driven decisions to include or exclude specific assessments from the curriculum.

The FMS was a tool used to assess movement quality in a variety of settings — from elementary physical education classes through professional sport training facilities

(Abraham, Sannasi, & Nair, 2015; Rowan, Kuropkat, Gumieniak, Gledhill, & Jamnik, 2015). The FMS was used in higher education classrooms when educating students in the fields of exercise science, athletic training, and physical education, as a tool to score movement quality, identify potential movement risks, and prescribe corrective exercise. As the use of this screen was increasingly embraced by educators of students and athletes, the researcher desired to establish how different scores on the screen may result in different injury rates.

The purpose of the study was to investigate a possible difference between the score on the shoulder mobility screen of the FMS (0-3) and injury rates of the shoulder and the upper body for collegiate football student-athletes and to identify professional practices and interventions developed by the strength and conditioning and athletic training staff based on FMS scores. This research generated information regarding the difference of a single component screen score (of the seven total screens of the FMS) and specific injuries related to the body area that was the focus of the screen. To determine the difference between shoulder mobility scores and injury rates of the shoulder and the upper body, the researcher used FMS student data from the strength and conditioning department and student injury reports from the athletic training department from the 2014-2015 and 2015-2016 school years. Specifically, the researcher wished to determine a possible difference between injury incidence of the shoulder and shoulder mobility sum score, injury incidence of the upper body and shoulder mobility sum score, injury incidence of the shoulder and shoulder mobility asymmetry, and injury incidence of the upper body and shoulder mobility asymmetry.

The researcher was attentive to determine if too little mobility or too much mobility was related to upper body injury incidence, as either factor may have led to a greater likelihood of experiencing injury. Too little mobility may have led to compensations in other areas of the body, resulting in inefficient movement patterns and might have predisposed the athlete to injury. "When poor or inefficient movement patterns are reinforced, this could lead to poor biomechanics and ultimately increase the potential for micro- or macro-traumatic injury" (Cook, Burton, Hoogenboom, & Voight, 2014a, p. 398). From the FMS scoring system, too little mobility was indicated by a score of 1 (Cook et al., 2014a, p. 400). Additionally, the researcher was attentive to determine if too much mobility was also detrimental and resulted in a difference of injury incidence. Increased joint laxity, which may have manifested itself in increased mobility, may have been another factor for increased injury incidence, as proposed by Borsa, Sauers, and Herling (2000). From the FMS scoring system, a greater amount of mobility was indicated by a score of 3 (Cook et al., 2014a, p. 400). Therefore, the researcher proposed both a score of 1 (indicating a deficient amount of mobility) and a score of 3 (indicating a potentially excessive amount of mobility) may have led to increased injury rates at the shoulder and at the upper body.

Any pain elicited by the Shoulder Mobility test (indicated by a score of 0) may have also led to increased injury rates at the shoulder and at the upper body (Bushman et al., 2015). Beyond the scores of 0 to 3, the researcher also hypothesized shoulder mobility asymmetry, as indicated by difference in scores on the left and right side may also have led to increased injury rates at the shoulder and at the upper body (Bardenett et al., 2015; Mokha, Sprague, & Gatens, 2016).

Additionally, the researcher conducted interviews with the study-site (a private Division II Midwestern University) team head athletic trainer (see Appendix A) to determine how the FMS results were used in the evaluation and treatment of student-athlete injuries. The study-site head strength and conditioning coaches (see Appendix B) during the 2014-2015 and 2015-2016 academic years were interviewed to determine the utilization of FMS scores for corrective exercise interventions and other exercise prescription choices, as these interventions could have influenced injury rates. The 2014-2015 and 2015-2016 groups were used to determine if identified significance was present in both years or if the relationships changed as the team population was altered.

Rationale

The literature current at the time of this writing identified that the FMS sum score of all seven component screens plus three clearing exams had a relationship with a likelihood of injury. Specifically, foundational research identified athletes who had a sum score of less than 14 also had an increased likelihood of injury (Kiesel, Plisky, & Voight, 2007). However, the then-current literature had not explored a possible relationship between all of the individual component screens and specific injury likelihood. This project explored one of the screens, the Shoulder Mobility Screen, and the relationship between scores of the screen and left/right side asymmetries identified by the screen and the incidence of shoulder injury and upper body injury in football players over the course of the 2014-2015 and 2015-2016 academic years. This specific screen and body area was chosen by the researcher because the Shoulder Mobility test was different from the other screens in terms of body area (being the only upper body-focused FMS screen) and simplicity (this pattern was much less complicated than the majority of the other patterns, there were fewer body areas involved, and no skill was required in the performance of the pattern).

Football was chosen as the target population due to the size of the team and the increased likelihood of shoulder injuries in the sport. Other larger teams, such as track and field, were less likely to incur shoulder injuries due to the lack of contact and upper body involvement. Football had a large roster and a theoretically higher likelihood of upper body and shoulder injury, due to the physicality requirements.

Hypotheses and Research Question

Research Question

How do educators in the fields of strength and conditioning and athletic training use the Functional Movement Screen to create data-driven interventions for student-athletes?

Hypotheses

H_1: There is a difference in shoulder injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_2: There is a difference in upper body injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_3: There is a difference in the shoulder injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to a score of 2.

H_4: There is a difference in the upper body injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to a score of 2.

H_5: There is a difference in shoulder injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_6: There is a difference in upper body injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_7: There is a difference in shoulder injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_8: There is a difference in upper body injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_9: There is a difference in shoulder injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H_{10}: There is a difference in upper body injury incidence for collegiate football athletes who score a 0 or 1 compared to a score or 2 or 3.

H_{11}: There is a difference in shoulder injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{12}: There is a difference in upper body injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{13}: There is no difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts.

Table 1, Hypotheses Statements, offers the reader an easier format for viewing proposed hypotheses, H_1 through H_{12}, related to shoulder mobility scores and injury incidence.

Table 1

Hypotheses Statements

	Parameters		Body Area	Hypothesis
There is a difference in injury incidence rates for collegiate football athletes	based on shoulder mobility sum score		for shoulder injury	H_1
			for upper body injury	H_2
	who have shoulder mobility sum scores of 0, 1, 3	compared to a score of 2	for shoulder injury	H_3
			for upper body injury	H_4
	who have shoulder mobility asymmetry	compared to a symmetrical score	for shoulder injury	H_5
			for upper body injury	H_6
	who score a 0, 1, 2 with asymmetry, or 3	compared to a 2 with symmetry	for shoulder injury	H_7
			for upper body injury	H_8
	who score a 0 or 1	compared to a score of 2 or 3	for shoulder injury	H_9
			for upper body injury	H_{10}
	based on their shoulder mobility score and asymmetry status		for shoulder injury	H_{11}
			for upper body injury	H_{12}

The final hypothesis statement, H_{13}, related to the two cohorts of athletes studied potential difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts, rather than potential relationships to the scores of the Shoulder Mobility test.

Overview of Methodology

The researcher used secondary data of FMS scores from the study-site strength and conditioning department and injury occurrences from the study-site athletic training department to evaluate the relationship between shoulder mobility scores and injury of the shoulder and the upper body. The data spanned the 2014-2015 and 2015-2016 academic years. Injuries were classified as all reported and recorded injuries and injuries that caused the student-athlete to lose three or more days of training and/or competition. Additionally, interviews were conducted with the study-site head football strength and conditioning coaches and the study-site head football athletic trainer to identify how the FMS results were utilized to inform the educators' professional practices.

Limitations

The limitations of the study, identified by the researcher, included the following:

FMS variability. FMS scores may have changed over the course of the academic year. The FMS scores used by the researcher were captured at the start of the academic year; however, they may not have reflected the FMS score of the athlete throughout the year, including at time of injury. The FMS score of 0 was based on a self-reported pain rating from each athlete. Athletes may have been hesitant to report the presence of pain to the raters scoring the FMS. The strength and conditioning program completed by the athletes may have influenced a change in FMS scores. Because there were different strength and conditioning coaches over the two academic years, the change in the approach to training may have influenced the athletes' FMS scores and/or the athletes' injury resilience. Scoring of the FMS may have been subject to interrater and intrarater variability.

Injury variability. Injury reporting to the athletic training staff was partially dependent on athletes reporting sustained injuries. Not all injuries may have been reported to the athletic training staff. Since there were two athletic trainers responsible for football, there may have been variability in reporting practices from one athletic trainer to the next. Additionally, reporting practices may change from one institution to the next, so these results may not be translatable to other institutions based on reporting practices.

The definition of what constitutes injury varied widely throughout the then-current literature; therefore, the results of this study may not translate to other settings and time periods, based on determined injury definitions. The sport of football is violent, and at times, unpredictable in injuries sustained, due to the collision nature of the game. Therefore, some injuries may have occurred based not on compensation or unideal movement patterns, but because of the nature of the game.

Translation to other populations. There was an unknown ability of this research to translate to other sports, other levels of play, other institutions, other ages, other genders, and other populations in general.

Definition of Terms

Abduction - “Movement away from your body such as what occurs when you raise your arm straight out to the side” (Stoppani, 2006, p. 381).

Adduction - “Movement of a limb toward the body such as what occurs when your arm is straight out to your side and you lower it down to the side of your body” (Stoppani, 2006, p. 381).

Athlete injury - For the purpose of this study, injury was identified in two ways: an injury-related encounter between the athlete and the athletic trainer in which the athletic trainer documented the visit and an injury-related encounter indicated by the same standards previously noted in addition to an athlete unable to participate in sport for three or more days. Both ways of identification were explored.

Functional Movement Screen - “The FMS is comprised of seven fundamental movement patterns (tests) that . . . are designed to provide observable performance of basic locomotor, manipulative, and stabilizing movements” (Cook et al., 2014a, p. 389).

Functional Movement Screen Clearing Examinations - In three of the seven movement patterns in the FMS, there were clearing examinations that took place immediately following the performance of the movement pattern. These clearing examinations were intended to identify the presence of pain and they are scored as positive, indicating the presence of pain, or negative, indicating the absence of pain on the particular movement (Cook, Burton, Hoogenboom, & Voight, 2014b).

Functional Movement Screen individual score -

> The scoring for the FMS consists of four discrete possibilities. The scores range from zero to three, three being the best possible score. . . . An individual is given a score of zero if at any time during the testing he/she has pain anywhere in the body. . . . If the patient does not score a zero, a score of one is given if the person is unable to complete the movement pattern or is unable to assume the position to perform the movement. A score of two is given if the person is able to complete the movement but must compensate in some way to perform the fundamental movement. A score of three is given if the person performs the movement correctly without any compensation, complying with standard movement expectations associated with each test. (Cook et al., 2014a, p. 400)

Functional Movement Screen movement patterns - The seven movement patterns of the FMS were: deep squat, inline lunge, hurdle step, shoulder mobility, active straight leg raise, trunk stability pushup, and rotary stability (Bardenett et al., 2015).

Functional Movement Screen sum score - The total sum score of all seven movement patterns and three clearing examinations. Since each pattern was scored from

0 to 3, the sum score for the whole screening ranged from 0 to 21 (Cook et al., 2014a, pp. 400-401).

Shoulder Mobility Asymmetry - A difference in the score assigned to the pattern between the left to the right sides in the shoulder mobility screen (Functional Movement Systems [FMS] & Cook, 2010).

Shoulder Mobility screen - "The shoulder mobility screen assesses bilateral and reciprocal shoulder range of motion, combining internal rotation with adduction of one shoulder and external rotation with abduction of the other. The test also requires normal scapular mobility and thoracic spine extension" (Cook et al., 2014b, p. 551).

Shoulder Mobility Screen sum score - The sum score took into account both the scores of the right and the left sides, plus the shoulder impingement clearing examination. The lower of the two sides (left and right) made up the sum score. If the shoulder impingement clearing examination was positive (pain is elicited), then the entire shoulder mobility screen sum score became 0 (Cook et al., 2014b).

Summary

The researcher evaluated the relationship between shoulder mobility scores measured by the FMS and injury incidence of the upper body and the shoulder in Division II football athletes at a Midwestern university over the 2014-2015 and 2015-2016 academic years. Chapter Two provides a foundation of the background of the FMS, the research conducted on the FMS, and shoulder-specific concerns. Chapter Three explains the process in which the researcher obtained secondary data on FMS scores and injury history, the process of analysis for the secondary data, and the interview process for strength and conditioning and athletic training professionals involved in using the

FMS data. The researcher details results and findings in Chapter Four, with exploration into the analysis of injury and FMS score over the course of two academic years for the football team. Chapter Five discusses interpretations of the results and presents conclusions and recommendations for future research related to the use of the FMS for identification of increased injury risk at the upper body and the application of the FMS to collegiate football teams.

Chapter Two: The Literature Review

Overview

Chapter Two begins by exploring the background of the Functional Movement Screen (FMS) from the purpose of the inception of the screen to the utilization of the screen. It explains the screening process and the component tests and clearing examinations that comprise the FMS and how to evaluate scores once they are earned. Factor structure of the FMS and reliability of the screen are described. There is an examination of the research on how FMS scores relate to performance metrics and injury rates. Next, the use of corrective exercise to address concerning FMS scores is considered. Finally, since the shoulder was the area of study, shoulder specific considerations were explored.

Functional Movement Screen Background

The FMS was introduced as a tool to use to standardize and quantify ideal movement. Cook (2010), a developer of the FMS and a physical therapist, described the need for standardization in his book *Movement*:

> Physical therapy, chiropractic, sports medicine, formal physical education, personal training, and strength coaching are very new professions—most formalized standard education is less than 100 years old. These all work with the same medium of movement, but lack the consistency and SOPs [standard operating procedures] of pilots, surgeons, and artists. . . . Without an SOP, we often fall victim to personal perspectives and subjectivity. (Cook, 2010, p. 51)

The lack of a standard operating procedure in the health, fitness, and wellness fields propelled Cook to develop the FMS to fill the void. The FMS was first introduced in workshops, starting in 1998, and in print in 2001 by Cook in *High Performance Sports Conditioning* (Cook, 2010, p. 29). The FMS consisted of seven movement patterns, plus three clearing examinations (Beardsley, Hons, & Contreras, 2014; Chimera & Warren, 2016; FMS & Cook, 2010). In the seven movement patterns, the individual tested was placed in positions which challenged the body to highlight weaknesses, imbalances, instability, and immobility (Cook et al., 2014a, p. 398). Clearing examinations were movement patterns used to screen for the presence or absence of pain and were not evaluated on the movement ability as the seven movement patterns were evaluated; each of the three clearing examinations was paired with one of the seven movement patterns related to the body area (FMS & Cook, 2010).

Each of the movement patterns was scored on a four-point scale, from 0 to 3. The intention of the screening was not to score a perfect 3 on each pattern; rather, it was to identify poor movement patterns (Cook, 2010). In addition, the FMS was “not intended to determine why a dysfunctional pattern or faulty movement pattern exists. Instead, it’s a discovery of which patterns are problematic” (Cook, 2010, p. 87). An analogy of the function of a blood pressure cuff was used to explain this concept. A blood pressure cuff identifies if a patient is hypotensive (low blood pressure), within normal ranges, or hypertensive (high blood pressure). The blood pressure cuff acts as an indicator of the presence of a potential issue. However, the blood pressure cuff could not tell the physician why the patient had a problem, just if a problem existed (Cook et al., 2014b). The same was true for the FMS. The FMS identified if there was a movement problem present; however, the FMS did not identify why the problem existed (Cook et al., 2014b; Frost, Beach, Callaghan, & McGill, 2012).

The Screening Process

The FMS should be completed on a regular basis, as Cook (2010) noted: "Screening is not a one-time thing. Activity levels change; fatigue, strain and tension levels fluctuate" (p. 50). All of these factors had an impact on FMS scores and therefore had an impact on an individual's movement patterns in activities of daily life and sporting activities. One specifically highlighted time for an athletic population screening was during the pre-season period and during return-to-play for injured athletes (Cook et al., 2014a, p. 398). Return-to-play occurred when previously injured athletes completed a clearing process with a medical practitioner to be permitted to return into practice and competition (Menta & D'Angelo, 2016). The FMS was a beneficial component of return-to-play, as it provided a pre-injury baseline of movement quality for the athlete.

Completion time of the FMS was quantified by Teyhen et al. (2012b) with the FMS taking approximately 14.5 minutes to complete per individual, by using three test stations (p. S68). Approaches to set up for large groups varied, as Sprague, Mokha, and Gatens (2014a) used seven stations (p. 3159) and Wright, Portas, Evans, and Weston (2015) used four stations (p. 255). To administer the FMS, a testing kit was necessary. A testing kit could be purchased commercially for either $180 for plastic or $350 for wood (Functional Movement, 2017b). The kit could be self-assembled utilizing a two-by-six, a four-foot dowel, two smaller dowels, and an elastic band (FMS & Cook, 2010). Multiple kits were needed if utilizing stations for group testing. There was a certification centered on the FMS test and interpretations of scores for the cost of $400 for the Level 1 certification and a certification centered on exercise prescription based on FMS results for $700 for the Level 2 certification (Functional Movement, 2017b).

When the individual was screened, it was important for the tester to view the movement patterns from different angles and positions. Each movement pattern was completed for at least three repetitions. The tester then took the highest score from each pattern (FMS & Cook, 2010). The tester should not focus on analyzing why the pattern was happening during the time of the screen. The intention of the screen was to merely identify if there were problematic movement patterns. In addition, by analyzing after the completion of the whole screening, it was then apparent if there was just a single pattern of concern or a multitude of concerning patterns (Cook, 2010, p. 43).

Another support for focusing on the screening and not the interpretation of the results while testing a screen was the concept of regional interdependence. Regional interdependence stated dysfunction, immobility, instability, imbalance, and weakness of one area of the body could influence the poor movement patterns of another area of the body (Cook et al., 2014a, p. 399). For example, if the knees went into a valgus (knock-kneed) position during a squatting motion, the knees may not have been problematic — it may have been a dysfunction at the hip or at the ankle. Therefore, the combination of the individual’s test performance may enlighten the tester regarding his or her areas of concern.

Specifically, the seven tests of the FMS were grouped into the big three and the little four. The big three tests were the deep squat, hurdle step, and in-line lunge, and the little four tests were shoulder mobility, active straight leg raise, trunk stability pushup, and rotary stability (Chimera & Warren, 2016). The big three tests looked like movement patterns completed in everyday life — squatting, stepping, and walking or running. “The first three tests of the FMS — the squat, the hurdle step, and the lunge — are primarily important because these demonstrate the representation of core stability in the three essential foot positions humans experience each day" (Cook, 2010, p. 79). However, these patterns were complex, and if there was a dysfunction identified within them, the problem was not easily identified. For example, a poor movement pattern in the deep squat could be related to poor mobility in the ankle, hip, shoulders or thoracic spine; poor stability in the core, lower body, or upper body; motor patterning issues of the overhead squat pattern; or a host of other reasons. The little four tests could help to narrow the focus of where the problem may reside, as they were less complex patterns, using less joints (Chimera & Warren, 2016). Said Cook (2010), "However, the other four tests in the FMS will systemically help refine information, and it is the way in which all seven tests interact upon each other that helps identify the weakest link" (p. 79). In light of this information, revisiting the poor movement pattern in the deep squat, if the shoulder mobility score was also poor and all of the other little four tests were good, then shoulder and thoracic spine immobility may have been a factor for both tests. Examining the deep squat test score alone would not identify this; however, examining the big pattern in light of the little pattern enlightened the entire process.

Purpose of the Screen

The purpose of the FMS included acting as a screening tool prior to beginning a sport season or prior to beginning an exercise program. The screen was designed as a "comprehensive pre-participation and pre-season screen, and consists of seven tests/movements which challenge an individual's ability to perform basic movement patterns that reflect combinations of muscle strength, flexibility, range of motion, coordination, balance, and proprioception" (Schneiders, Davidsson, Hörman, & Sullivan, 2011, p. 76). The purpose of the screen was to identify faulty patterns to prescribe exercise; examine the body as a whole, rather than joints in isolation; create a movement baseline; and identify increased risk for injury (Beardsley et al., 2014; Shultz, Anderson, Matheson, Marcello, & Besier, 2013).

Even though exercise was generally embraced for improving health and quality of life, not all exercises were good for everyone. The FMS identified concerning movement patterns and compensations in those patterns to better inform fitness professionals about exercises, which would and would not be appropriate to perform (Cook, 2010). According to Cook et al. (2014a), some exercises or movement patterns needed to be eliminated until the FMS score improved. Some exercises or corrective movement patterns needed to be emphasized with certain FMS screen scores to assist in score improvement. Additionally, the overall screen assisted by determining effectiveness of corrective interventions on the baseline movement score (Cook et al., 2014a; Shultz et al., 2013).

According to Cook (2010), one of the developers of the screen, the FMS was "designed to capture tightness, weakness, poor mobility and poor stability within the pattern that represents the most significant movement pattern dysfunction" (p. 52). Not only did the screen identify potential problems in tightness, weakness, mobility, stability, and asymmetry, it also provided a system in which to rank the most problematic movement patterns. Each test was scored and additionally, the importance of each test was considered when prescribing corrective exercise based on results. "Movement-related dysfunctions are of particular interest because they are considered modifiable risk factors that can be targeted by intervention programs, which may decrease injury risk" (Mokha et al., 2016, p. 276).

The purpose of the FMS was also related to how the tests examined full body movement patterns (Frost et al., 2012). "The FMS is a unique assessment tool because it incorporates comprehensive whole-body movements to identify potential deficiencies proximal to distal to the injury or weakness site" (Onate et al., 2012, p. 409). Exploring comprehensive movement patterns, rather than just one joint at a time, helped researchers to see the whole picture of movement dysfunction, as the body worked as a whole, not with joints in isolation (Gribble, Brigle, Pietrosimone, Pfile, & Webster, 2013). Minick et al. (2010) supported the FMS as a way to capture how the body works together, based on the concept of regional interdependence.

> The term . . . conceptually explain[ed] why dysfunction in one body region may be contributing to weakness, tightness, or pain in another region. Thus, a valid and reliable measurement tool that assesses multiple domains of function simultaneously is in demand. (p. 479)

The ability of the FMS to assess the linkage between body segments was also explained by Schneiders, Davidsson, A., Hörman, E., & Sullivan (2011). "The primary goal of the FMS is to evaluate the body's kinetic chain system, where the body is evaluated as a linked system of interdependent segments, which often work in a proximal to distal direction to initiate movement" (p. 76). Seeing the body perform as a whole illuminated different concerning patterns that looking at joints in isolation could not.

The poor movement patterns or compensations identified by the FMS were concerning, because poor patterning may have led to injury. "When poor or inefficient movement patterns are reinforced, this could lead to further mobility and stability imbalances, which have previously been identified as risk factors for injury" (Cook et al., 2014a, p. 399). Based on this concept, practitioners and researchers used the FMS as an identification tool for individuals with an expected higher risk of injury, based on poor movement patterns. This was important for athletes and for occupational athletes, such as military, firefighters, and police officers. According to Bonazza, Smuin, Onks, Silvis, and Dhawan (2016) "Musculoskeletal issues are a major source of lost participation time, lost income, and medical resources for the care of these injuries" (p. 1). The authors continued, the identification of concerning patterns was important for those populations because of the intention of the screening as it "was developed with the goal of identifying deficits in movements that may predispose an otherwise healthy person to injuries during activity" (p. 1). Oftentimes, the compensations highlighted in the FMS were not apparent in everyday activity; however, when the movement patterns were slowed down and standardized, faulty movement patterns were much more apparent.

Components of the Screen

The seven screens and the three corresponding clearing exams which composed the FMS are explored in the following sections. The rationale behind the pattern selection and the basics of set up and scoring are detailed.

Deep Squat. The inclusion of the deep squat pattern in the FMS was related to the following components: mobility and stability requirements at the hip, knee, ankle, shoulder, scapula, and thoracic spine in addition to core stability, coordination, and body control (FMS & Cook, 2010; Ransdell & Murray, 2016).

In this test, the client stood with feet shoulder width apart and toes pointed straight ahead. Then, a four-foot dowel rod was placed on the top of the head and hands were adjusted until the elbows were at a 90-degree angle while holding the rod. After hand placement was set, while holding the dowel with both hands, the arms were extended fully overhead. The client was then instructed to go into the deepest squat possible, while keeping the feet flat on the floor and the head and chest upright (Butler, Plisky, Southers, Scoma, & Kiesel, 2010; Frost, Beach, Campbell, Callaghan, & McGill, 2015; Hammes, aus der Fünten, Bizzini, & Meyer, 2016; Waldron, Worsfold, & Twist, 2014). If this pattern was completed without compensation, then the pattern was scored as a 3. Table 2 outlines the scoring guide to establish ideal movement quality.

If the pattern was completed with compensation, then the same set up occurred, but this time the heels were elevated on a two-by-six box. If the pattern was then completed without compensation, it was scored as a 2. If the pattern with heels elevated still contained compensation, it was scored as a 1. If pain was noted by the client during the pattern, it was scored as a 0 (Butler et al., 2010; FMS & Cook, 2010).

Table 2 demonstrates criteria noted by The Functional Movement Screen and Exercise Progressions Manual. For a score of 3, all criteria must have been met. For a score of 2, if any of the criteria were met, then the score shifted down to a 2. For a score of 1, if any of the criteria were met, then the score shifted down to a 1. Once a score was determined for each of the seven patterns, a composite score could be calculated. The highest composite score was 21, calculated from earning a 3 on each of the seven tests.

Table 2

Scoring Guides by FMS Pattern

FMS Pattern	Score of 3	Score of 2	Score of 1
Deep squat	Upper torso was parallel with tibia or toward vertical Femur below horizontal Knees were aligned over feet Dowel aligned over feet	Upper torso was parallel with tibia or toward vertical Femur was below horizontal Knees were aligned over feet Dowel was aligned over feet Heels were elevated on board	Tibia and upper torso were not parallel Femur was not below horizontal Knees were not aligned over feet
Hurdle step	Hips, knees and ankles remained aligned in the sagittal plane Minimal to no movement was noted in lumbar spine Dowel and hurdle remain parallel	Alignment was lost between hips, knees, and ankles Movement was noted in lumbar spine Dowel and hurdle did not remain parallel	Contact between foot and hurdle occurred Loss of balance was noted
Inline lunge	Dowel contacts maintained Dowel remained vertical No torso movement noted Dowel and feet remained in sagittal plane	Dowel contacts not maintained Dowel did not remain vertical Movement noted in torso Dowel and feet did not remain in sagittal plane	Loss of balance was noted

continued

Table 2. Continued

	Knee touched board behind heel of front foot	Knee did not touch behind heel of front foot	
Shoulder mobility	Fists were within one hand length	Fists were within one-and-a half hand lengths	Fists were not within one and half hand lengths
Active straight-leg raise	Vertical line of the malleolus resided between mid-thigh and ASIS The non-moving limb remained in neural position	Vertical line of the malleolus resided between mid-thigh and joint line The non-moving limb remained in neutral position	Vertical line of the malleolus resided below joint line The non-moving limb remained in neutral position
Trunk stability pushup	The body lifted as a unit with no lag in the spine Men performed a repetition with thumbs aligned with the top of the head Women performed a repetition with thumbs aligned with the chin	The body lifted as a unit with no lag in the spine Men performed a repetition with thumbs aligned with the chin Women performed with thumbs aligned with clavicle	Men were unable to perform a repetition with hands aligned with the chin Women were unable with thumbs aligned with clavicle
Rotary stability	Performed a correct unilateral repetition	Performed a correct diagonal repetition	Inability to perform a diagonal repetition

Note: Adapted from "Functional Movement Screening Manual," by Functional Movement Systems (FMS) and G. Cook, 2010, pp. 5, 7, 9, 11, 13, 15, 17. Copyright 2010 by Functional Movement Systems and Cook.

Hurdle Step. The hurdle step pattern was included in the FMS because "the step test challenges the body's step and stride mechanics, while testing stability and control in a single-leg stance" (FMS & Cook, 2010, p. 6). The hurdle step was a multiple joint pattern which required core activation and mobility and stability of the hip, knee, ankle, shoulder, scapula, and thoracic spine and it tested each leg separately, offering the opportunity to have identified asymmetries (Randsdell & Murray, 2016).

The first process in the hurdle step pattern of the FMS was to set the height of the hurdle, determined by tibial height of the client. Tibial height was measured from the tibial tuberosity down to the ground. Once the hurdle height was set, the client stood with toes touching the hurdle and feet together with the dowel rod placed across the shoulders, racked on the back, and held with both hands. With eyes focused straight ahead and the trunk upright, the client attempted to step up and over the hurdle, without making contact with the hurdle, while maintaining alignment of the hip, knee, and ankle. The heel would then touch down on the opposite side of the hurdle and the client would step back together (Frost et al., 2015; Hammes et al., 2016; Waldron et al., 2014). A score of 3 was awarded when this pattern could be completed without compensation. A score of 2 was awarded when this pattern could be completed, but a compensation occurred. A score of 1 was awarded when the pattern could not be completed, due to loss of balance or contact with the hurdle. A score of 0 was awarded if there was pain noted by the client during the movement pattern (Frost et al., 2012; FMS & Cook, 2010; Gribble et al., 2013). Table 2 outlines the scoring guide to establish ideal movement quality.

Inline Lunge. The lunging pattern was ‘intended to place the body in a position to focus on the stresses as stimulated during rotation, deceleration, and lateral movements” (FMS & Cook, 2010, p. 7). This lunge pattern was not like a typical lunge pattern, because the feet were fixed and the client did not step to the lunge. The explanation for the lack of step at the start of the pattern was stepping would add additional variables and would make the scoring system more challenging. The other reason this pattern was not like a typical lunge pattern was the legs were in line with each other, rather than staggered. This inline positioning challenged balance and added additional mobility requirements compared to a typical lunge. This pattern challenged core stability and mobility and stability of the hip, knee, ankle, shoulder, and thoracic spine (Randsdell & Murray, 2016).

The inline lunge used the tibial height to determine the distance between the two feet. The client stood on the two-by-six with feet at a set distance apart, aligned in the middle of the box and toes pointed straight ahead. The dowel was placed along the spine, touching at three points: the head, the thoracic spine, and the sacrum. One hand (opposite the front leg) held the dowel at the cervical spine and the other hand held the dowel at the lumbar spine. The client descended into a lunge pattern maintaining the dowel position, with the front foot in full contact with the board, the knee touching the board, and an upright torso (Frost et al., 2015; Hammes et al., 2016; Waldron et al., 2014). Scoring was consistent with procedures outlined in the hurdle step (Frost et al., 2012; Functional Movement System & Cook, 2010; Gribble et al., 2013).

Shoulder Mobility. The Shoulder Mobility test "demonstrates the natural complementary rhythm of the scapular-thoracic region, thoracic spine and rib cage during reciprocal upper-extremity shoulder movements" (Functional Movement System & Cook, 2010, p. 9). This pattern required mobility of the shoulder, "combining extension, internal rotation and adduction in one extremity, and flexion, external rotation and abduction of the other" (Functional Movement System & Cook, 2010, p. 9). It also required thoracic spine extension in support of the arm movements (Randsdell & Murray, 2016).

To prepare for the Shoulder Mobility test, hand length was measured from distal wrist crease to the tip of the longest finger. To complete the test, the client stood with both feet together, arms in a ‘T’ position, hands in a fist with the thumb inside. In one smooth motion, one hand came around the top while the other hand came around the bottom to rest as close as possible on the back (Frost et al., 2015; Waldron et al., 2014). The distance between the fists was measured. If the distance was within one hand length, the score was a 3. If the distance was from one hand length to within 1.5 of measured hand length, then the score was a 2. If the distance was at or above 1.5 of measured hand length, then the score was a 1. If pain was experienced, then the score was a 0 (Frost et al., 2012; Functional Movement System & Cook, 2010; Sprague, Mokha, Gatens, & Rodriguez, 2014b).

Shoulder Impingement Clearing Test. The Shoulder Mobility test also had an associated clearing exam. Clearing exams were scored either as positive, when pain was experienced, or negative, when pain was not experienced on the clearing exam. The shoulder impingement clearing exam was completed by having the client place a hand on the opposite shoulder with the palm down (Hammes et al., 2016). The client then maximally raised the elbow towards the face. The presence or absence of pain was noted. If pain was present on this exam, the total shoulder mobility score became 0 (Functional Movement System & Cook, 2010; Gribble et al., 2013; Sprague et al., 2014b).

Active Straight-Leg Raise. The active straight-leg raise was a test which explored the ability to flex the hip, stabilize the core, and extend the opposing hip. "This pattern challenges the ability to dissociate the lower extremities while maintaining stability in the pelvis and core. The movement also challenges active hamstring and gastroc-soleus flexibility, while maintaining a stable pelvis and active extension of the opposite leg" (Functional Movement System & Cook, 2010, p. 11).

To perform the pattern, the client laid supine, with hands facing up and close to the sides of the body and head on the ground. A two-by-six board was placed under the knees. Feet were together with toes pulled towards shins. A landmark was noted by finding the midpoint between the anterior superior iliac spine and the midline of the patella. While keeping the non-moving leg stable, the moving leg was raised as high as possible, while maintaining an extended knee (Frost et al., 2015; Hammes et al., 2016; Waldron et al., 2014). The client scored a 3 if the malleolus of the top leg resided past the landmark on the opposite thigh. The client scored a 2 if the malleolus of the top leg resided from the midline of the patella to the landmark on the thigh. The client scored a 1 if the malleolus of the top leg did not pass the midline of the patella. The client scored a 0 if pain was noted on the pattern (Frost et al., 2012; Functional Movement System & Cook, 2010; Gribble et al., 2013).

Trunk Stability Pushup. The trunk stability pushup pattern "tests the ability to stabilize the spine in the sagittal plane during the closed kinetic chain, upper body symmetrical pushing movement" (Functional Movement System & Cook, 2010, p. 13). This was a single repetition pushup pattern from the floor.

To complete the pattern, hands were placed at the designated area per gender. Males placed thumbs in line with the temples and females placed thumbs in line with the chin, with both genders setting hands at the width of the shoulder joint. Clients started in a prone position, laying fully on the ground with hands placed and toes tucked. In one smooth motion, the client pressed up into full elbow extension, while keeping the torso in a straight line (Frost et al., 2015; Hammes et al., 2016; Waldron et al., 2014). If this pattern could be done without compensation, a score of 3 was earned. If this pattern had compensation, then the hands were placed at the chin for males and at the clavicle for females. With the new hand placement, if the pattern could be completed without compensation, a score of 2 was earned. If this pattern could not be completed without compensation, a score of 1 was earned. If pain was experienced on this pattern, a score of 0 was earned (Frost et al., 2012; Functional Movement System & Cook, 2010; Gribble et al., 2013).

Spinal Extension Clearing Test. The trunk stability pushup test also had an associated clearing exam. Clearing exams were scored either as positive, when pain was experienced, or negative, when pain was not experienced on the clearing exam. The spinal extension clearing test began with the client laying prone. Hands were placed on the floor by the chest. The client then fully extended the arms, while keeping the hips on the ground (Hammes et al., 2016). The presence or absence of pain was noted. If pain was noted on the clearing test, the total trunk stability pushup score became 0 (Functional Movement System & Cook, 2010).

Rotary Stability. The rotary stability pattern challenged the body in a quadruped, or all-fours, position. The pattern “observes multi-plane pelvis, core and shoulder girdle stability during a combined upper- and lower-extremity movement" (Functional Movement System & Cook, 2010, p. 15). This test required mobility and stability through the developmental crawling and climbing patterns.

To perform this pattern, the two-by-six board was placed under the body, with the client's hands and knees on both sides, while in a quadruped position. Hands, knees, and toes were in contact with the board to begin, with the hands directly underneath the shoulders, the knees directly underneath the hips, and the toes tucked under. The movement pattern was initiated with the same-side arm and leg extending out away from the midline of the body, then coming back together to touch elbow-to-knee, and extending out again before resuming the starting position. Meanwhile, the non-moving arm and leg were to stay in contact with the board (Frost et al., 2015; Hammes et al., 2016; Waldron et al., 2014). If this pattern was performed without compensation, a score of 3 was earned. If this pattern was performed with compensation, the same pattern was performed, except this time it occurred with alternate arm and leg. If the new pattern was performed without compensation, a score of 2 was earned. If the new pattern was performed with compensation, a score of 1 was earned. If pain was experienced on the pattern, then a score of 0 was earned (Frost et al., 2012; Gribble et al., 2013).

Spinal Flexion Clearing Test. The rotary stability test also had an associated clearing exam. Clearing exams were scored either as positive, when pain was experienced, or negative, when pain was not experienced on the clearing exam. The client started in the quadruped position and shifted hips back to rest buttocks-to-feet with head down and arms reaching forward, away from the body (Hammes et al., 2016). The presence or absence of pain was noted. If pain was noted on the clearing test, the total rotary stability score became 0 (Functional Movement System & Cook, 2010).

Scoring system

For each movement pattern, the pattern could be completed up to three times, so the rater could capture the pattern from different angles. The best pattern from the three trials was the score of the given pattern. If the tester was in doubt of the score of the pattern, the screening manual instructed to score low (FMS & Cook, 2010). Three of the patterns had associated clearing tests. If pain was elicited on the clearing test, even if the associated pattern itself did not elicit pain, then the score was updated to a zero. Five of the seven patterns were scored both on the right and on the left. When the sum score for each pattern was determined, the lower of the right and left scores was used and the presence of an asymmetry was noted. For example, if the right leg hurdle step was scored a 3 and the left leg hurdle step was scored a 1, then the sum score for hurdle step was a 1 (FMS & Cook, 2010).

There were positives and negatives associated with the ordinal scoring system of the FMS. The ordinal system was considered to increase reliability of results, especially for less-trained raters (Elias, 2013). However, with the ordinal system, there was a wide range of abilities which may get grouped into the 2 category, and therefore earning a score of 2 lacked description. “This ordinal scale provides a grouping and classification of similar movement-pattern proficiency or deficiency across seven tests and three clearing exams” (Cook, 2010, p. 60). A score of 3 indicated the pattern was completed effortlessly and without compensation. A score of 2 indicated the pattern was completed with compensation. A score of 1 indicated the pattern was not able to be completed. A score of 0 indicated pain was experienced during the pattern (Gribble et al., 2013). While the scores of 3, 1, and 0 gave a clear explanation of the ability or inability in the pattern, a score of 2 could contain one compensation, or a score of 2 could contain many compensations.

Evaluation of Scores

The first step in the evaluation of scores was to determine if pain was present on any patterns (Randsdell & Murray, 2016). "If pain presents with one or more of the tests within the screen, the screen has done its job — the screen is over . . . The first rule of movement is this: *Pain changes everything*" (Cook, 2010, p. 81). The presence of pain indicated a necessary intervention by a physician, physical therapist, athletic trainer, or other medical professional.

After the presence of pain, the next factor examined was the presence of movement limitation or movement compensations, with asymmetry (Randsdell & Murray, 2016). The first place practitioners examined on score sheets was asymmetries containing a score of 1. "If a person receives a score of one and there is an imbalance, certain mechanical laws are being compromised and the individual is likely to be causing micro-trauma to certain areas during activity" (FMS & Cook, 2010, p. 17). After asymmetries with a score of 1, the next concern was bilateral scores of 1. The next area evaluated was asymmetries of 2. Finally, bilateral scores of 2 were the last to be assessed (Cook, 2010; FMS & Cook, 2010; Randsdell & Murray, 2016).

Beyond the scores, if there were multiple patterns of concern, there was also a hierarchy for intervention based on the pattern. The first patterns to correct were the shoulder mobility and active straight-leg raise, as these two patterns were the most foundational and simple patterns (FMS & Cook, 2010; Randsdell & Murray, 2016). The next patterns to correct were rotary stability and trunk stability pushup, as the patterns were more complex. The final patterns for intervention were inline lunge, hurdle step, and deep squat, as the most complex patterns (FMS & Cook, 2010; Randsdell & Murrary, 2016).

Factor Structure

The sum score was comprised of the addition of each of the seven component scores. Utilization of the sum score in the evaluation process was both challenged and embraced by practitioners and scholars. When the sum score was used, the assumption was each component test measured a variable which, when added together, would provide a better picture of overall functional movement. "Although not explicitly captured by the current grading criteria, the composite FMS score could reflect a group's tendency to employ risky movement behaviors when performing physically demanding work/sport tasks" (Frost et al., 2015, p. 327). However, detractors suggested each component test should be examined individually, rather than as a part of a sum. The creators of the FMS even noted the sum score should not have been utilized, since the component tests were "not correlated with one another and are therefore not measuring the same underlying variable" (Cook et al., 2014b, p. 558).

Kazman, Galecki, Lisman, Deuster, and O'Connor (2014) performed a factor structure analysis on the components of the FMS and did not find the component screens were testing a unitary construct. This suggested the component screens were independent. "If the FMS is truly measuring 7 unique complicated constructs, then it is unlikely that each movement is adequately measuring its respective specific construct"

(p. 677). The authors stressed the importance of using the individual component screens when making decisions about exercise selection and other training decisions.

Koehle, Sinnen, Saffer, and MacInnis (2015) found through a factor analysis, the FMS individual screens could effectively be grouped into a Complex Movement Factor and a Basic Movement Factor. The Complex Movement Factor contained the ‘big three’ movement patterns — deep squat, hurdle step, and in-line lunge — in addition to the trunk stability pushup. The Basic Movement Factor contained shoulder mobility and active straight leg raise, two of the ‘little four’ discussed previously. “The rotary stability test loaded onto both of factors almost equally, suggesting that is played a role in both; however, the model fit was improved when it was removed from the analysis” (Koehle, Sinnen, Saffer, & MacInnis, 2015, p. 7). This grouping suggested the more complex patterns were measuring a similar variable, and the more basic patterns were measuring a different, similar variable.

Interrater and Intrarater Reliability

When examining the reliability of an assessment, it was essential to explore both the intrarater reliability, also referred to as test-retest reliability, and interrater reliability. Intrarater reliability examined the consistency of the individual rater while interrater reliability examined the consistency between raters. “The reliability and validity of screening is crucial to allow accurate interpretation of the findings and subsequent implementation of prevention strategies” (Elias, 2013, para. 6). If the screening could not consistently be replicated, then its usefulness significantly diminished. There was an argument the scoring system of the FMS, with the 4 number ordinal system, helped to increase reliability (Elias, 2013, para 7). However, other authors noted potential issues with the scoring system.

> Some tests have less clearly defined descriptors of midrange performance. This is most appreciable in the lunge, hurdle step, and rotary stability . . . The dichotomous extremes of performance are easily extinguishable; however, the division of the intermediate scores is less apparent. (Minick et al., 2010, p. 485)

Many studies supported the reliability of the FMS. Gulgin and Hoogenboom (2014) noted, "The scores of four raters demonstrated good to excellent correlation" (p. 17). Minick et al. (2010) agreed, "The FMS has high interrater reliability and can confidently be applied by trained individuals when the standard procedure is used" (p. 485). Parenteau-G et al. (2014) also found high reliability in a study of two raters on video-recorded screen. "The active straight leg raise, trunk stability push-up, shoulder mobility subtests and one clearing exam (shoulder pain tests) are considered almost perfectly reliable. All the other subtests . . . obtained substantial reliability values" (p. 173).

The hurdle step was found by Smith, Chimera, Wright, and Warren (2013) to have the lowest reliability, while shoulder mobility was rated as the most reliable. Caution regarding the hurdle step was echoed by Onate et al. (2012), while they noted "fair to high reliability . . . across each task of the system" (p. 412). Schneiders et al. (2011) also indicated the hurdle step and in-line lunge tests had substantial agreement, while other tests had excellent agreement. Rotary stability was the low scoring component in a study by Sorenson (2016) as "the median interrater agreement coefficient was considered acceptable . . . for the FMS composite score and six of seven component tests" (p. 39). Teyhen et al. (2012a) studied novice raters and noted excellent agreement on the pushup and only moderate agreement on the in-line lunge, with substantial agreement on the other tests.

In a meta-analysis of FMS research, Beardsley, Hons, & Contreras (2014) summarized an exploration of the literature regarding reliability with, “The FMS seems to display an acceptable degree of reliability for a field test in most populations and with most types of raters” (p. 73). Another meta-analysis supported a moderate level of evidence for intrarater reliability for live scoring. However, the authors noted, “Level of evidence for *live* inter-rater reliability is conflicting for three test (Hurdle Step, In-line Lunge, Rotary Stability) and in circumstances where multiple practitioners are working collaboratively” (Moran, Schneiders, Major, & Sullivan, 2016, para. 21). A meta-analysis by Bonazza et al. (2016) indicated “nine of the 10 studies found acceptable interrater reliability . . . Of the individual test components, the in-line lunge, rotary stability, and the hurdle step were all implicated as the least reliable component by at least 1 study” (p. 4). Cuchna, Hoch, and Hoch’s (2016) meta-analysis also supported the FMS “demonstrates good reliability” (p. 60).

In contrast, Shultz, Anderson, Matheson, Marcello, & Besier (2013) found the opposite, noting, “poor interrater reliability showed caution should be taken when comparing FMS scores across raters” (p. 333). When Shultz et al. (2013) broke down raters based on experience with the FMS test, they also found, “One interesting observation was that the raters with less experience (the athletic trainer and the physical therapist) had fair reliability, whereas the raters with more than 2 years of experience had poor reliability” (p. 333).

A concern for interrater reliability stemmed from the assignment of 0 for pain. “Although there is a clear Pain Criterion Checklist in the official FMS Manual, the raters in this study agreed to say the concept of ‘Discomfort’ (which should be scored the same as pain) described in the Manual remains unclear” (Parenteau-G et al., 2014, p. 173). Finding the appropriate definition of a painful pattern may have been difficult for both the testers and for the subjects to define. To remedy, Moran, Schneiders, Major, & Sullivan et al. (2016) suggested “whenever possible, practitioners working together in the same setting should review test administration and scoring criteria in order to calibrate among themselves” (para. 21).

Just as with interrater reliability, numerous studies indicated support for intrarater reliability (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2016; Cuchna et al., 2016; Moran et al., 2016; Onate et al., 2012; Shultz et al., 2013). Teyhen et al. (2012a) identified with testing sessions 48 to 72 hours apart, there was “substantial agreement on the trunk stability push-up, shoulder mobility, active straight leg raise, deep squat, and in-line lunge component tests; moderate agreement on the hurdle step; and poor agreement on the quadruped rotary stability component test” (pp. 533-534). With training sessions separated by 48 to 72 hours, the researchers were able to determine rater consistency over time.

Variability within the rater was also explored on the basis of the amount of training of the rater. Smith et al. (2013) indicated “higher intrarater reliability appeared to be more related to education in movement analysis than FMS certification” (p. 986). While another study identified, “Regardless of the level of expertise in scoring the FMS (eg, minimal training, FMS certified), clinicians can demonstrate good to excellent intrarater . . . reliability" (Stobierski, Fayson, Minthorn, Valovich McCloud, & Welch, 2015, p. 219). Gribble et al. (2013) noted as experience levels increased, intrarater reliability increased as well. "Strong reliability was associated with clinicians who had previous experience using the FMS, whereas moderate reliability was observed by ATs [Athletic Trainers] who had no previous experience . . . students preparing to be ATs demonstrated poor reliability" (p. 980).

Overall, studies supported both the interrater and intrarater reliability of the Functional Movement Screen. However, some component tests indicated more reliability compared to others. Hurdle step, inline lunge, rotary stability were indicated to have a greater variability in scoring.

Functional Movement Screen and performance

Expected relationship between Functional Movement Screen and performance. The ability to move well, as identified by the Functional Movement Screen, may have also indicated an increased ability for sport performance. Ransdell and Murray (2016) supported the concept in which functional movement may be indicative of higher performance levels. The authors stated, "The ability to perform multijoint and multiplanar movements efficiently and explosively, without compensation, is requisite for success in sport" (p. 41). In a similar line of consideration, a higher FMS score would have indicated increased sport performance levels. However, the developers of the screen indicated this was not an intention of the screen, nor should the screen be used instead of sport performance assessments. Said Cook et al. (2014a), "The goal of the Functional Movement Screen is not to measure sport performance . . . the FMS is a screen of 1x BW [body weight] fundamental movement competency, and additional assessment is necessary to determine sport performance capabilities" (p. 559). However, the potential link between FMS scores and athletic performance had been studied numerous times, with varying conclusions.

Positive relationship between Functional Movement Screen and performance. A positive relationship between FMS sum scores and swimming performance were identified by Bond, Goodson, Oxford, Nevill, and Duncan (2015). The authors noted "as faster swimmers had better FMS scores, this study highlights potential utility of the FMS in swimming" (p. 8). Similarly, Chapman, Laymon, and Arnold (2014) explored sum FMS scores and running performance. They found "subjects with FMS scores >14 had a significant difference in performance change from 2010 to 2011 compared with subjects with FMS scores ≤14" (p. 205). Additionally, when broken down by gender and track and field specialty, there was statistical significance related to positive performance and higher FMS scores for "men, USATF tiers 1 and 2 women, sprints/hurdles, distance, and jumps" (p. 205). In conjunction with sum FMS scores, the authors also explored the relationship between individual FMS components and performance. They found, "subjects who scored a 3 on the deep squat had significantly larger mean improvement in performance than subjects who scored a 1 or 2" (pp. 205-206). Both swimming and track and field were relatively easy to directly track and measure sport performance, as faster times were a direct measurement of performance in these sports.

While it was quite simple to track performance measures by the stopwatch for swimming and track and field, for other sports or non-sporting populations, the measurement of performance came through additional tests. Okada, Huxel, and Nesser

(2011) explored the backward medicine ball throw, the agility t-run, and the single leg squat in relationship with the Functional Movement Screen. The agility t-run required athletes to sprint, defensive slide, and backpedal in a T-shape and measured ability to change direction between those movement patterns (Ratamess, 2012). The researchers identified the backward medicine ball throw had a positive relationship with performance on the hurdle step, pushup, and rotary stability (right side only), and the t-run had a positive relationship with performance with shoulder mobility (right side only) in a population of healthy adults. Healthy men additionally showed a positive relationship between deep squat scores and a smaller difference in agility scores on the right and left sides, and both bilateral and single leg jumping performance (Lockie, 2015b).

Healthy adults were not the only population in which a larger FMS score indicated increased performance ability. In a study of children aged 8 to 11, with core strength performance indicated by the ability to hold a plank, there was a statistically significant relationship between core strength and total FMS score (Mitchell, Johnson, & Adamson, 2015, p. 1175). Lockie et al. (2015a) studied female athletes and identified higher scores for inline lunge (right leg only), active straight leg raise, and sum score resulted in increased measured flexibility thorough the unilateral sit-and-reach test. Higher deep squat, hurdle step (right and left sides), and hurdle step (right side only) were significantly related to a smaller between-leg difference in the sit-and-reach (Lockie et al. 2015a, p. 49). In a study of active duty service members, higher FMS composite scores had a positive relationship with performances "associated with greater anterior reach on the YBT [Y balance test], greater distance measured for crossover hop test, increased hamstring flexibility, and higher levels of self-reported lower-extremity function through the LEFS [lower extremity functional scale]" (Teyhen et al., 2014, p. 1279).

Overall, there were studies on multiple populations, ranging from children to female athletes, to general adult population, to active duty military, which indicated higher FMS scores, either in sum or in individual tests, did have a positive relationship with performance.

No relationship between Functional Movement Screen and performance. While there were multiple populations where FMS scores were found to be positively related to performance, there were also many populations where there was no relationship between the two factors, and some research even indicated a higher FMS score was significantly related to a lower achievement on a given performance measure. In addition to the positive measures obtained by Lockie et al. (2015a) in the study of female athletes, they also identified an area of no relationship in the 20 m sprint and areas where higher FMS scores related to lower performance measures. Slower change of direction times for two agility tests, the 505 and modified t-test, were related to higher scores in rotary stability, active straight leg raise, hurdle step, and inline lunge (Lockie et al., 2015a, p. 49). In addition, better scores on the hurdle step (left side) and active straight leg raise "related to greater differences between the 505 and T-test conditions, which infer a greater imbalance in change of-direction speed performance" (Lockie et al., 2015a, p. 49).

In comparison to Mitchell, Johnson, Adamson's (2015) work, which identified a strong correlation between FMS score and core strength in children 8-11, Okada et al. (2011) did not find a correlation between core stability and FMS scores in a population of healthy adults. Additionally, the authors also found the backward medicine ball throw was negatively related to scores on the Shoulder Mobility test (right side only). Shoulder mobility (right side only) was also negatively related to single leg squat (Okada et al., 2011, p. 259).

In a population of golfers, Parchmann and McBride (2011) stated, “FMS score had no significant relationship to sprinting, jumping, or agility performance. In addition, the FMS score had no significant relationship to sport-specific performance (club head velocity)” (p. 3382). Additionally, Lockie et al. (2015b) found higher FMS sum scores did not have a relationship with multidirectional speed or jumping results in healthy men (p. 202). Similarly, “Movement competency in the in-line lunge, hurdle step . . . shoulder mobility, push-up, and rotary stability showed no links” to performance as measured by points, assists, rebounds, steals, and/or blocks per game for a male collegiate basketball team (McGill, Andersen, & Horne, 2012, p. 1738).

FMS and performance summary. Results were mixed regarding the relationship between performance on the Functional Movement Screen and athletic performance indicators. Glass and Ross (2015) suggested placing the individual under load when performing the FMS may have been beneficial to better predict performance: “This may lend support to the practice of screening movement quality for its potential impact on performance, but might also suggest more demanding conditions are required before performance-relevant differences movement behaviors can be observed” (p. 617). This would support the statement from Cook et al. (2014a) at the beginning of this section on the FMS and performance, which stated because the FMS was only performed under body weight, more assessments are necessary for identifying athletic performance abilities.

Functional Movement Screen and Injury

Expected relationship between Functional Movement Screen and injury. The Functional Movement Screen sought to establish a standard operating procedure in the quantification of movement, in part to determine a threshold for acceptable and unacceptable movement patterns (Cook, 2010). Researchers suggested poor movement patterns may have resulted in a higher likelihood of injury (Beardsley et al., 2014; Clay, Mansell, & Tierney, 2016; Cook, 2010; Mokha et al., 2016). A sum score of 14 or less was "thought to be indicative of prevalent compensation patterns and which is also believed to be predictive of increased risk of injury and reduced performance" (Beardsley et al., 2014, p. 72). Cook (2010) stated, "Those who score poorly on the screens are using compensatory movement patterns during regular activities. If these compensations continue, sub-optimal movement patterns are reinforced, leading to poor biomechanics and possibly contributing to future injury" (p. 87). Mokha et al. (2016) agreed, "If movement in basic patterns is dysfunctional, then the higher demands of athletic movements may also be impaired and could contribute to injury potential" (p. 280). Not only was the screen impactful in its ability to highlight faulty or compensatory movement patterns, it also identified asymmetries in the body. "Asymmetries and compensations are important to recognize because they may be related to increased risk of injury" (Clay et al., 2016, p. 346). The arguments here supported the concept that a lower Functional Movement Screen score resulted in an increased risk of injury, due to compensations from faulty movement patterns and potential asymmetries.

Bardenett et al. (2015) argued the opposite to be plausible; a higher FMS score led to an increased risk for injury. Athletes with a "higher score may have better movement quality and patterns, and consequently be better athletes. Better athletes are more likely to be starters in competitions and have more exposures, which may in turn lead to an increased risk of injury" (Bardenett et al., 2015, p. 307). Others argued with the nature of some injuries, the FMS score would likely have no impact. "Traumatic injuries often occur in a more 'accidental' manner, which may . . . make predicting traumatic injuries more difficult than overuse injuries" (Bushman et al., 2015, p. S69).

Still other researchers stated the FMS had the ability to identify previous injuries, rather than the ability to flag a higher potential risk for future injuries. Noted Chimera, Smith, and Warren (2015), "Poor performance on the FMS may actually reflect injury history rather than predict future injury risk" (p. 482). The authors continued, when studies linked low FMS scores and increased injury risk, it was because researchers did not take into account previous injury (p. 482). A major identifiable risk factor for future injury was a previous injury.

It was also notable that a high FMS score was not expected to protect individuals from sustaining injury. "If someone scores well (within the norms) on the FMS that he/she can still be at risk of injury because of several factors, including but not limited to, poor landing mechanics, strength, endurance, agility, or power deficits" (Cook et al., 2014b, p. 559). However, the authors continued a better score on the FMS would have indicated "demonstrated movement competency" in the possession of "fundamental movement capabilities to improve those higher-level performance measures" (p. 559).

The use of the FMS sum or composite score was highlighted as a concern. "Some researchers have claimed that despite the importance of the kinetic chain, one cannot assume that problems with the upper body will translate into problems with the lower body" (Ransdell & Murray, 2016, p. 44). For example, if one used the sum score to determine an increased likelihood of knee injuries, many would not expect shoulder mobility scores — which are part of the sum — to have a meaningful impact on knee injury rates. Mokha, Sprague, and Gatens (2016) agreed about concerns in using the FMS sum score, "For a composite score on a test composed of individual items to be valid, each item is assumed to measure the same latent variable . . . Individual movement patterns are likely more informative than the composite score" (p. 277). Tee, Klingbiel, Collins, Lambert, and Coopoo (2016) offered it was better for those interpreting FMS scores to "understand which particular movement dysfunction causes the injury risk factor, rather than to link risk to a 'global' movement quality score. This allows for the actual risk factor to be addressed and mitigated more accurately" (p. 14).

Sum FMS scores and injury incidence. A frequently cited, foundational study in the ability of the FMS to identify injury risk was conducted on professional football players, with injury classified as being on the injury reserve for at least three weeks: Kiesel, Plisky, & Voight (2007) identified, "a player [has] an eleven-fold increased chance of injury when their FMS score is 14 or less when compared to a player whose score was greater than 14 at the start of the season" (p. 150). The findings of this study influenced numerous studies on the FMS and injury, as many researchers presumed to use a score of 14 as a cut point.

Chorba, Chorba, Bouillon, Overmyer, and Landis (2010) supported the use of the sum score of 14 or less as an increased likelihood of sustaining an injury (p. 50). O'Connor, Deuster, Davis, Pappas, and Knapik (2011) found a sum score of less than or equal to 14 multiplied the relative risk of injury by 1.5 in a population of military cadets (p. 2227). In a population of Division I female rowers, the likelihood of back pain during season was significantly increased if the FMS sum score was less than or equal to 14 (Clay et al., 2016, p. 645). Maritime Response Team "candidates with FMS scores ≤14 has over 5 times the risk of injury compared with those with scores >14" (Cosio-Lima et al., 2016, p. 645). Additionally, in Division I college athletes, both male and female from various teams, "an FMS composite score of 14 or less combined with a self-reported history of previous injury are at a 15 times increased risk for injury compared to athletes scoring higher on the FMS" (Garrison, Westrick, Johnson, & Benenson, 2015, p. 25). Bushman et al., (2016) also identified "Soldiers who scored ≤14 were 1.84, 1.26, and 1.60 times more likely to experience an injury compared to those who scored >14 for overuse injuries, traumatic injuries, and for any injury" (p. 300). Kiesel, Butler, and Plisky (2014) also supported the use of the score of 14 as a cutoff point (p. 91).

Beyond the studies by authors who either through statistical analysis or from the standard set by Kiesel et al. (2007) used the cut off of a sum score of 14, other researchers identified different cut off points. In a study of Coast Guard cadets, the optimal cut off points for the FMS were "≤11 for men and ≤14 for women. At these optimal cutpoints, injury risk among both men and women was greater for those with lower FMS scores" (Knapik, Cosio-Lima, Reynolds, & Shumway, 2015, p. 1161). Hammes et al. (2016) identified "players with an FMS score of <10 points had a significantly higher injury incidence (considering all injuries) compared to the reference group" in a population of veteran soccer players (p. 1374). A study by Letafatkar, Hadadnezhad, Shojaedin, and Mohamadi (2014) set the cutoff point much higher. "Those who scored less than 17 on the FMS were 4.7 times more likely to sustain an injury of the lower extremity" in a population composed of males and females who were competitive and recreational university athletes competing in soccer, handball, and basketball (p. 26). O'Connor et al. (2011), beyond findings in support of the cut off of 14, also identified

> cumulative injury risk was higher at FMS scores of 18 compared with FMS scores of 17 . . . the risk of injury was significantly higher in the ≤14 group, as before, but also significantly higher for the ≥18 category . . . which suggests a bimodal distribution. (p. 2227)

While there were numerous studies to support the use of a cut off as a significant threshold of FMS sum score in relationship to injury risk, there were a number of studies which did not show any relationship between FMS sum score and injury likelihood. Bardenett et al. (2015) did not find FMS to predict injury likelihood in high school athletes with statistical significance. The same finding was identified for running injuries, with the injury threshold being set at four or more weeks of lost training time (Hotta et al., 2015, p. 2813). Dossa, Cashman, Howitt, West, and Murray (2014) noted "a lower score on the FMS was not significantly associated with injury" in a population of junior hockey players (p. 426). When O'Connor et al. (2011) specifically explored overuse injuries in relationship to FMS sum scores, there was no statistical significance identified. Warren, Smith, and Chimera (2015) found similar results in a population of

Division I athletes, as did Mokha et al. (2016) for Division II male and female rowers, volleyball, and soccer athletes. "The inability to replicate consistent findings in subsequent studies undermines the utility of the proposed single cut-off score of ≤14" summarized Wright et al. (2016, para. 4).

Even the founders of the FMS, along with colleagues, stressed the following, "The use of a total FMS score for predicting injury risk should be avoided, as the individual components of the test are not correlated with one another and therefore are not measuring the same underlying variable" (Cook et al., 2014b, p. 558). The authors continued the score of 14 may be meaningful, "A total score below 14 indicates greater relative risk, however the converse is not true, a total score greater than 14 does not mean lower relative risk" (p. 558). Kiesel et al. (2007) who performed the initial cut off research in 2007, even noted in the study at the time, "The findings of this report 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, but cannot be used to establish a cause-effect relationship" (p. 151). The use of the total score for the FMS may have been a misguided approach by researchers who expected the total score would have a causal relationship with injury rates.

Presence of asymmetry and injury incidence. Asymmetrical movement patterns on the FMS was suggested as a factor in increased injury likelihood. Chimera et al. (2015) noted,

> Risk factors for noncontact injuries are [suggested to be] modifiable when identified through movement patterns, right-to-left asymmetry, or balance

> abnormalities . . . [The screen is] being used clinically to assess injury risk based on abnormal movement patterns, asymmetry, and dynamic balance. (p. 475)

In a study of professional football players, the relationship between asymmetry, as identified by the FMS and injury was noted. "Having at least 1 asymmetry on the FMS, regardless of a player's composite score, increased injury risk" (Kiesel, Butler, and Plisky, 2014, p. 166). Presence of asymmetry was also a significant factor in the occurrence of musculoskeletal injuries in Division II male and female athletes who participated in soccer, rowing, and volleyball (Mokha et al., 2016, p. 279). However, a 2015 study by Warren et al. demonstrated the opposite. "No significant associations between presence of asymmetric performance on any FMS movement pattern and noncontact injury" was identified on a variety of Division I male athletes (p. 166).

Individual FMS tests and injury incidence. Many researchers explored how the individual FMS tests related to overall injury incidence, with varying results. Two studies identified pain elicited by the FMS had statistically significant relationships with injury incidence. Bushman et al. (2015) identified pain on the deep squat, hurdle step, inline lunge, trunk stability pushup, and rotary stability resulted in a greater injury risk (p. S69). In a study of Army Rangers, pain elicited from a clearing test was found to be a stand-alone factor for the prediction of overuse injuries (Teyhen et al., 2015).

Two studies identified higher scores on individual FMS assessments — indicating better movement patterns — were related to increased injury likelihood. This identification was not expected, as better movement patterns were projected to decrease injury likelihood. Bardenett et al. (2015) identified inline lunge scores were higher for players who sustained injury. Warren et al. (2015) also noted Division I athletes from a variety of sports were more likely to sustain an injury with an inline lunge score of 3 compared to an inline lunge score of 2.

While those two studies found higher inline lunge scores related to increased injury risk, Tee et al. (2016) found the opposite. The researchers found injured individuals not only had a higher proportion of scores of 1 on the inline lunge, but also there were significant differences between injured and non-injured athletes' scores on the inline lunge and active straight leg raise (pp. 10, 14). In addition to the inline lunge, the authors identified a higher proportion of scores of 1 in the deep squat, shoulder mobility, active straight leg raise, and rotary stability existed for athletes who became injured. However, the authors did not find the same predictive ability when exploring individual tests related to severe contact injuries (p. 13).

Hammes, aus der Fünten, Bizzini, & Meyer (2016) grouped scores into low (0-1) and high (2-3) and identified the "active straight leg raise revealed a significant higher injury incidence in players achieving a low score" in a study of soccer players aged 32 and older (p. 1374). Hotta et al. (2015) combined active straight leg raise and deep squat scores and found this small sum predicted injuries resulting in the loss of four or more weeks of training for runners. "DS [deep squat] and ASLR [active straight leg raise] score of ≤3 during preseason was a more useful approach for predicting running injuries during season in 18- to 24-year-old competitive male runners" (p. 2813). The deep squat and pushup as individual component tests were also significant for firefighters in predicting injury (Butler et al., 2013). Bardenett et al. (2015) found lower shoulder mobility scores in injured athletes.

Definition of Injury

A challenge when research was evaluated on the FMS's ability to identify an increased likelihood for injury was there were varying definitions of what constituted injury. "Epidemiological data about injury is entirely depended on the definition of injury. Variable injury definitions place individuals in different injury classifications making it difficult to compare across studies" (Wright et al., 2016, para. 6). Studies explored a variety of injury definitions. Wiese, Boone, Mattacola, McKeon, and Uhl (2014) had the following approach: "Injuries were collected for the sample as a whole and were further stratified for type of injury by upper extremity injury, lower extremity injury, overuse injury, noncontact injury, and injury resulting in a loss of >10 days" (p. 163). Schroeder, Wellmann, Stein, and Braumann (2016) only considered injuries which occurred in the lower body, due to a non-contact event and resulted in at least three days of lost time (p.39). Butler et al. (2013) also used three days of lost training as the threshold for injury (p. 14). Hammes et al. (2016) classified more generally as "only injuries that led to a time loss . . . were taken into account" (p. 1373). On a more extreme approach only severe injuries were utilized, with the threshold of 28 days or more out from games and practices (Tee, Klingbiel, Collins, Lambert, & Coopoo, 2016, p. 7).

The inclusion or exclusion of contact versus non-contact injuries was considered. Some studies excluded contact or collision-based injuries on the premise dysfunctional movement should have had a greater negative impact on overuse injuries (Schroeder, Wellmann, Stein, & Braumann, 2016). However, Tee et al. (2016) made an argument for the inclusion of contact and collision-based injuries to be included, due to the impact of functional movement patterns on tackling technique. Speaking specifically about rugby, the researchers stated, “The presence of a dysfunctional movement pattern would therefore affect the ability of a player to tackle with optimal technique, which would likely affect the players’ injury risk” (p. 4). Overall, the variety of definitions of injury made the comparison between studies to be extremely challenging and limited the overarching conclusions.

Use of FMS Results to Prescribe Corrective Exercise

To mitigate injury risk due to compensatory movement patterns, the FMS was used to prescribe corrective exercise for patterns scored as 1, asymmetries with 1s, or asymmetries with 2s, beginning first with the little four screens (active straight leg raise, shoulder mobility, rotatory stability, and trunk stability pushup), and then focusing on the big three screens (hurdle step, in-line lunge, deep squat) (FMS & Cook, 2010). Bodden, Needham, and Chockalingam (2015) found the use of corrective exercise improved FMS scores at four-week and eight-week intervals for an intervention group, compared to the control in mixed martial arts athletes (p. 223). Frost, Beach, Callaghan, & McGill (2012) found there was no statistical significance in FMS scores from three groups: two groups with different training interventions and a control group. However, 85% of the members in the control group had a different score between the first testing and final testing sessions (Frost et al., p. 1626). Wright et al. (2015) used a four-week training intervention on children and found the training did not significantly increase FMS scores. Thus far, results were mixed regarding the use of corrective exercise to improve FMS scores.

Shoulder Specific Concerns

Next, shoulder specific concerns were explored, as this was the focused body area of the study and the anatomy of the shoulder required specific considerations. The shoulder was a ball and socket joint and had the greatest range of motion of any joint in the body. However, the shoulder was not just the humerus articulating in the glenoid fossa of the scapula — there were three additional articulations beyond the glenohumeral joint — the scapulothoracic, the acrimioclavicular, and the sternoclavicular. Ideal shoulder movement came from coordinated movement from all four areas. Shoulder dysfunction emerged from an impairment at any of the four articulations (Bora, Laudner, & Sauers, 2008). Not only did the shoulder have to act in a coordinated movement with all component articulations, additional coordination and sequencing throughout the body was essential for functional movement (Butler et al., 2014). The core must have had appropriate endurance to stabilize the upper body patterns and the lower body must link effectively through the kinetic chain.

Beyond the coordination throughout the body, the increased range of motion of the shoulder joint required the appropriate balance of both mobility and stability from the shoulder for both functional and pain-free movement. Stated Jansson, Saartok, Werner, and Renström (2005), “There is a very subtle balance between excessive mobility and instability” (p. 170). There needed to be enough range of motion to allow for functioning but not so much range of motion to have led to an increase in injury to the joint. Athletes were at an increased risk for injury if the shoulder joint was either too mobile, had too much or too little laxity in the joint, or if the range of motion was too great or too small (Jansson, Saartok, Werner, & Renström, 2005).

Asymmetries in range of motion from the left to the right side had been an indicator for increased injury risk (Sprague et al., 2014b). The authors identified even differences greater than 5 degrees of range of motion in the shoulder were considered clinically relevant (p. 659). The authors examined if the Shoulder Mobility screen of the FMS was sensitive enough to detect small range of motion variation from one shoulder to the other. With the four-point ordinal scale, the Shoulder Mobility screen was not able to identify asymmetry of the glenohumeral joint range of motion of 10 degrees or greater (p. 661). “Contributors to dysfunction during the FMS Shoulder Mobility test may include thoracic extension mobility limitations, scapular mobility or stability limitations, and [glenohumeral] GH joint stability or mobility impairments” (p. 662). Notably, the Shoulder Mobility screen was not just measuring range of motion at the shoulder, but also how the shoulder worked in coordination with the thoracic spine through movement.

Due to the complicated nature of the coordination of the shoulder joint and the need for appropriate mobility and stability of the joint, pain had many different potential causes. Some of the common factors were imbalance of the muscles of the shoulder, hypermobility or immobility, poor patterning, muscle imbalance or weakness — these factors were exacerbated by repeated motions at the shoulder joint (Lucado, 2011; Manske & Ellenbecker, 2013).

Summary

Chapter Two explored the background of the Functional Movement Screening. Notably, the ordinal scoring system was highlighted as a positive for increased reliability of testing (Elias, 2013). However, the ordinal system lacked specificity, as there was much variability in what may constitute the score of a 2 for many assessments. The factor structure analysis of the FMS did not support that the seven component screens were testing a unitary construct (Kazman, Galecki, Lisman, Deuster, & O'Connor, 2014; Koehle et al., 2015). The shoulder mobility screen specifically was found to have good reliability (Parenteau-G, et al., 2014; Smith, Chimera, Wright, & Warren, 2013; Teyhen et al., 2012a). Results were mixed related to the relationship of the FMS and performance and the FMS and injury.

The next chapter details the researcher's utilization of secondary data consisting of injury incidence and FMS scores over two years for Division II football players. Additionally, the researcher conducted interviews with the professionals who collected and utilized data on movement quality and injury occurrence for the athletes.

Chapter Three: Methodology

Purpose

The purpose of this study was to investigate shoulder mobility scores measured by the Functional Movement Screening and reported upper body injury in collegiate football athletes at a Division II Midwestern university. Kazman et al. (2014) suggested the FMS sum score, often used in identification of injury in studies, such as Chorba et al. (2010), Kiesel et al. (2007), O'Connor et al., (2011), and others, was not as effective in identification of injury likelihood, based on factor structure. Additionally, the creator of the FMS, Cook, also stated the sum score should not be used as a value in the identification of injury (Cook et al., 2014b). Instead, others (Bardenett et al., 2015; Bushman et al., 2015; Teyhen et al., 2015; Warren, Smith, & Chimera, 2015) argued individual scores were more appropriate in the identification of injuries. The researcher was not aware of any then-present studies, which explored a specific FMS score and its relationship with injury likelihood of a specific body area.

The Shoulder Mobility test was chosen for this study, as it was arguably the most isolated of tests in relationship to body area. This study explored these variables over the course of the 2014-2015 and 2015-2015 academic years. Injuries were explored by the grouping of both shoulder injury and upper body injury, as dysfunctional patterns may have impacted the body area of dysfunction or the body area within proximity in the kinetic chain (Bora et al., 2008; Butler et al., 2014). Within these categories, injuries were classified as all reported and recorded injuries and injuries which caused the athlete to abstain from games and practice for three days or more. These injury classification groupings utilized three days as an injury threshold were used, based on studies by Butler et al. (2013) and Schroeder et al. (2016).

Methodology

The researcher utilized secondary data from a private Division II Midwestern university football team. Data used included individual FMS scores provided by the strength and conditioning department and injury records provided by the athletic training department. The FMS score document and the injury records were separately submitted to the Program Director of Athletic Training, who then paired the FMS scores with injury records. All names were then removed and the document with anonymous paired FMS scores and injury records was sent to the researcher. The Program Director of Athletic Training did not exclude any data when the pairing and scrubbing of names occurred.

As per FMS guidelines, shoulder mobility sum score was determined by taking the lower of the right and left side scores (FMS & Cook, 2010). For example, if an athlete scored a 2 on the right and the 3 on the left side in shoulder mobility, then the sum score was a 2. If pain was elicited by the clearing exam, regardless of the right and left scores, the shoulder mobility sum score was 0. If there was a difference in scores from the right to the left, then asymmetry between sides was noted.

The researcher excluded any data which did not have full shoulder mobility Functional Movement Screening results included. This occurred when the student-athlete did not participate in the screen or when only partial data was available for the athlete from the strength and conditioning department. Selection criteria of secondary data was inclusive of all study-site university football athletes in the 2014-2015 and 2015-2016 academic years, who completed the Functional Movement Screen with the Strength and

Conditioning Department (2014-2015 n=102, 2015-2016 n=96). This was consistent with other researchers utilizing the FMS in relationship to overall injury likelihood. Bardenett et al. (2015) used similar selection criteria in a study on high school athletes and injury rates, as did Garrison, Westrick, Johnson, and Benenson's (2015) study of Division I and club athletes at the collegiate level, and Dossa et al.'s (2014) study of junior hockey athletes.

Injury data from the Athletic Training Department was gathered through an online data collection system, Sportsware Online. Injuries were classified by body part, and any injuries classified in the system under the shoulder were counted towards shoulder injuries. Any injuries classified in the system under shoulder, upper arm, elbow, lower arm, wrist, hand, and finger were classified as upper body injuries. Injuries were also classified by number of days (if any) lost from practice or completion. Any injuries which resulted in three of more days of lost practice and/or competition were classified as such. Any injuries to the particular body areas present in the system, regardless of if any time was lost were classified as 'all reported and recorded.'

In all statistical analyses, the following classifications were explored: area of injury (shoulder injury, upper body injury), duration of injury (all reported and recorded injuries, injuries resulting in three or more days of lost practice), and academic year (2014-2015 and 2015-2016).

Since FMS scores were ordinal, data was analyzed via Chi Square contingency tables to explore the statistical significance of the difference in proportions for shoulder mobility sum score (0-3) and injury incidence (yes or no) for all classifications noted in the previous paragraph (Bluman, 2013). A Chi Square contingency table was also used to compare groupings, based on shoulder mobility score and asymmetry status (0 asymmetry, 0 symmetry, 1 asymmetry, 1 symmetry, 2 asymmetry, 2 symmetry, 3 symmetry) and injury incidence (yes or no). The *z*-test for difference in proportions was used for any results from the Chi Square contingency table that were statistically significant, indicated by $p < 0.05$ or for any results close in statistical significance, to further explore the relationships between variables (Bluman, 2013).

Additionally, the *z*-test for difference in proportions was used to compare all groupings of proportions that met a 2 by 2 configuration. A *z*-test for difference in proportions was appropriate here, because there was a binominal distribution, meaning there were only two outcomes (injured yes or no) for each grouping (Bluman, 2013). These groupings included the following: shoulder mobility scores of 0, 1, and 3 grouped compared to a score of 2; symmetrical compared to asymmetrical shoulder mobility scores; shoulder mobility scores of 0, 1, asymmetrical 2s, and 3s compared to the grouping of symmetrical 2s; and shoulder mobility scores of 0 and 1 compared to 2 and 3. These groupings were explored, relative to injury incidence (yes or no). All of these groupings were explored with the classifications outlined above related to area and duration of injury and academic year.

A Chi Square contingency table was also used to compare shoulder mobility scores from the 2014-2015 and the 2015-2016 academic years. The Chi Square contingency table was used, as the data was organized in a table format based on proportions of the population who were injured.

The researcher conducted interviews with the athletic training faculty and the strength and conditioning staff directly responsible for football during the academic years of study. Interviews took approximately 45 minutes each, were conducted face-to-face, recorded, transcribed, and coded. After the interview, the researcher reviewed the recordings and the transcribed document of the recordings and identified key components of each interview. Common themes were grouped until the key ideas emerged from the data and aligned between interviewees. The strategies utilized by the researcher in the analysis of the data were detailed by Maxwell (2005). Appendix A contains the interview questions for the athletic trainer and Appendix B contains the interview questions for the strength and conditioning coaches.

Research Question

How do educators in the fields of strength and conditioning and athletic training use the Functional Movement Screen to create data-driven interventions for student-athletes?

Null Hypotheses

The null hypotheses examined in this study were:

H_{01}: There is no difference in shoulder injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_{02}: There is no difference in upper body injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_{03}: There is no difference in the shoulder injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to a score of 2.

H_{04}: There is no difference in the upper body injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to a score of 2.

H_{05}: There is no difference in shoulder injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_{06}: There is no difference in upper body injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_{07}: There is no difference in shoulder injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_{08}: There is no difference in upper body injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_{09}: There is no difference in shoulder injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H_{010}: There is no difference in upper body injury incidence for collegiate football athletes who score a 0 or 1 compared to a score or 2 or 3.

H_{011}: There is no difference in shoulder injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{012}: There is no difference in upper body injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{013}: There is no difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts.

Limitations

The limitations of the study, identified by the researcher, included the following:

FMS variability. FMS scores may have changed over the course of the academic year. The FMS scores used by the researcher were captured at the start of the academic year; however, they may not reflect the FMS score of the athlete throughout the year, including at time of injury. The FMS score of 0 was based on a self-reported pain rating from each athlete. Athletes may have been hesitant to report the presence of pain to the raters scoring the FMS. The strength and conditioning program completed by the athletes may have influenced a change in the FMS scores. Because there were different strength and conditioning coaches over the two academic years, the change in the approach to training may have influenced FMS scores and/or injury resilience. Scoring of the FMS may have been subject to interrater and intrarater variability.

Injury variability. Injury reporting to the athletic training staff was partially dependent on athletes reporting sustained injuries. Not all injuries may have been reported to the athletic training staff. Since there were two athletic trainers responsible for football, there may have been variability in reporting practices from one athletic trainer to the next. Additionally, reporting practices may change from one institution to the next, so these results may not be translatable to other institutions, based on reporting practices.

The definition of what constitutes injury varied widely throughout the then-current literature; therefore, the results of this study may not translate to other settings and time periods, based on determined injury definitions. The sport of football was violent, and at times, unpredictable in injuries sustained due to the collision nature of the game. Therefore, some injuries may have occurred based not on compensation or movement patterns, but because of the nature of the game.

Translation to other populations. There was an unknown ability of this research to translate to other sports, other levels of play, other institutions, other ages, other genders, and other populations in general.

The Research Site and Participants

The research site was a private NCAA Division II Midwestern university. In the 2014-2015 academic year, there were 102 football athletes who fully completed the FMS shoulder mobility screening and 96 football athletes who did the same in 2015-2016. There were different head football strength and conditioning coaches for the 2014-2015 and 2015-2016 academic years and the same head football athletic trainer; so, there were three total individuals interviewed.

Summary

Chapter Three details the methodology utilized in the analysis of secondary data provided by the athletic training and strength and conditioning departments, in addition to a description of the analysis of the primary interview data collected by the researcher. Secondary data were analyzed with Chi Square contingency tables if larger than a 2 by 2 table, and if the resulting p values were at or near significance, then the z-test for difference in proportions was utilized. Tables of the dimension 2 by 2 also utilized the z-test for difference in proportions. Primary data were collected through interviews with the strength and conditioning head football coaches and the head football athletic trainer. The data were recorded, transcribed, and coded. Next, Chapter Four explores the results of data analysis.

Chapter Four: Results

Overview

Chapter Four describes each null hypothesis and provides the data analysis components for the different conditions represented by data over the 2014-2015 and 2015-2016 academic years. Statistical significance was identified for the following components of the 2014-2015 academic year: shoulder mobility sum score for all reported and recorded shoulder injuries, specifically scores of 0 compared to scores of 2; groupings of 0, 1, and 3 compared to scores of 2 for all reported and recorded shoulder and upper body injuries, and upper body injuries resulting in three or more days lost; presence of symmetry for shoulder injuries resulting in three or more days lost; combination of shoulder mobility score and symmetry for all reported and recorded shoulder injuries for asymmetrical 0 versus symmetrical 2, asymmetrical 0 versus symmetrical 3, and asymmetrical 0 versus asymmetrical 2. For the 2015-2016 academic year, statistical significance was identified for shoulder mobility score groupings of 0, 1, 2 with asymmetry, and 3 compared to a symmetrical 2 for all reported and recorded upper body injuries. Interviews with strength and conditioning and athletic training professionals revealed perceptions of the FMS, barriers to ideal implementation, and the use of FMS results in prescription of exercise.

Null Hypotheses 1 and 2

H_{01}: There is no difference in shoulder injury incidence rates for collegiate football athletes based on shoulder mobility sum score.

H_{02}: There is no difference in upper body injury incidence rates for collegiate football athletes based on shoulder mobility sum score.

Table 3

Injury Proportion by Shoulder Mobility Score

Body area of injury	Injury type	FMS score	2014-2015			2015-2016		
			Injury incidence	Total number	Injury proportion	Injury incidence	Total number	Injury proportion
Shoulder injury	All reported, recorded	0	2	4	0.50	0	17	0.00
		1	6	35	0.17	4	21	0.19
		2	1	33	0.03	2	29	0.07
		3	5	30	0.17	5	29	0.17
	3+ days out	0	0	4	0.00	0	17	0.00
		1	3	35	0.09	3	21	0.14
		2	0	33	0.00	1	29	0.03
		3	3	30	0.10	2	29	0.07
Upper body injury	All reported, recorded	0	2	4	0.50	2	17	0.12
		1	11	35	0.31	5	21	0.24
		2	4	33	0.12	4	29	0.14
		3	10	30	0.33	11	29	0.38
	3+ days out	0	0	4	0.00	1	17	0.06
		1	4	35	0.11	3	21	0.14
		2	0	33	0.00	1	29	0.03
		3	5	30	0.17	4	29	0.14

Table 3 provides the proportions collected based on shoulder mobility sum score, injury incidence per score, total number of football athletes per score, and injury proportion, broken down by body area of injury, injury type, and academic year.

Chi-Square homogeneity of proportions tests were performed to determine if the proportions of athletes with a shoulder injury and with an upper body injury were equal, H_{01} and H_{02}, based on groupings by shoulder mobility sum score (0-3), at a 95% confidence level. These tests yielded χ^2 values that determined the significance or lack of significance of the difference in proportions. For χ^2 values that were significant or nearly significant, a *z*-test for difference in two proportions was completed at a 95% confidence level. This test yielded a *z*-score that determined the significance or lack of significance of the difference in proportions.

The researcher showed in Table 4 the results of examining the difference in proportions of athletes who scored a 0, 1, 2, or 3 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file.

Table 4

Injury by Shoulder Mobility Sum Score (0 vs 1 vs 2 vs 3)

Body area of injury	Injury type	2014-2015		2015-2016	
		χ^2	*p*	χ^2	*p*
Shoulder injury	All reported, recorded	8.197	*0.0421**	4.943	0.1760
	3+ days out	3.688	0.2971	3.857	0.2773
Upper body injury	All reported, recorded	5.797	0.1219	6.274	0.0990
	3+ days out	6.170	0.1036	2.705	0.4393

Note. Italicized results were further explored via *z*-test of two proportions in Table 5.
*p <0.05

Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for 2014-2015 and 2015-2016 academic years.

Statistical significance was identified for the 2014-2015 all reported and recorded shoulder injuries, as the *p* value was less than 0.05, as shown on Table 4. For this condition, the null hypothesis was rejected and a significant difference in proportion was established. For all other conditions, the researcher failed to reject the null hypothesis. As shown by the *p* values recorded in Table 4, the null hypothesis was not rejected for 2014-2015 Shoulder Injury, 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out. Also, for 2015-2016, the *p* values recorded in Table 4 indicate that all four categories supported rejection of the null hypothesis, Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out.

In Table 5 the researcher recorded the results of exploring the statistically significant condition of the 2014-2015 academic year for all reported and recorded shoulder injuries based on shoulder mobility sum score. Table 5 data reveals a statistical significance in the proportion of football athletes with a reported and recorded shoulder injury who scored a 0 on the Shoulder Mobility test compared to those who scored a 2 in the 2014-2015 academic year. The *p* value of 0.0011 was below the alpha value of 0.01 and the null was rejected for this condition. For all other conditions, the researcher failed to reject the null hypothesis. As shown by the *p* values recorded in Table 5, the null hypothesis was not rejected for 2014-2015 data when comparing the two proportions for scores of 0 versus 1, 1 versus 2, 1 versus 3, 0 versus 3, and 2 versus 3.

Table 5

2014-2015 Shoulder Injury by Shoulder Mobility Sum Score, All Reported and Recorded

Sum score comparison	Proportion 1	Proportion 2	*z*	*p*
0's versus 1's	0.5	0.17	1.544	0.1227
1's versus 2's	0.17	0.03	1.912	0.0558
1's versus 3's	0.17	0.17	0.043	0.9658
0's versus 2's	0.5	0.17	3.252	0.0011**
0's versus 3's	0.5	0.17	1.547	0.1218
2's versus 3's	0.03	0.17	-1.850	0.0643

Note. ***p* <0.01

Null Hypotheses 3 and 4

H_{03}: There is no difference in the shoulder injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to the injury rate for scores of 2.

H_{04}: There is no difference in the upper body injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to the injury rate for scores of 2.

Table 6 provides a breakdown of data collected, based on shoulder mobility sum score groupings of 0, 1, and 3 compared to 2, injury incidence per score, total number of football athletes per score, and injury proportion, broken down by body area of injury, injury type, and academic year, for H_{03} and H_{04}.

Table 6

Injury Proportion by Shoulder Mobility Score 0, 1, 3 Versus 2

Body area of injury	Injury type	FMS score	2014-2015			2015-2016		
			Injury incidence	Total number	Injury proportion	Injury incidence	Total number	Injury proportion
Shoulder injury	All reported, recorded	0, 1, 3	13	69	0.19	9	67	0.13
		2	1	33	0.03	2	29	0.07
	3+ days out	0, 1, 3	6	69	0.09	5	67	0.07
		2	0	33	0.00	1	29	0.03
Upper body injury	All reported, recorded	0, 1, 3	23	69	0.33	18	67	0.27
		2	4	33	0.12	4	29	0.14
	3+ days out	0, 1, 3	9	69	0.13	8	67	0.12
		2	0	33	0.00	1	29	0.03

A *z*-test for difference in proportions was performed to determine if the proportion of athletes with a shoulder injury and upper body injury was equal based on groupings by shoulder mobility sum score, with the scores of 0, 1, and 3 grouped compared to scores of 2 at a 95% confidence level. This test yielded a *z* score that determined the significance of the difference in proportions, when compared to the alpha value of .05.

The results of Table 7 show the difference in proportions of athletes who scored a 0, 1, or 3 compared to a score of 2 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries in 2014-2015. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days.

Table 7

2014-2015 Injury by Shoulder Mobility Score 0, 1, 3 Versus 2

Body area of injury	Injury type	2014-2015			
		0, 1, 3 proportion	2 proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.19	0.03	2.169	0.0301*
	3+ days out	0.09	0.0	1.747	0.0806
Upper body injury	All reported, recorded	0.33	0.12	2.270	0.0232*
	3+ days out	0.13	0.0	2.166	0.0303*

Note. *p <0.05

In Table 7 the data indicate a statistical significant difference in the proportion of football athletes with a reported and recorded shoulder injury who scored a 0, 1, or 3 on the Shoulder Mobility test compared to those who scored a 2 in the 2014-2015 academic year. The *p* value of 0.0301 was below 0.05 and the null was rejected for this condition. Additionally, there was statistical significance in the proportion of football athletes with a reported and recorded upper body injury who scored a 0, 1, or 3 on the Shoulder Mobility test compared to those who scored a 2 in the 2014-2015 academic year. The *p* value of 0.0232 was below 0.05 and the null was rejected for this condition. Table 7 data also indicated a statistical significance in the proportion of football athletes with an upper body injury resulting in 3 or more days out who scored a 0, 1, or 3 on the Shoulder Mobility test compared to those who scored a 2 in the 2014-2015 academic year. The *p* value of 0.0303 was below 0.05 and the null was rejected for this condition. The researcher failed to reject the null for the condition of shoulder injuries at 3 or more days out, for the 2014-2015 academic year.

Data within Table 8 reveals a difference in proportions of athletes who scored a 0, 1, or 3 compared to a score of 2 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries in 2015-2016, for H_{03} and H_{04}. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. No statistical significance resulted for the conditions noted in Table 8 and the researcher failed to reject the null hypothesis.

Specifically, there were no significant differences identified in the 2015-2016 academic years for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out.

Table 8

2015-2016 Injury by Shoulder Mobility Score 0, 1, 3 Versus 2

Body area of injury	Injury type	2015-2016			
		0, 1, 3 proportion	2 proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.13	0.07	0.918	0.3586
	3+ days out	0.075	0.034	0.762	0.4461
Upper body injury	All reported, recorded	0.27	0.14	1.402	0.1608
	3+ days out	0.12	0.03	1.312	0.1895

Note. *p <0.05

Null Hypotheses 5 and 6

H_{05}: There is no difference in shoulder injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_{06}: There is no difference in upper body injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

Table 9 provides a breakdown of data collected based on the presence of symmetrical or asymmetrical shoulder mobility scores, injury incidence per score, total number of football athletes per score, and injury proportion, broken down by body area of injury, injury type, and academic year, for use in analysis of H_{05} and H_{06}.

The researcher performed a *z*-test for difference in proportions to determine if the proportion of athletes with a shoulder injury was equal based on groupings by shoulder mobility symmetry or asymmetry at a 95% confidence level. This test yielded a *z* score that determined the significance or lack of significance of the difference in proportions.

Table 9

Injury Proportion by Shoulder Mobility Asymmetry

Body area of injury	Injury type	FMS Symmetry	2014-2015			2015-2016		
			Injury incidence	Total number	Injury proportion	Injury incidence	Total number	Injury proportion
Shoulder injury	All reported, recorded	Symmetrical	7	55	0.13	7	60	0.12
		Asymmetrical	7	47	0.15	4	36	0.11
	3+ days out	Symmetrical	4	55	0.07	3	60	0.05
		Asymmetrical	2	47	0.04	3	36	0.08
Upper body injury	All reported, recorded	Symmetrical	14	55	0.25	14	60	0.23
		Asymmetrical	13	47	0.28	8	36	0.22
	3+ days out	Symmetrical	6	55	0.11	5	60	0.08
		Asymmetrical	3	47	0.06	4	36	0.11

Data within Table 10 reveals the difference in proportions of athletes who had the presence of symmetry or asymmetry from left to right shoulders, based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for 2014-2015 academic year. For shoulder injuries that resulted in 3 or more days out, the presence of symmetrical shoulders was statistically significant. The *p* value was less than the alpha value of .01. The researcher failed to reject the null for all other conditions based on shoulder mobility asymmetry. There were no significant differences identified in the 2014-2015 academic years for Shoulder Injury, all reported and recorded, and Upper Body Injury, all reported and recorded and 3+ days out. As shown on Table 10, for these values the *p* value was greater than the alpha value of .01.

Table 10

2014-2015 Injury by Shoulder Mobility Asymmetry

Body area of injury	Injury type	2014-2015			
		Asymmetry proportion	Symmetry proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.15	0.13	0.322	0.7476
	3+ days out	0.04	0.26	-2.935	0.0033**
Upper body injury	All reported, recorded	0.28	0.26	0.251	0.8018
	3+ days out	0.06	0.11	-0.799	0.4245

Note. ***p* <0.01

Data within Table 11 revealed the difference in proportions of athletes who had the presence of symmetry or asymmetry from left to right shoulders, based on body area of injury, for both shoulder injuries and upper body injuries for the 2015-2016 academic year. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for the 2015-2016 academic year. The researcher failed to reject the null for all conditions based on shoulder mobility asymmetry. The null hypothesis was not rejected for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out, for the 2015-2016 academic year. The *p* values were greater than the alpha of .05.

Table 11

2015-2016 Injury by Shoulder Mobility Asymmetry

Body area of injury	Injury type	2015-2016			
		Asymmetry proportion	Symmetry proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.11	0.12	-0.089	0.9288
	3+ days out	0.08	0.23	-1.864	0.0623
Upper body injury	All reported, recorded	0.22	0.23	-0.124	0.9012
	3+ days out	0.08	0.08	0.000	1.0000

Note. $^{**}p < 0.05$

Null Hypotheses 7 and 8

H07: There is no difference in shoulder injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

Table 12

Injury Proportion by Shoulder Mobility Score 0, 1, 2A, 3 Versus 2S

Body area of injury	Injury type	FMS score	2014-2015			2015-2016		
			Injury incidence	Total number	Injury proportion	Injury incidence	Total number	Injury proportion
Shoulder injury	All reported, recorded	0, 1, 2A, 3	14	90	0.16	11	76	0.14
		2S	0	12	0.00	0	20	0.00
	3+ days out	0, 1, 2A, 3	6	90	0.07	6	76	0.08
		2S	0	12	0.00	0	20	0.00
Upper body injury	All reported, recorded	0, 1, 2A, 3	26	90	0.29	21	76	0.28
		2S	1	12	0.08	1	20	0.05
	3+ days out	0, 1, 2A, 3	9	90	0.10	9	76	0.12
		2S	0	12	0.00	0	20	0.00

H_{08}: There is no difference in upper body injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

The data of Table 12 reveals a breakdown of data collected based on the groupings of scores of 0, 1, asymmetrical 2, and 3 compared to symmetrical 2, injury incidence per score, total number of football athletes per score, and injury proportion, broken down by body area of injury, injury type, and academic year, for use in analysis of H_{07} and H_{08}.

The researcher performed a *z*-test for difference in proportions to determine if the proportion of athletes with a shoulder injury was equal based on groupings by shoulder mobility scores of 0, 1, 2 with asymmetry, and 3 compared to 2 with symmetry at a 95% confidence level. This test yielded a *z*-score that determined the significance of the difference in proportions.

Data presented in Table 13 reveals the difference in proportions of athletes who scored a 0, 1, 2 with asymmetry, or 3 compared to a symmetrical 2 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for the 2014-2015 academic year. No statistical significance was identified and the researcher failed to reject the null hypothesis, for the academic year 2014-2015. Specifically, the null hypothesis was not rejected for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body

Injury, all reported and recorded and 3+ days out. The *p* values were greater than the alpha of .05.

Table 13

2014-2015 Injury by Shoulder Mobility Score 0, 1, 2A, 3 Versus 2S

Body area of injury	Injury type	2014-2015			
		0, 1, 3, 2A proportion	2S proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.16	0.00	1.475	0.1402
	3+ days out	0.07	0.00	0.927	0.3542
Upper body injury	All reported, recorded	0.29	0.09	1.401	0.1613
	3+ days out	0.10	0.00	1.147	0.2513

Note. $^{**}p < 0.05$

Data presented in Table 14 reveals the difference in proportions of athletes who scored a 0, 1, 2 with asymmetry, or 3 compared to a symmetrical 2 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for the 2015-2016 academic year.

Statistical significance was identified for the 2015-2016 all reported and recorded upper body injuries, as the *p* value was less than 0.01. For this condition, the null hypothesis was rejected. The higher likelihood of upper body injury occurred with the scores of 0, 1, 2 with asymmetry, and 3. For all other conditions, the researcher failed to reject the null hypothesis. The null hypothesis was not rejected for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out, for the 2015-2016 academic year.

Table 14

2015-2016 Injury by Shoulder Mobility Score 0, 1, 2A, 3 Versus 2S

Body area of injury	Injury type	2015-2016			
		0, 1, 3, 2A proportion	2S proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.15	0.00	1.811	0.0701
	3+ days out	0.08	0.00	1.299	0.1914
Upper body injury	All reported, recorded	0.28	0.00	2.657	0.0079**
	3+ days out	0.12	0.00	1.611	0.1072

Note. ***p* <0.01

Null Hypotheses 9 and 10

H_{09}: There is no difference in shoulder injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H_{010}: There is no difference in upper body injury incidence for collegiate football athletes who score a 0 or 1 compared to a score or 2 or 3.

Table 15 provided a breakdown of data collected based on the groupings of scores of 0 or 1 compared to 2 or 3, injury incidence per score, total number of football athletes per score, and injury proportion, broken down by body area of injury, injury type, and academic year, for use in analysis of H_{09} and H_{010}.

The researcher performed a *z*-test for difference in proportions to determine if the proportion of athletes with a shoulder injury was equal based on groupings by shoulder mobility scores of 0 and 1 compared to 2 and 3 at a 95% confidence level. This test yielded a *z* score that determined the significance or lack of significance of the difference in proportions.

Table 15

Injury Proportion by Shoulder Mobility Score 0, 1 Versus 2, 3

Body area of injury	Injury type	FMS score	2014-2015			2015-2016		
			Injury incidence	Total number	Injury proportion	Injury incidence	Total number	Injury proportion
Shoulder injury	All reported, recorded	0, 1	8	39	0.21	4	38	0.11
		2, 3	6	63	0.10	7	58	0.12
	3+ days out	0, 1	3	39	0.08	3	38	0.08
		2, 3	3	63	0.05	3	58	0.05
Upper body injury	All reported, recorded	0, 1	13	39	0.33	7	38	0.18
		2, 3	14	63	0.22	15	58	0.26
	3+ days out	0, 1	4	39	0.10	4	38	0.11
		2, 3	5	63	0.08	5	58	0.09

Data within Table 16 reveals the difference in proportions of athletes who scored a 0 or 1 compared to a 2 or 3 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for the 2014-2015 academic year. No statistical significance was identified and the researcher failed to reject the null hypothesis. Specifically, the null hypothesis was not rejected for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out, for the 2014-2015 academic year. The *p* values were greater than the alpha of .05.

Table 16

2014-2015 Injury by Shoulder Mobility Score 0, 1 Versus 2, 3

Body area of injury	Injury type	2014-2015			
		0, 1 proportion	2, 3 proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.21	0.10	1.569	0.1167
	3+ days out	0.08	0.05	0.605	0.5452
Upper body injury	All reported, recorded	0.33	0.22	1.235	0.2169
	3+ days out	0.10	0.91	0.415	0.6779

Note. $**p < 0.05$

Data within Table 17 reveals the difference in proportions of athletes who scored a 0 or 1 compared to a 2 or 3 in shoulder mobility based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for the 2015-2016 academic year. No statistical significance was identified and the researcher failed to reject the null hypothesis. Specifically, the null hypothesis was not rejected for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out, for the 2015-2016 academic year. The *p* values were greater than the alpha of .05.

Table 17

2015-2016 Injury by Shoulder Mobility Score 0, 1 Versus 2, 3

Body area of injury	Injury type	2015-2016			
		0, 1 proportion	2, 3 proportion	*z*	*p*
Shoulder injury	All reported, recorded	0.105	0.121	-0.241	0.8098
	3+ days out	0.079	0.052	0.534	0.5930
Upper body injury	All reported, recorded	0.184	0.259	-0.855	0.3925
	3+ days out	0.105	0.086	0.312	0.7548

Note. **p <0.05

Null Hypotheses 11 and 12

H_{011}: There is no difference in shoulder injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{012}: There is no difference in upper body injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

Table 18 provides a breakdown of data collected based on the groupings of scores related to both shoulder mobility and asymmetry status, injury incidence per score, total number of football athletes per score, and injury proportion, broken down by body area of injury, injury type, and academic year, for H_{011} and H_{012}.

Table 18

Injury Proportion by Shoulder Mobility Score and Asymmetry

Body area of injury	Injury type	FMS score	2014-2015			2015-2016		
			Injury incidence	Total number	Injury proportion	Injury incidence	Total number	Injury proportion
Shoulder injury	All reported, recorded	0S	0	1	0.00	0	4	0.00
		0A	2	3	0.67	0	13	0.00
		1S	2	12	0.17	2	7	0.29
		1A	4	23	0.17	2	14	0.14
		2S	0	12	0.00	0	20	0.00
		2A	1	21	0.05	2	9	0.22
		3S	5	30	0.17	5	29	0.17
	3+ days out	0S	0	1	0.00	0	4	0.00
		0A	0	3	0.00	0	13	0.00
		1S	1	12	0.08	1	7	0.14
		1A	2	23	0.09	2	14	0.14
		2S	0	12	0.00	0	20	0.00
		2A	0	21	0.00	1	9	0.11
		3S	3	29	0.10	2	29	0.07

continued

Table 18 continued.

Upper body injury	All reported, recorded	0S	0	1	0.00	0	4	0.00
		0A	2	3	0.67	2	13	0.15
		1S	3	12	0.25	2	7	0.29
		1A	8	23	0.35	3	14	0.21
		2S	1	12	0.08	1	20	0.05
		2A	3	21	0.14	3	9	0.33
		3S	10	30	0.33	11	29	0.38
	3+ days out	0S	0	1	0.00	0	4	0.00
		0A	0	3	0.00	1	13	0.08
		1S	1	12	0.08	1	7	0.14
		1A	3	23	0.13	2	14	0.14
		2S	0	12	0.00	0	20	0.00
		2A	0	21	0.00	1	9	0.11
		3S	5	30	0.17	4	29	0.14

Chi-Square homogeneity of proportions tests were performed to determine if the proportion of athletes with a shoulder injury or upper body injury was equal, based on groupings by shoulder mobility scores including asymmetry at a 95% confidence level. Comparison groups were 0 asymmetry, 0 symmetry, 1 asymmetry, 1 symmetry, 2 asymmetry, 2 symmetry, and 3 symmetry. These tests yielded χ^2 values that determined the significance or lack of significance of the difference in proportions. For χ^2 values that were significant or nearly significant, a *z*-test for difference in two proportions was completed at a 95% confidence level. This test yielded a *z*-score that determined the significance or lack of significance of the difference in proportions.

Data presented in Table 19 indicates the difference in proportions of athletes related to shoulder mobility score and presence of asymmetry, based on body area of injury, for both shoulder injuries and upper body injuries. These injuries were further classified as either reported and recorded injuries communicated to the athletic trainer and subsequently reported in an electronic medical file. Alternatively, injuries were classified if the injury caused the athlete to be out from games and/or practices for three or more days. Results were presented for the 2014-2015 and 2015-2016 academic years. The researcher failed to reject the null for all conditions based on groupings of scores and presence of asymmetry. Specifically, the null hypothesis was not rejected for Shoulder Injury, all reported and recorded and 3+ days out, and Upper Body Injury, all reported and recorded and 3+ days out. The *p* values were greater than the alpha of .05.

Table 19

Injury by Shoulder Mobility Sum Score and Asymmetry (0S vs 1S vs 2S vs 3S vs 0A vs 1A vs 2A)

Body area of injury	Injury type	2014-2015		2015-2016	
		χ^2	*p*	χ^2	*p*
Shoulder injury	All reported, recorded	11.162	*0.0835*	8.903	0.1791
	3+ days out	3.690	0.7185	5.165	0.5229
Upper body injury	All reported, recorded	8.036	0.2355	9.639	0.1407
	3+ days out	6.387	0.3812	3.820	0.7010

Note. Italicized results were further explored via *z*-test of two proportions in Table 20.

Data within Table 19 reveals the closely significant condition of the 2014-2015 academic year for all reported and recorded shoulder injuries based on shoulder mobility sum score and presence of asymmetry in further detail.

Data within Table 20 indicates football athletes with a reported and recorded shoulder injury who scored a 0 with asymmetry on the Shoulder Mobility test were significantly more likely to sustain a shoulder injury compared to those who scored a 2 with symmetry in the 2014-2015 academic year. The *p* value of 0.0024 was below 0.01 and the null was rejected for this condition.

Statistical significance was present in the proportion of football athletes with a reported and recorded shoulder injury who scored a 0 with asymmetry on the Shoulder Mobility test, as they were significantly more likely to sustain a shoulder injury compared to those who scored a 3 with symmetry in the 2014-2015 academic year. The *p* value of 0.0434 was below 0.05 and the null was rejected for this condition.

Additionally, there was statistical significance in the proportion of football athletes with a reported and recorded shoulder injury who scored a 0 with asymmetry on the Shoulder Mobility test, as they were significantly more likely to sustain a shoulder injury compared to those who scored a 2 with asymmetry in the 2014-2015 academic year. The *p* value of 0.0024 was below 0.01 and the null was rejected for this condition.

Table 20

2014-2015 Shoulder Injury by Shoulder Mobility Score and Symmetry, All Reported and Recorded

Shoulder mobility and symmetry score	Proportion 1	Proportion 2	*z*	*p*
0 Asymmetry versus 0 Symmetry	0.67	0.00	1.155	0.2480
0 Asymmetry versus 1 Symmetry	0.67	0.17	1.752	0.0798
0 Asymmetry versus 2 Symmetry	0.67	0.00	3.040	0.0024**
0 Asymmetry versus 3 Symmetry	0.67	0.17	2.020	0.0434*
0 Asymmetry versus 1 Asymmetry	0.67	0.17	1.906	0.0566
0 Asymmetry versus 2 Asymmetry	0.67	0.05	3.032	0.0024**
1 Asymmetry versus 0 Symmetry	0.17	0.00	0.457	0.6476
1 Asymmetry versus 1 Symmetry	0.17	0.17	0.052	0.9584
1 Asymmetry versus 2 Symmetry	0.17	0.00	1.536	0.1246
1 Asymmetry versus 3 Symmetry	0.17	0.17	0.067	0.9464
1 Asymmetry versus 2 Asymmetry	0.17	0.05	1.315	0.1884
2 Asymmetry versus 0 Symmetry	0.05	0.00	0.225	0.8219
2 Asymmetry versus 1 Symmetry	0.05	0.17	-1.144	0.2527
2 Asymmetry versus 2 Symmetry	0.05	0.00	0.774	0.4391
2 Asymmetry versus 3 Symmetry	0.05	0.17	-1.298	0.1942
0 Symmetry versus 1 Symmetry	0.00	0.17	-0.445	0.6565
0 Symmetry versus 2 Symmetry	0.00	0.00	--	--
0 Symmetry versus 3 Symmetry	0.00	0.17	-0.447	0.6551
1 Symmetry versus 2 Symmetry	0.17	0.00	1.480	0.1389
1 Symmetry versus 3 Symmetry	0.17	0.17	0.000	1.0000
2 Symmetry versus 3 Symmetry	0.00	0.17	-1.510	0.1311

Note. **p* <0.05, ***p* <0.01
-- No injuries in either group occurred

The researcher failed to reject the null in all other conditions, which included 0 Asymmetry versus 0 Symmetry, 0 Asymmetry versus 1 Symmetry, 0 Asymmetry versus 1 Asymmetry, 1 Asymmetry versus 0 Symmetry, 1 Asymmetry versus 1 Symmetry, 1

Asymmetry versus 2 Symmetry, 1 Asymmetry versus 3 Symmetry, 1 Asymmetry versus 2 Asymmetry, 2 Asymmetry versus 0 Symmetry, 2 Asymmetry versus 1 Symmetry, 2 Asymmetry versus 2 Symmetry, 2 Asymmetry versus 3 Symmetry, 0 Symmetry versus 1 Symmetry, 0 Symmetry versus 3 Symmetry, 1 Symmetry versus 2 Symmetry, 1 Symmetry versus 3 Symmetry, and 2 Symmetry versus 3 Symmetry. The *p* values were greater than .05.

Null Hypothesis 13

H_{013}: There is no difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts.

Table 21 presents the shoulder mobility scores by score per year, for and H_{013}.

Table 21

Shoulder Mobility Score Breakdown per Academic Year

Shoulder Mobility Score	2014-2015	2015-2016
0	4	17
1	35	21
2	33	29
3	30	29

A Chi-Square homogeneity of proportions test was performed to determine if the proportion shoulder mobility scores of athletes was equal from the 2014-2015 to 2015-2016 school years at a 95% confidence level. This test yielded a χ^2 value that determined the significance of the difference in proportions. The calculated χ^2 was 11.652 (p = 0.0087). These values indicated statistical significance, as the *p* value was less than 0.01. Because the p value of 0.0087 was greater than the alpha value of .01, the null was rejected and differences were significant.

Research Question

How do educators in the fields of strength and conditioning and athletic training use the Functional Movement Screen to create data-driven interventions for student-athletes?

Perceptions of FMS. Perceptions of the FMS were explored during all three interviews with the head football athletic trainer and the two football strength and conditioning coaches, who were present during the 2014-2015 and 2015-2016 academic years. Similar sentiments were echoed regarding the ability of the movement screening to identify injury likelihood for football players specifically. The athletic trainer (AT) noted concerns in the FMS's ability to identify student athletes with an increased likelihood of injury for some sports. He stated:

> In football, the validity may be lower because a lot of the injuries [athletic trainers] see are caused by direct contact or trauma . . . But for the overuse injuries or for some of the non-contact, multi-directional injuries like non-contact knee sprain, ankle sprain, definitely the linemen with shoulder problems, the biomechanical variances can predispose them to injury, even if it is trauma related.

The 2014-2015 strength coach (14-15 SC) echoed similar thoughts, 'with football, it is hard to validate because it is a collision sport and there is so much impact.' In his perceptions of the FMS's ability to identify injury likelihood, the 14-15 SC noted it was a good place to start, 'the movements are simple, basic. It is a good way to identify weak links in the chain.' The 2015-2016 strength coach (15-16 SC) agreed with the above characterizations and potential limitations using the screen for football players and stated,

> With the nature of football being violent and random, [the FMS] has not had a huge payoff for the investment. It seems like you get a better payoff when the athletes are not smashing into each other. The [injury] variables are a little more controlled.

All three educators had similar remarks about the nature of football and how it introduced more variables to injury, which potentially complicated injury likelihood rates.

Barriers to ideal implementation. The educators interviewed, the strength coaches and the athletic trainer, did find value in the FMS, even with potential limitations posed by the collision nature of the sport of football. However, all mentioned barriers to ideal utilization of the FMS results in the prevention of student-athlete injuries. Common barriers included time, priorities, and communication.

Time was a common barrier for all three educators. The AT noted he did not have enough time to implement programming to prevent injury based on FMS scores due to other job demands. He also noted time for the strength coaches was lacking in actual implementation of exercise programming strategies due to short face-to-face time with the athlete. 'Numbers [of athletes on a team] and a group approach to training make it very hard to make corrective programs individualistic with the people, the space, and the time.' Additionally, related to corrective exercise programming, the AT noted a lack of time negatively obstructed the implementation, coaching, and proper progression of corrective exercises. The 14-15 SC agreed lack of time, combined with large team numbers made the process of using the FMS difficult. The 15-16 SC discussed time in relationship to priorities, 'As for resources, if the FMS was our top priority, we could have done a lot more. Our resources have not been utilized. We are busy using them for other things.' Lack of time overall, lack of time to dedicate to all priorities, and lack of time related to a large team size were all mentioned by the educators interviewed.

An additional barrier explored was the perception of the FMS by the football coaching staff. The 14-15 SC characterized this perception as a lack of 'buy-in from the top' and the 15-16 SC noted, 'you need to have coaches who care about FMS scores.' He went on to elaborate:

> If you have a staff over you who does not care if you take them from a [FMS sum score of] 13 to a 15 but they want to know what they bench press, then that intrinsically alters your course and shows you where the value is.

The researcher concluded if the coaches who ultimately dictated the direction of the team did not prioritize the FMS, then the time and resources allocated to training to improve FMS or to address issues highlighted by the FMS will be diminished.

Communication between the athletic training and strength and conditioning staff was also an identified barrier. The AT characterized the relationship with the strength and conditioning staff as 'ever-changing.' The AT noted ideally, the strength coach and the athletic trainer would 'become much more partners in the process rather than just people that stay in touch every few days via email.' The 15-16 SC agreed the two professionals must collaborate, because 'often we are too much in our silos and we are not on the same page.' The researcher concluded effective communication between athletic training and strength and conditioning could have led to improvements for both the rehabilitative and the sport performance aspects of the educators' respective positions.

Use of FMS results in prescription of exercise. While the head football athletic trainer remained in the same role for both academic years of the study, the head football strength and conditioning coach changed from the 2014-2015 to the 2015-2016 academic years. The change in strength coaches resulted in a change in training approach. Based on the perception of the AT who was present for both strength and conditioning coaches, the 14-15 SC was ‘more engaged in [injury prevention] and he did a good job in terms of adding additional work for certain positions that were known to be more at risk.’ The 14-15 SC used the shoulder mobility and active straight leg raise components of the FMS to prescribe corrective exercise. Additionally, the strength and conditioning coach used the FMS to eliminate potentially problematic movement patterns, in conjunction with input from the athletic trainer. The 15-16 SC used common issues, broadly based on the FMS to choose the areas to implement corrective exercise. Additionally, movement patterns were not eliminated based on FMS scores. Neither of the two strength and conditioning coaches prescribed individual correctives for the football student-athletes. Both strength and conditioning coaches focused on shoulder and thoracic spine mobility, with the 14-15 SC focusing on shoulder mobility twice a week in season and three to four times a week out of season, with two to three exercises per day. The 15-16 SC used shoulder and thoracic spine mobility exercises two to three days a week. Overall, both strength and conditioning coaches considered FMS scores when highlighting problematic areas for corrective exercise; but, neither coach was able to prescribe individual correctives based on the size of the team and the limitations of time.

Summary

Chapter Four explored both quantitative and qualitative results, with statistically significant results listed. Statistical significance was identified in the 2014-2015 academic year in the likelihood of increased injury rates for all shoulder injuries for student-athletes who scored a 0 compared to 2; 0, 1, or 3 compared to 2; 0 with asymmetry compared to 2 with symmetry; 0 with asymmetry compared to 3 with symmetry; and 0 with asymmetry compared to 2 with asymmetry. Statistical significance was also identified in the 2014-2015 academic year in the likelihood of increased injury rates for shoulder injuries resulting in at least three days out from practice or games for student-athletes who had symmetrical compared to asymmetrical shoulders. Statistical significance was identified in the likelihood of increased injury rates for all upper body injuries and for upper body injuries resulting in at least three days off from practice or games for student-athletes who scored a 0, 1, or 3 compared to a 2. In the 2015-2106 academic year, statistical significance was noted in the increased likelihood for all upper body injuries for student-athletes who scored a 0, 1, asymmetrical 2, or 3 compared to a symmetrical 2. In qualitative results, perceptions of the FMS, barriers to implementation of an FMS-centric program, and differences in coaching approaches were common themes that emerged from the interviews. In Chapter Five, the results are discussed and reflected upon.

Chapter Five: Discussion and Reflection

Overview

Chapter Five frames the quantitative information about the relationships between shoulder mobility scores and injury incidence, in light of the qualitative results from the strength and conditioning and athletic training educators. The researcher also offers personal reflections, recommendations to the program, and recommendations for future research.

Triangulation of Results

Hypotheses 1 and 2

H1: There is a difference in shoulder injury incidence rates for collegiate football athletes based on shoulder mobility sum score.

H2: There is a difference in upper body injury incidence rates for collegiate football athletes based on shoulder mobility sum score.

The complete sum score (of all seven tests) of the Functional Movement Screen was utilized by researchers in linking to performance (Bond, Goodson, Oxford, Nevill, & Duncan, 2015; Chapman, Laymon, & Arnold., 2014; Lockie et al., 2015a; Lockie et al., 2015b; McGill et al., 2012; Okada et al., 2011; Parchmann & McBride, 2011; Teyhen et al., 2014) and injury (Chorba, Chorba, Bouillon, Overmyer, and Landis, 2010; Clay et al., 2016; Cosio-Lima et al., 2016; Kiesel et al., 2007; O'Connor et al., 2011) with varying results. However, concerns with factor structure of the FMS had been expressed (Frost et al., 2015; Kazman et al., 2014) and the creator of the FMS expressed concern in the usage of the sum score (Cook et al., 2014b). To that end, the researcher was interested in determining if a specific test (shoulder mobility) was linked to specific injuries (shoulder and upper body), rather than exploring how the sum score of all seven tests was related to injury incidence.

The proportions expressed in Table 3, Injury Proportion by Shoulder Mobility Score, indicated a higher injury incidence for shoulder injury (all reported and recorded) for athletes who scored a 0 in the 2014-2015 year with a proportion of 0.50, the highest injury proportion of the entire study. However, with this same population, the injury proportion dropped to 0.0 when only injuries resulting in three days of lost time were considered, so all of these recorded injuries were seemingly mild. Additionally, for the 2015-2016 year, no athletes with a score of 0 had any shoulder injuries reported and recorded, even though the number of athletes who scored a 0 drastically increased from four athletes in 2014-2015 to 17 athletes in 2015-2016.

Table 4, Injury by Shoulder Mobility Sum Score (0 vs 1 vs 2 vs 3), indicated statistical significance for all reported, recorded shoulder injuries in 2014-2015 at the 0.05 level. When disaggregated further in Table 5, the area of statistical significance was the comparison of athletes who scored a 0 compared to those who scored a 2, with the athletes who scored a 0 at a higher likelihood for injury. Additionally, comparisons of scores of 1 versus 2 and 2 versus 3 were both very close to significance (at 0.0558 and 0.0643, respectively), with a decreased likelihood of injury with the score of 2. This relationship of increased injury likelihood when pain was elicited (indicated by a score of 0), lack of mobility (indicated by a score of 1), or increased mobility (indicated by a score of 3), compared to a score of 2, supported considerations by the researcher that pain and too little and too much mobility may be contributing factors in increased likelihood of injury. However, when exploring the data from the other conditions in 2014-2015 and all shoulder and upper body injuries in 2015-2016, there was no additional support for the consideration.

Hypotheses 3 and 4

H3: There is a difference in shoulder injury incidence rates for collegiate football athletes who have shoulder mobility scores of 0, 1, and 3 compared to a score of a 2.

H4: There is a difference in upper body injury incidence rates for collegiate football athletes who have shoulder mobility scores of 0, 1, and 3 compared to a score of a 2.

Beyond exploring the data merely by comparing scores of 0, 1, 2, and 3 across the different conditions, the researcher explored how groupings of the data may provide additional support for the score of 2 being the ideal range of motion — not too little, as indicated by a 1 and not too much, as potentially indicated by a 3. By grouping scores of 0, 1, and 3 and comparing to a score of 2, the researcher found statistical significance in the 2014-2015 cohort for 3 of the 4 conditions (with the fourth condition being relatively close to significance with a *p* of 0.0806), as shown in Table 7. The significant conditions were all reported and recorded shoulder injuries, all reported and recorded upper body injuries, and upper body injuries resulting in three or more days out from playing time. This supported the researcher's inquiry in which greater range of motion may not always be better. However, with the statistical significance in 2014-2015, there was no significance for any of the conditions under this grouping in 2015-2016, as indicated in Table 8.

The range of what falls under each score 1, 2, and 3 may have been problematic, as the ranges may have been too broad. An athlete may have just barely scored a 3 on the

Shoulder Mobility test or the athlete's hands may have been so close together on his back to be touching — the test did not differentiate between the two scores. Another potentially problematic design was related to asymmetry. If an athlete scored a 3 on the right and a 2 on the left, his sum score was an asymmetrical 2. But if he injured his right side, the data set up by the researcher portrayed him having an injury with a 2 shoulder mobility, which was not indicating the full story, as his injured side really had the mobility of a 3.

Hypotheses 5 and 6

H5: There is a difference in shoulder injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H6: There is a difference in upper body injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

Clay, Mansell, and Tierney (2016) indicated left to right asymmetry increased the likelihood for injury. To that end, the researcher was interested in the relationship between asymmetry identified by the shoulder mobility screen and injury incidence.

The presence of asymmetry indicated an increased likelihood of shoulder injury resulting in three or more days out for athletes with symmetrical shoulders, at the 0.01 level for the 2014-2015 cohort (see Table 10). Table 11 indicated the same conditions for the 2015-2016 cohort resulted in a p of 0.0623, and while not significant, these two findings went against Kiesel et al. (2014) in the expectation that symmetry of the body would result in a lower likelihood of injury for football players, not a *greater* likelihood.

Mokha et al. (2016) also supported the link between asymmetry and injury in soccer, rowing, and volleyball athletes while Warren et al. (2015) did not find an association in Division I male athletes.

Hypotheses 7 and 8

H7: There is a difference in shoulder injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H8: There is a difference in upper body injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

In considering the ideal range of motion and the expected positive of shoulder symmetry, the researcher then grouped injury proportions of athletes who scored a 0, 1, asymmetrical 2, and 3 and compared them to injury proportions of athletes who scored a symmetrical 2. This was intended to support the hypothesis the lowest likelihood of injury proportion would come from athletes with no pain, just enough mobility, and symmetry in the shoulders. For the 2014-2015 cohort, there was no statistical significance (see Table 13). For the 2015-2016 cohort, statistical significance was noted for all reported and recorded upper body injuries. All reported and recorded shoulder injuries was additionally close ($p = 0.0701$), but not significant (see Table 14). Tables 13 and 14 also indicated the injury proportion for a symmetrical 2 was at 0.0 for 7 of the 8 conditions over the two different academic years — the only condition which had any injuries with a symmetrical 2 was all reported and recorded upper body injuries in 2014-2015 with a proportion of 0.09. Even though there was only one condition of significance among the groups, the lack of injury rates for the score of symmetrical 2 was notable.

Hypotheses 9 and 10

H9: There is a difference in shoulder injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H10: There is a difference in upper body injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

Another grouping explored by the researcher was the comparison of proportions of a 0 and 1 compared to scores of 2 and 3. This grouping came from the prescriptive exercise approach supported by FMS that scores of 0 and 1 were the first areas of intervention and a score of 2 or better was acceptable (FMS & Cook, 2010). Additionally, Hammes et al. (2016) grouped scores into 0 with 1 and 2 with 3 and found for adult soccer players that the lower active straight leg raise scores were linked to a greater injury incidence. However, in this study, no statistical significance in the 2014-2015 (see Table 16) or 2015-2016 (see Table 17) cohorts was identified. This finding did not support the corrective exercise intervention strategy of priority intervention with scores of 0 or 1.

Hypotheses 11 and 12

H11: There is a difference in shoulder injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H12: There is a difference in upper body injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

The researcher was also interested in separating the injury proportions by both shoulder mobility score and presence of asymmetry, as completed in Table 19. In this grouping, there were comparisons of symmetrical 0, asymmetrical 0, symmetrical 1, asymmetrical 1, symmetrical 2, asymmetrical 2, and symmetrical 3. Of note, based on the FMS scoring, an asymmetrical 3 was not possible to earn because the numerical score came from the lower score of the right and left sides. No statistical significance was indicated among any of the conditions for either academic year. However, for the 2014-2015 year in all reported and recorded shoulder injuries, the *p* of 0.0835 was close to significance; so, the researcher ran a *z*-test for difference in two proportions to explore the material further, after the χ^2 results. Table 20 indicated statistical significance of injury likelihood for scores of asymmetrical 0 compared to symmetrical 2 ($p = 0.0024$), symmetrical 3 ($p = 0.0434$), and asymmetrical 2 ($p = 0.0024$). Two comparisons also related to asymmetrical 0 were also close to significance, with the likelihood of injury decreasing compared to a symmetrical 1 ($p = 0.0798$) and an asymmetrical 1 ($p = .0566$). For the 2014-2015 cohort, the presence of an asymmetrical 0 generally increased the likelihood of injury compared to all other scores except for a symmetrical 0 (even though no athletes with a symmetrical 0 had any reported and recorded shoulder injuries). This suggested the presence of pain and asymmetry on the Shoulder Mobility test was a factor that could identify athletes at risk of injury. However, no other conditions in 2014-2015 or 2015-2016 indicated significance.

Hypothesis 13

H13: There is a difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts.

The researcher was also interested in the similarity of score breakdown from the 2014-2015 and the 2015-2016 cohorts. Table 21 showed the breakdown of scores from each year, with a sizable difference in the number of the scores of 0 (with four athletes in 2014-2015 and 17 athletes in 2015-2016). There was a statistically significant difference (p = 0.0087) between the two cohorts. Even though there was just one academic year between the cohorts, only 52 of the athletes completed the FMS for both years, indicating turnover from the 2014-2015 population of 45.8% of the team's 96 student-athletes who were tested in 2015-2016. The turnover in athletes likely explains why there was not agreement in significance among the conditions from one year to the other.

Research Question

How do educators in the fields of strength and conditioning and athletic training use the Functional Movement Screen to create data-driven interventions for student athletes?

The perceptions of the FMS from the strength and conditioning and athletic training personnel indicated mixed feelings about the effectiveness of the utilization of the tool on a football population. Concerns centered around the usefulness of the screen with a collision-based sport, as ideal movement patterns indicated by the FMS may have no bearing on some of the injuries sustained due to collision. However, the landmark study from Kiesel et al. (2007) centered on low FMS sum scores, injury likelihood, and football athletes. There were additional concerns about proper time to dedicate to the implementation of corrective exercise for athletes who had lower scores. Time was also limited by the priorities of the head sport coach and by the priorities of the athletic trainer and strength and conditioning coaches. If the FMS was not one of the priorities, then the time and effort necessary to dedicate to implement the screen, analyze the results, and program exercises based on the results was not available. The argument that, if nothing else, the FMS identified athletes who experienced a painful range of motion for intervention was not supported by the data that athletes who had a pain score on the Shoulder Mobility test, as indicated by a 0, were more likely to sustain a shoulder or upper body injury for both academic years. While the 2014-2015 year did show significance for scores of 0 compared to 2 for shoulder injury, the significance was eliminated when exploring injuries resulting in three or more days of missed play and when exploring the 2015-2016 cohort.

Additionally, the variation from year to year in terms of significant results may have indicated the lack of consistency of the FMS in the ability to identify athletes at an increased likelihood of injury at the shoulder or upper body, potentially because of the violent and unpredictable nature of the game of football. While the 2014-2015 cohort showed a number of statistically significant relationships, the 2015-2016 showed only one. With the lack of consistency from year to year, with athletes who were at a similar athletic ability; at the same level of play; in the same sport; and the same private, Midwestern, Division II institution — the author did not feel confident if these findings were to be translated to other institutions that the significance identified in 2014-2015 and the lack of significance in 2015-2016 were transferrable to another similar population, since they were not even transferrable from one year to the next.

With the variability in significant results from one year to the next, in light of the time and effort required to properly train screeners, physically screen the athletes, input and analyze the data, develop corrective exercise plans, and continue to progress the plans as athletes improve, it was questionable if the time spent was worthwhile for this population of private, Midwestern, Division II football athletes, for this specific FMS screen of shoulder mobility, and in relationship to shoulder and upper body injury incidence. For this population, there was a lack of the FMS to consistently identify increased likelihood of sustaining injury to the shoulder or upper body. This lack of consistency, combined with overarching concerns from the strength and conditioning and athletic training educators that there was little time to properly implement an intervention based on FMS results and the skepticism all educators expressed in the ability of the FMS to properly identify increased likelihood of injuries for football athletes, led the researcher to express doubt that the shoulder mobility component of the FMS was an effective use of time for the educators and the athletes.

In the interview with the 15-16 SC, it was indicated for the 2016-2017 academic year, the strength and conditioning staff was only utilizing the ‘little four’ tests of the seven in the FMS system for the football team. This approach was geared towards the hierarchy approach developed by Cook (2010), related to when intervention was needed and how it should have been triaged. Perhaps this approach would not have overwhelmed the AT and SC educators with information and would have helped them to focus on the important foundational functional movements. This approach would have only been beneficial if the other ‘little four’ components of the FMS — the active straight leg raise, the trunk stability pushup, and rotary stability — along with shoulder mobility, were either indicated individually or collectively to provide valuable information related to increased injury likelihood, increased performance, or other useful evidence.

Personal Reflections

The researcher selected the specific test of shoulder mobility from the battery of the Functional Movement Screen, because the test was the only test of the seven that focused on the upper body alone. This isolation assisted the researcher in linking upper body and shoulder injuries to this screen. In comparison, other tests in the FMS utilized a combination of upper and lower body movement and stabilization; so, a poor score on the test may have been influenced by a combination of body area dysfunctions. Additionally, this test was simple for athletes to perform and was indicated to have good reliability (Parenteau-G et al., 2015; Schneiders et al., 2011; Smith et al., 2013). Additionally, the researcher, as a former strength and conditioning professional herself, was interested in the shoulder mobility score as it, and the active straight leg raise test, awarded increasingly higher points to increased mobility at the given joint. Jansson et al. (2005) noted that more mobility may not always be ideal at any given joint. Because of these considerations, the researcher was very interested to explore if the score of a 2 would indicate a better movement pattern, as it was not too little or too much mobility. Some of the findings supported the researcher's questions related to increased mobility and increased risk of injury. However, this was not supported equally from the 2014-2015 cohort to the 2015-2016 cohort. Perhaps the increments of measurement for scoring a 1, 2, or 3 were too broad to conclusively identify a range of motion that was ideal.

The researcher was most surprised by the 2014-2015 shoulder injury resulting in three or more days of lost playing time in relationship to the presence of shoulder symmetry. The researcher did not expect that athletes with symmetrical shoulders would be statistically more likely to experience a shoulder injury compared to those with asymmetrical shoulders. It was also interesting that, while not significant, results were nearly significant for the same conditions in the 2015-2016 cohort ($p = 0.0623$). The expectation was that symmetrical shoulders would result in a decreased likelihood for injury, especially in a sport like football that was not particularly unilateral. These results may have been expected in a sport, such a softball or baseball, where the athletes often exhibited differences from left to right, due to the unilateral demands of the activity. Perhaps, athletes with symmetrical shoulders were more likely to be better athletes and to play, therefore exposing themselves to a higher injury likelihood, due to increased exposure from more playing time, as a similar rationale was utilized by Bardenett et al. (2015).

The differences in breakdown of scores and the lack of consistency of significance from the 2014-2015 to the 2015-2016 cohorts was of interest to the researcher. The jump from four athletes reporting pain on the Shoulder Mobility test in the 2014-2015 year compared with 17 athletes reporting pain the following year was of interest. The researcher wondered if the increased number of athletes reporting pain was related to an increased comfort level in reporting the presence of pain, an increased understanding of the intentions of the FMS by the athletes, a change in how — or even if — the tester inquired about the presence of pain during the test, and/or variability in how the testers recorded pain or discomfort expressed by the athletes. As noted by Parenteau-G et al. (2014), what constituted a painful pattern and was recorded as 0 may be a concern for interrater reliability and not all of the testers may have been of the same understanding of pain ratings from the 2014-2015 to 2015-2016 academic years.

It was also puzzling that in the 2015-2016 year, 17 athletes noted pain on the Shoulder Mobility test, but none of those athletes sought treatment for shoulder pain related to practice or weight training movement patterns. Was it that pain was not experienced or was it that they did not want to report the pain that they did experience? While there was turnover of the athletes on the team roster, the quality of the athlete, the type of training experienced, and the demands of a Division II football player were similar. However, with the variability of results from one year to the next, the researcher is hesitant to recommend that valuable time be spent on this specific test if the intention of screening is to identify athletes with an increased likelihood of experiencing shoulder or upper body injury. Historically, an entire day was set aside by the strength and conditioning staff to complete the FMS on the football team. If the strength and conditioning and athletic training staff wish to keep the test, a focus on the standardization of wording from the testers and a confirmation of agreement from the testers of how the presence of pain is defined and how/when it is inquired for each athlete, for each of the component tests is recommended.

Additionally, it would have been beneficial to note how each type of injury occurred to determine if there was a difference based on overuse injuries and collision based injuries. This could have alleviated some of the concern echoed by the athletic trainer and strength and conditioning coaches based on the violence of the game of football and the potential randomness of injury based on the collision aspects of the sport. Schroeder et al. (2016) eliminated collision-based injuries from the study, while Tee et al. (2016) included them, arguing that tackling technique was influenced by functional movement in rugby players.

Recommendations to the Program

During the interview process, both of the strength and conditioning coaches and the athletic trainer expressed concerns about the effectiveness of the FMS to identify injury likelihood for football athletes, based on the collision nature of the sport. This concern, in light of the lack of time able to dedicate to FMS-driven corrective exercise programming for such a large population, and the variability in significance from one cohort to the next, led the researcher to question the usefulness of the implementation of the screen. While the results of this study were limited to only the Shoulder Mobility test, with the lack of time in developing personalized correctives based on scores, the researcher did not support the use of the FMS screen just to say that it was being completed. If the FMS results were not being effectively communicated to the athletic training staff and the results were not being effectively integrated into a holistic training program, then the support for dedicating the limited time to complete, record, and analyze the FMS was limited. Because group corrective exercise was often utilized, rather than individualized correctives based on personal FMS scores, the rationale behind screening was lost. Additionally, if the athletic training department was not receiving comprehensive information about athletes who did experience painful patterns, and the athletic trainers, in turn, had limited time to work with athletes who may have experienced painful patterns on the screen, but did not experience enough pain to warrant a complaint during practice or games, then the usefulness of the screen was lost.

Recommendations for Future Research

In keeping with the football population, the researcher was interested in how scores may continue to track over time and if significance would continue to vary with the influx of new athletes, or if trends would eventually emerge. Future research should continue with shoulder mobility scores and injury incidence with other populations of athletes and non-athletes, who are not involved in collision-related sports or activities. Additionally, it would be of interest to explore other FMS tests to see how they individually are related to injury incidence of different body areas. The researcher would also be interested in digging deeper into the football population with shoulder mobility and injury, while also controlling for previously experienced injuries and a more controlled environment for collecting FMS test data. The researcher is also interested in exploring how FMS scores impact more severe or long-lasting injury, perhaps that classified by being out from play for at least 30 days. Additionally, injuries could be classified as collision related or overuse, and the categories could be compared rather than grouping all injuries together, as was done in the then-present study.

With the football population (or any population), it would be of benefit to look beyond the shoulder and the upper body due to the concept of regional interdependence. Regional interdependence stated that poor movement in one area may lead to injury or dysfunction of another area, and alternatively, injury or dysfunction in an area may result in poor movement of another area (Cook et al., 2014a). With the relationship of regional interdependence, dysfunction at the shoulder may manifest itself in places other than the shoulder or upper body, such as the cervical, thoracic, or lumbar spine.

An exploration of this study with different populations is of interest, looking potentially at populations with historically greater mobility, such as females and children and how these considerations may manifest themselves differently. Alternatively, older populations, who exhibit generally less mobility would also provide an interesting angle.

A modified FMS for specific populations, such as the elderly, was recently introduced and an exploration how that assessment works compared to the standard FMS would also be of interest (Functional Movement, 2017a). In looking at different populations, an expanded study of FMS changes throughout the lifecycle and how that may relate to injury incidence or performance test changes would be fascinating.

Specifically focusing on the shoulder mobility screen, an exploration of the different measurements and the units of measurement may be problematic in the then-current set up. The range of scores may need to be increased to better differentiate a ‘good’ from a ‘poor’ score. This would also influence symmetry measurements, as scores would have to be closer together to be indicated as symmetrical. It would be interesting to measure in inches and then create either a set measurement range or a proportion based on hand size to identify ideal movement.

Another consideration would be to combine these studies with barriers for athletes or other populations in terms of reporting injuries. Athletic trainers and strength and conditioning professionals may not know about injuries unless they are informed by the individual. If there is a barrier to reporting injuries, or a barrier to reporting pain while completing the Functional Movement Screen, the results gathered were not accurate.

In any of the potential studies, more frequent screening would be a good foundation. As Cook (2010) suggested, “Screening is not a one-time thing” (p. 50). With changes in physical activity over the course of an athletic season or changes in physical activity over the course of a typical year for the general population, the variation in scores may contribute to variable injury incidence.

Bardenett et al. (2015) suggested that athletes with higher FMS scores, and therefore, more functional movement, were more likely to be better athletes and to have increased playing time and therefore increased likelihood of injury. This theory was not supported by any studies to the researcher's knowledge, but it was an interesting explanation for a lack of relationship between FMS score and injury likelihood. A related study may track time on the field in conjunction with injury likelihood and FMS scores.

Conclusion

The utilization of the Functional Movement Screen sum scores to identify individuals with increased likelihood of injury was supported in some studies (Bushman et al., 2016; Chorba et al., 2010; Clay et al., 2016; Cosio-Lima et al., 2016; Garrison et al., 2015; Kiesel et al., 2007; Kiesel et al., 2014; O'Connor et al., 2011), was lacking in other studies (Bardenett et al., 2015; Dossa, Cashman, Howitt, West, & Murray, 2014; Hotta et al., 2015; Mokha et al., 2016; Warren et al., 2015), and the practice overall was unsupported by the developer of the FMS (Cook et al., 2014). However, the foundational study by Kiesel et al. (2007) set a precedent for other researchers to explore if and how low combined sum scores on the FMS may contribute to identification of injury likelihood. As established by Kazman et al. (2014), concerns about factor structure decreased the appropriateness of utilizing the full Functional Movement Screen sum score. To that end, the researcher was interested in exploring how one specific screen, the shoulder mobility screen, was related to a specific body area, the shoulder and upper body, for injury incidence in collegiate Division II football athletes.

The intention of this research was to begin exploring specific screens and the relationship with specific body areas of injury. If the FMS total sum score was not developed to identify injury (Cook et al., 2014b), but one of the intentions of the FMS was to identify faulty movement patterns that may lead to injury (Cook et al., 2014b), then it was necessary to isolate the specific tests and the specific injuries. The researcher chose the Shoulder Mobility test, specifically due to its good reliability (Parenteau-G et al., 2014; Teyhenet al., 2012a), the isolation of a particular body area, and the simple linking of the pattern to injuries related to that same body area. The researcher chose the football population due to the larger relative size of a team in comparison to other teams and the increased likelihood of injuries occurring due to the nature of the sport. The researcher used two academic years of data to explore if trends could be established past one academic year. Beyond the secondary data of the FMS scores collected by the strength and conditioning staff and the injury data collected by the athletic training staff, the researcher also explored the perceptions and limitations of the utilization of the FMS by the head football athletic trainer and the head football strength and conditioning coaches at the time of data collection.

The secondary data was compiled and organized in a multitude of ways to establish relationships and was viewed through the lens of the perceptions and limitations identified by the athletic trainer and strength coaches. The organization of data was expressed to explore injury incidence at the shoulder and upper body in light of: shoulder mobility sum score; grouping of 0, 1, and 3 compared to score of 2; asymmetry presence; 0, 1, 2 with asymmetry, and 3 compared to a symmetrical 2; 0 and 1 compared to 2 and 3; and shoulder mobility score and asymmetry status.

Significant results were identified for the 2014-2015 cohort for an increased likelihood of all reported and recorded shoulder injuries and the scores of 0 compared to scores of 2; scores of 0, 1, and 3 compared to scores of 2; scores of asymmetrical 0 compared to symmetrical 2; scores of asymmetrical 0 compared to symmetrical 3; and scores of asymmetrical 0 compared to asymmetrical 2. Significant results were also identified for the 2014-2015 cohort for an increased likelihood of shoulder injuries resulting in three or more days of lost playing time for athletes who had symmetrical scores compared to asymmetrical scores. Significant upper body injury incidence rates were identified for scores of 0, 1, and 3 compared to 2 for all reported and recorded injuries and for injuries resulting in three or more days of lost playing time. In the 2015-2016 cohort, the only significant results were for all reported and recorded upper body injuries with a higher likelihood of injury for those grouped with scores of 0, 1, 2 with asymmetry, and 3 compared to 2 with symmetry. The interviews with the athletic training and strength and conditioning educators resulted in common concerns regarding the violent nature of the sport of football and the overarching applicability of the FMS in the identification of injuries, the lack of time and focus on functional movement scores and implications, and opportunities for improvement in the communication between the strength and conditioning and athletic training staff.

While many significant relationships were identified between injury and FMS shoulder mobility scores in the 2014-2015 cohort, there was only one in the 2015-2016 cohort. Because of the lack of transferability of results from one year to the next, the researcher was hesitant to expect the transferability of these results to a different team, at a different school, with different coaches. These results, in light of the lack of time and expectations of the educators that the FMS may not be a valid tool for the football population in general, led the researcher to recommend that this screening tool not be utilized by this school. The intention of this screening tool was to provide individual data to help the strength and conditioning staff and athletic training staff to individually meet the needs of student-athletes. During the two years studied, the FMS scores were used to identify trends within the team rather than individual results and to prescribe corrective exercise based on those trends. With a sport as large as football and the time barriers faced by the strength and conditioning and athletic training personnel, the benefits of using the Shoulder Mobility test of the FMS to identify athletes at an increased likelihood of upper body injury were not consistently supported by this study. Perhaps other components of the screen were more reliable indicators of injury likelihood consistently over cohorts and may be more beneficial for educators.

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Appendix A: Athletic Trainer Interview Questions

Describe your role as an athletic trainer in the prevention of injuries.

How do you use FMS scores in the evaluation and treatment of student-athlete injuries?

Describe any barriers you face professionally in using FMS scores of student-athletes.

Describe your view on the ability of the FMS to identify student-athletes with an increased likelihood of injury.

Describe your injury reporting practice.

> Please describe any professionally accepted times when an athlete encounter about an injury does not result in the documentation of the injury?
>
> Describe any changes in the reporting/recording of injuries from the 2014-2015 to 2015-2016 academic years?

Describe your relationship with the Strength and Conditioning staff who work with football.

> What methods of communication did you use?
>
> How frequently did you communicate?

Describe any changes in the staffing of Athletic Trainers for the football team from the 2014-2015 to 2015-2016 academic years?

Describe how data collection practices may change from one AT to the next? Is there a minimum use expectation for injury reporting into Sportsware Online?

Appendix B: Strength and Conditioning Coach Interview Questions

While programming for football:

How did you use FMS scores to prescribe corrective exercise for your athletes?

Did you prescribe corrective exercises for the shoulder/thoracic spine to be performed for all athletes?

If yes, how frequently (daily, weekly, etc.) were corrective exercises for that body area utilized?

What was your process for communicating concerning FMS scores to the Athletic Trainer?

What information did you include?

How did you use the FMS in prescribing exercise?

Did you use FMS scores to eliminate certain exercises for individual student-athletes?

What types of exercises did you eliminate for shoulder mobility concerns?

Appendix C: Hypotheses

H_1 There is a difference in shoulder injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_{01} There is no difference in shoulder injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_2 There is a difference in upper body injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_{02} There is no difference in upper body injury incidence rates for collegiate football athletes based on shoulder mobility sum score

H_3 There is a difference in shoulder injury incidence rates for collegiate football athletes who have shoulder mobility sum scores of 0, 1, and 3 compared to a score of a 2.

H_{03} There is no difference in the shoulder injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to a score of 2.

H_4 There is a difference in upper body injury incidence rates for collegiate football athletes who have shoulder mobility sum scores of 0, 1, and 3 compared to a score of a 2.

H_{04} There is no difference in the upper body injury rate for collegiate football athletes with shoulder mobility scores of 0, 1, and 3 compared to a score of 2.

H_5 There is a difference in shoulder injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_{05} There is no difference in shoulder injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_6 There is a difference in of upper body injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_{06} There is no difference in upper body injury incidence for collegiate football athletes who exhibit shoulder mobility asymmetry compared to those who do not have asymmetry, as measured by the Functional Movement Screen.

H_7 There is a difference in shoulder injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_{07} There is no difference in shoulder injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_8 There is a difference in upper body injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_{08} There is no difference in upper body injury incidence for collegiate football athletes who score a 0, 1, 2 with asymmetry, or 3 compared to a score of 2 without asymmetry.

H_9 There is a difference in shoulder injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H_{09} There is no difference in shoulder injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H_{10} There is a difference in upper body injury incidence for collegiate football athletes who score a 0 or 1 compared to a score of 2 or 3.

H_{010} There is no difference in upper body injury incidence for collegiate football athletes who score a 0 or 1 compared to a score or 2 or 3.

H_{11} There is a difference in shoulder injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{011} There is no difference in shoulder injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{12} There is a difference in upper body injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{012} There is no difference in upper body injury incidence for collegiate football athletes based on their shoulder mobility score and asymmetry status.

H_{13} There is a difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts.

H_{013} There is no difference in frequency counts of shoulder mobility scores between the 2014-2015 and 2015-2016 collegiate football athlete cohorts.

Vitae

Jessica L. Randolph earned a Bachelor of Arts in Biology from Carthage College in Kenosha, Wisconsin in 2007. She earned a Master of Science in Sports Science and Rehabilitation from Logan University in Chesterfield, Missouri in 2008. She anticipates completion of her Educational Doctorate in Instructional Leadership from Lindenwood University in St. Charles, MO in 2017.

Jessica has spent her entire higher education professional career at Lindenwood University. She began teaching classes in the Exercise Science department in 2009 and continues to do so. Also at that time she served as a strength and conditioning coach for a variety of teams, a position that she held from 2009-2015. In 2015, she shifted to the Director of the Fitness Center while adding additional academic responsibilities. Most recently, in 2016 she began the role as Program Director of Exercise Science.