ASSOCIATION OF FUNCTIONAL MOVEMENT AND INJURY INCIDENCE IN COLLEGIATE SOCCER ATHLETES

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Association of Functional Movement and Injury in Collegiate Soccer Athletes

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Abstract

Tools such as the Functional Movement Screen (FMS) and Y-Balance Test Lower Quarter (YBT-LQ) have been used to assess quality of functional movement. To date, research has been inconclusive regarding the association between performance on the FMS and YBT-LQ and lower extremity injury incidence in collegiate soccer athletes. The purpose of this retrospective study was to explore whether functional movement, as measured by the FMS and Y-balance tests, in junction with athlete demographics, is associated with lower extremity injury. The study included retrospective data collected on 143 men's and women's soccer athletes over three years (2014-2016) from NCAA Division III Lebanon Valley College located in south-central Pennsylvania. Using chi-square tests and Mann Whitney *U* tests, functional movement and demographic data were compared to determine if differences existed in the data in relation to injury categories. In addition, gender differences between the FMS and YBT-LQ were explored. Gender, body mass index, injury history, FMS composite score, and YBT-LQ reach asymmetries were not associated with lower extremity injury. Additionally, the scores were not related to lower extremity noncontact injury categories. There were no significant differences between genders in YBT-LQ reach asymmetries or in the FMS CS. However, significant differences between genders were noted on ASLR and trunk stability push-up components of the FMS. Future research should seek to establish population-specific normative data for, and clinical utility of, the FMS and YBT-LQ. Clinicians should use caution in using any of these factors in isolation in clinical decision making with regard to injury prevention and return to play after injury.

Keywords: functional movement, Functional Movement Screen, Y-Balance, soccer, injury, lower extremity injury, noncontact injury

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Association of Functional Movement and Injury in Collegiate Soccer Athletes

It has been estimated that annually, over 210,500 injuries (6.0 per 1,000 athlete-exposures) occur as a result of National Collegiate Athletic Association (NCAA) sports play. Men's and women's NCAA soccer are among the sports with the highest reported rates of injury with 8.0 and 8.4 injured per 1,000 exposures, respectively (Kerr et al., 2015). Of those injuries, approximately three-quarters occurred in the lower extremity (DiStefano et al., 2018; Kerr et al., 2018; Roos et al., 2017). The most frequent mechanisms for injury during men's and women's soccer practices are noncontact in nature (DiStefano et al., 2018; Kerr et al., 2018). Thus, lower extremity noncontact injuries have proven problematic in collegiate soccer.

Soccer participation has grown to become among the highest in the NCAA. From 1981-1982 season to 2017-2018 season, the number of rostered NCAA soccer athletes increased nationally from 1,855 to 27,883 for women and from 12,957 to 25,072 for men (Irick, 2018). With participation in soccer on the rise, it is important to examine lower extremity injury risk factors in this population of athletes. The full understanding of factors associated with increased occurrence of injury remains unclear despite the frequency of noncontact injuries in men's and women's soccer athletes. Researchers have investigated the predictive ability of various factors and algorithms, including injury history, gender, and sport (Chimera, Smith, & Warren, 2015; Fousekis, Tsepis, Poulmedis, Athanasopoulos, & Vagenas, 2011). In addition, biomechanical factors such as isokinetic hamstring to quadriceps strength ratios have been studied relative to predicting lower extremity injuries (Dauty, Menu, & Fouasson-Chailloux, 2018). Most recently, neuromuscular screening tools, including the Functional Movement Screen (FMS) and Y-Balance Test - Lower Quarter (YBT-LQ), aimed at assessing functional movement quality, have been investigated. Some early researchers reported promising results related to the ability of functional movement pattern assessment to predict injury (Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Gonell, Romero, & Soler, 2015; Huebner, Plisky, Kiesel, & Schwartzkopf-Phifer, 2019; Kiesel, Plisky, & Voight, 2007; Lehr et al., 2013). Thus, it may be possible to use functional movement screens to identify deficits that may be contributing factors to increased rates of lower extremity injury, which have been troublesome in soccer.

The purpose of this retrospective study was to explore whether functional movement, as measured by the FMS and Y-balance tests, in junction with athlete demographics, is associated with lower extremity injury in NCAA Division III men's and women's soccer athletes. The study addressed the following primary research question:

- Is there a significant difference in functional movement, as measured with the frequency of FMS composite score (FMS CS) and the YBT-LQ injury risk categories, among NCAA Division III soccer athletes who sustained a lower extremity injury versus those who did not sustain a lower extremity injury?

Additionally, the following secondary questions were explored:

1. Is there a significant difference in the frequency of FMS CS and YBT-LQ injury risk categories among NCAA Division III soccer athletes who sustained a lower extremity noncontact injury versus those who did not sustain any injury?
2. Is athlete body mass indices (BMI) and history of recent injury associated with the presence and absence of lower extremity injuries in NCAA Division III soccer athletes?
3. Is there a significant difference in presence and no presence of lower extremity injuries between male and female NCAA Division III soccer athletes?
4. Is there a significant difference in functional movement, as measured by FMS CS

scores, FMS individual test score frequency, and YBT-LQ direction scores, between male and female NCAA Division III soccer athletes?

A study of the association between variables such as FMS scores and YBT-LQ scores and injury is relevant to clinicians and researchers for several reasons. First, clinicians interested in reducing incidence of injury may use functional movement screening tools during the pre-participation process to screen athletes at risk and employ strategies to mitigate injury risk. Second, clinicians making return to play decisions after injury could use functional movement screens results to aid in their decision-making process as they aim to return athletes to play as quickly and safely as possible. Finally, the results from this study in functional movement screens and associations with injury add to the existing literature by examining a large cohort of men's and women's soccer athletes. Specifically, the sample size is a larger sample size than many previous studies, and the focus on one sport group eliminates preexisting confounding variables related to type of sport played.

Literature Review

Epidemiology of Soccer Injuries

Over 210,500 annual injuries (6.0 per 1,000 athlete-exposures) are estimated to occur as a result of NCAA sport play (Kerr et al., 2015). Men's and women's soccer are among the sports with the highest number of injuries per year with 13,435 (8.0 per 1,000 athlete-exposures) and 15,113 (8.4 per 1,000 athlete-exposures) injuries respectively (Kerr et al., 2015; Roos et al., 2017). Only football and men's basketball reported a higher number of injuries annually (Kerr et al., 2015). These figures show that men's and women's soccer injuries constituted approximately 13% of the total annual injuries, as reported by 25 different sports (Kerr et al., 2015; Roos et al., 2017). As evidenced by the rates above, a higher than average injury per exposure rate was displayed (Kerr et al., 2015; Roos et al., 2017). It is apparent that men's and women's collegiate soccer athletes are at a higher than average risk for sustaining an injury as compared to other sports.

It is vital to quantify injuries and to understand the types of injuries sustained by soccer athletes. While data show specific epidemiological nuances between type and occurrence of injuries between men's and women's soccer, several general assertions can be made. First, roughly three-quarters of all reported injuries in men's and women's soccer occurred to the lower extremity during practices and competitions (DiStefano et al., 2018; Kerr et al., 2018; Roos et al., 2017). Because soccer involves a heavy emphasis on lower extremity tasks like kicking, running, cutting, and dribbling, it is not surprising that its athletes are at an increased risk of sustaining lower extremity injuries.

Second, approximately half of all reported injuries were due to a combination of noncontact and overuse mechanisms of injury during practices (DiStefano et al., 2018; Kerr et al., 2018; Roos et al., 2017). Finally, athletes are frequently assessed and treated for an injury that results in no restrictions in participation. These injuries are referred to as *non-time loss injuries* (Dompier, Marshall, Kerr, & Hayden, 2015; Kerr et al., 2014). Often injuries that result in no restrictions on participation happen as a result of overuse or noncontact mechanisms of injury and are still treated and managed by the sports medicine staff (Roos et al., 2017). However, non-time loss injuries are underrepresented in the literature. Despite the paucity of data surrounding non-time loss injuries, they have been estimated to account for nearly half (47%) of all injuries (Roos et al., 2017). Management of non-time loss injuries incur increases in time, attention, and resources from a medical standpoint. Thus, it may be vital to include injuries that do not result in time loss when considering factors associated with noncontact mechanisms of injury.

Injury Risk Factors

Within the sports of men's and women's soccer, lower extremity noncontact muscle injuries are common (DiStefano et al., 2018; Kerr et al., 2018; Roos et al., 2017). However, it may be possible to identify risk factors for lower extremity injuries, which are troublesome to soccer athletes. While injury-causing events involving contact with another player or object may not be modifiable, factors contributing to noncontact injury events may prove modifiable. In particular, identifying modifiable risk factors and strategies aimed at reducing incidences of injury is of interest to many stakeholders such as athletes, coaches, athletic trainers, strength and conditioning coaches, and researchers.

Intrinsic and extrinsic risk factors may play a role in the occurrence of noncontact injuries. Extrinsic risk factors include type and quality of the playing surface, footwear, and environmental factors such as rain and field grade (Orchard, Seward, McGivern, & Hood, 2001). Intrinsic factors, or player characteristics, that have been shown to contribute to injury risk include variables such as height and weight (Fousekis et al., 2011), aerobic fitness (Lisman, O'Connor, Deuster, & Knapik, 2013), injury history (Fousekis et al., 2011; Orchard et al., 2001), and muscle strength and flexibility factors (Dauty et al., 2018; Fousekis et al., 2011). Many types of intrinsic variables are collected routinely by medical staff in NCAA athletics and may have associations with injury risk. However, incorporation of movement screening as part of the pre-participation examination is not routine (Cook, Burton, & Hoogenboom, 2006). Consideration of the association between various regularly collected variables in junction with movement screening could provide valuable insight into injury risk factors.

Movement Screening in Sport

Athlete safety and readiness to participate in sport have long been assessed through medical pre-participation examinations and subsequent sports performance testing. However, assessment of fundamental movement patterns required for sport-specific movements is lacking. Tests such as the FMS and YBT-LQ are assessment tools that may fill the gap between medical clearance and sport performance testing (Cook et al., 2006; Plisky et al., 2009). The FMS consists of a battery of seven individual movement pattern tests, each with a possible score ranging from 0-3 for a total possible score of 21 (Cook, 2015). It was developed as a means of standardizing and measuring functional movement patterns and combines factors such as stability, functional asymmetries, and dynamic balance (Cook, 2015; Cook et al., 2006). The practical intent of the FMS is for clinicians to have a means of screening to identify movement dysfunction as well as establishing a standardized means of communication between sports medicine and performance enhancement teams (Cook, 2015; Cook et al., 2006). Similarly, the YBT-LQ, derived from the Star Excursion Balance Test, assesses for functional movement and dynamic balance deficits to the lower extremity (Plisky et al., 2009). While the emphasis on creating screening tools aimed at identifying movement dysfunction may serve as a guide for clinicians in their practice, it is unclear if quality of functional movement leads to increased injury incidence.

Researchers interested in identifying injury risk factors quickly gained interest in studying the association between functional movement screens such as the FMS and YBT-LQ and injury due to some early studies. Kiesel et al. (2007) were the first to publish promising results on the topic; they reported an eleven-fold increased risk of injury in a cohort of professional football athletes with an FMSCS of 14 or less out of 21 possible. This landmark study established the cutoff commonly used by clinicians of 14 and was supported by Chorba et al. (2010), who found a fourfold increase in injury risk using the same cutoff for a group of NCAA Division II female soccer, volleyball, and basketball athletes. Garrison et al. (2015) further supported the cut score of 14, reporting a 15-fold increase in injury risk in a group of NCAA Division I varsity and club athletes from a variety of unspecified sports. Similarly, some researchers reported that greater than a 4 cm bilateral reach variance in the YBT-LQ resulted in an increased likelihood of injury (Gonell et al., 2015; Smith, Chimera, & Warren, 2015).

However, research shows inconsistent findings when it comes to an association between increased injury incidence and FMS and YBT-LQ composite scores. Some researchers found a greater association with individual battery test scores or right versus left-sided asymmetries rather than composite scores on the FMS and YBT-LQ (Fousekis et al., 2011; Mokha, Sprague, & Gatens, 2016; Warren, Smith, & Chimera, 2015). For example, Mokha et al. (2016) found no increased likelihood of injury associated with FMS composite score. However, they did identify an increased likelihood associated with any recorded asymmetry or individual test scores of one or less (out of a possible three). Meanwhile, other researchers found increases in predictive ability of the FMS composite scores only when combined with other risk factors such as injury history (Garrison et al., 2015) or age (Cosio-Lima et al., 2016). Still, several researchers found no association between injury and the FMS (Dorrel, Long, Shaffer, & Myer, 2018; Lisman, Hildebrand, Nadelen, & Leppert, 2019; Smith & Hanlon, 2017; Walbright, Walbright, Ojha, & Davenport, 2017; Warren et al., 2015) or YBT-LQ (Lai et al., 2017; Lisman et al., 2019; Walbright et al., 2017; Wright, Dischiavi, Smoliga, Taylor, & Hegedus, 2017) in collegiate athletes. The association between incidences of injury and variables such as performance on functional movement screens remains unclear in the literature. Additional studies are warranted to identify trends that either support or refute associations between injury incidence and functional movement.

Movement Screening in Other Populations

While the FMS and YBT-LQ are primarily geared toward traditional athletic groups, other physically active populations have taken an interest in these tests. The military is a large, physically active population for which the prospect of injury reduction via identification of modifiable risk factors has garnered attention (de la Motte, Gribbin, Lisman, Beutler, & Deuster, 2017; Lisman et al., 2013; Teyhen, 2014). Similar to baseline screening done during the PPE process in athletics, the military has used various functional movement screens, including the FMS and YBT-LQ, as part of the entrance examination process or physical fitness testing (de la Motte et al., 2017; Lisman et al., 2013). Specific aims of these initiatives include establishing population specific norms (de la Motte et al., 2017; Teyhen, 2014), reliability testing (Shaffer et al., 2013), and injury prediction (Cosio-Lima et al., 2016; Lisman et al., 2013). Lisman et al. (2013) found increases in injury occurrence when FMS CS was combined with other variables such as aerobic fitness. Meanwhile, Cosio-Lima (2016) reported associations between increased injury incidence with both increased age and lower FMS CS (< 14) but no association with YBT-LQ scores.

Occupational medicine also has a vested interest in exploring functional movement screening, particularly in fields requiring a high level of physical activity such as first responders and performing arts professionals. Butler et al. (2013) identified an increased association between injury incidence and both the FMS CS as well as two of the seven individual FMS components (deep squat and trunk stability push-up) in a group of firefighters during training. In performing arts, recent studies have been aimed at seeking associations between various functional movement screening tests and loading forces, which are considered precursors to many overuse dance injuries (Armstrong, 2020; Armstrong, Brogden, Milner, Norris, & Greig, 2018).

Injury Prediction Challenges

Identification of methods aimed at predicting injuries is challenging to establish due to the complexity of confounding variables. Basic demographics such as age (Cosio-Lima et al., 2016; Warren et al., 2015), previous history of injury (Chorba et al., 2010; Fousekis et al., 2011; Garrison et al., 2015; Warren et al., 2015), gender and sport (DiStefano et al., 2018; Dompier et al., 2015; Eckard, Kerr, Padua, Djoko, & Dompier, 2017; Kerr et al., 2015; Kerr et al., 2018; Roos et al., 2017; Tenan, 2016), and anthropometric data such as height, weight, and body mass index (BMI) (Fousekis et al., 2011; Warren et al., 2015) have been reported to play a role in increased injury incidence. Of note, the association between increased injury incidence and FMS score reported by Chorba et al. (2010), was only supported when patients with a history of anterior cruciate ligament repair (ACLR) were excluded from the data. This exclusionary finding suggests a possible positive association between history of injuries and the role of subsequent rehabilitation with higher FMS scores. While history of injury is thought to increase injury incidence, in this case, the authors suggested that the significant lower extremity strength, conditioning, and neuromuscular training involved in post ACLR rehabilitation, may have resulted in increased FMS scores and decreased injury incidence (Chorba et al., 2010). Since improved performance on the FMS has been demonstrated via an injury prevention intervention program (Huebner et al., 2019), it is possible that post-injury rehabilitation can improve a patient's functional movement to above baseline and, in turn, decrease injury risk. An additional consideration includes the causality of interacting variables. For example, a history of injury and specific FMS components were found to be related. However, it is not clear if movement dysfunction(s) caused the initial injury or if the effects of the injury resulted in subsequent movement dysfunction (Chimera et al., 2015).

Limitations identified in previous studies include consideration of confounding variables. For instance, all published studies that compared gender differences included a variety of sports, many of which do not have comparable opposite gender counterparts such as football (men's) and field hockey (women's) (Chimera et al., 2015; Lai et al., 2017; Mokha et al., 2016). No known studies have sampled a male and female population who exclusively play the same sport as a means of controlling for sport differences between genders, such as soccer. Soccer, commonly played worldwide, maintains consistent rules and style of play between men's and women's soccer, allowing for greater confidence in findings relative to gender differences. The prevalence of soccer around the world and consistency of play between genders makes it an ideal sport to research.

Another limitation noted involves the operational definition of *injury* used in each study. Some researchers included only significant injuries, as defined by varying amounts of playing time lost (Dauty et al., 2018; Fousekis et al., 2011; Gonell et al., 2015; Kiesel et al., 2007; Lai et al., 2017; Lisman et al., 2019; Walbright et al., 2017). For the NCAA's Injury Surveillance System, an epidemiological database gathering data from many NCAA institutions, a reported injury was operationalized to include only time-loss injuries. However, this definition was also noted to be a limitation in capturing a significant number of injuries that result in no time loss but still require medical attention and resources (Dompier et al., 2015; Kerr et al., 2014; Roos et al., 2017). Thus, other researchers defined injury to include minor injuries or non-time loss injuries (Chorba et al., 2010; Dorrel et al., 2018; Lisman et al., 2013; Mokha et al., 2016; Smith & Hanlon, 2017; Warren et al., 2015).

Additional limitations in previous studies include small sample sizes (Chorba et al., 2010; Dossa, Cashman, Howitt, West, & Murray, 2014; Lisman et al., 2019; Mokha et al., 2016; Walbright et al., 2017; Warren et al., 2015), sport inconsistency between gender groups (Chimera et al., 2015; Lai et al., 2017; Mokha et al., 2016; Warren et al., 2015), a short length of injury surveillance (Smith & Hanlon, 2017), and inability to account for confounding variables (Chimera et al., 2015; Garrison et al., 2015; Kiesel et al., 2007; Lai et al., 2017; Mokha et al., 2016; Walbright et al., 2017). The numerous limitations identified in research studies to date add to the rationale that more studies are needed in this area.

Injury prediction variables have proven too numerous and diverse to tackle with consistent results in a few landmark studies. As a result, researchers parse-out related independent and dependent variables into smaller, more manageable studies. Although the current literature is extensive and rich, it does not paint a complete picture. Researching the sport of soccer and factors associated with common injuries that occur within the sport, improves the generalizability of the study and may have clinical applications.

Clinical Application

Functional assessment screening tools aim to bridge the gap between PPEs and sport-specific performance testing (Cook et al., 2006). Tests designed to fill this void supply clinicians with a screening tool that has two main practical applications. First, practitioners involved in injury prevention, have a particular interest in identifying modifiable injury risk factors. In the case of poor functional movement, clinicians seek to implement interventions aimed at correcting dysfunctional movement in order to decrease injury risk (Chorba et al., 2010; Gonell et al., 2015; Huebner et al., 2019). Second, clinicians involved in rehabilitation and return to play decisions after an injury occurs can use functional movement screens as a guide to symmetrical and optimal movement quality and as a benchmark in the process of returning to sport participation (Chorba et al., 2010; Doherty et al., 2015; Gonell et al., 2015; Kiesel et al., 2007; Lehr et al., 2013). In order to make informed decisions, clinicians need to understand the clinical utility of such tools as well as have access to population-specific normative data (Agresta, Slobodinsky, & Tucker, 2014; de la Motte et al., 2017; Teyhen, 2014)

More evidence is needed to enable clinicians to make decisions on how best to utilize the FMS and YBT-LQ tools in their practice. In addition, access to normative data representative of specific populations is critical to decisions surrounding injury prevention and return to sport after injury. Therefore, this retrospective cohort study aims to fill some critical gaps in the literature, contributing to the larger picture of the role of functional movement screens in identification of injury risk.

Method

Study Design

This was a non-experimental study using a retrospective cohort study design. The study took place at Lebanon Valley College (LVC) in the Athletic Training department, where the data are stored. The study occurred between January 2020 and April 2020. Prior to data collection, institutional review board approval was obtained from LVC, (Appendix A) and a reliance agreement was established between LVC and University of Indianapolis (Appendix B).

Participants

A convenience sample of 143 athletes, including all rostered NCAA Division III men's and women's soccer team members at LVC, was included in this study. Inclusion criteria included all rostered athletes who remained on the active roster for the 2014-2015, 2015-2016, and 2016-2017 seasons. At the time of testing, athletes were asked if they had sustained a significant musculoskeletal injury or concussion in the previous six months that caused or (in the case of offseason) would have caused loss in playing time. Exclusion criteria included athletes who were not medically cleared for unrestricted athletic participation at the time of testing.

Data Collection

Data from the academic years 2014-2015, 2015-2016, and 2016-2017 were extracted from Athletic Trainer System (ATS), the electronic health record used to record athlete data, from patient paper charts, and from the college's network drive. Lower extremity injury (yes/no) and mechanism (contact/noncontact) was collected from ATS. For each athlete the following data were collected from either the athlete's paper chart or from the college's network drive depending on the storage method used for athlete health records: the maximum of each of three YBT-LQ directions (cm), lower limb length (cm), individual and composite FMS scores, gender (male/female), age, height, weight, and recent injury history. See Figure 1 for organizational flow of data collection sources.

Operationalization of variables. For the purpose of this study, *injury* was defined as any musculoskeletal injury that occurred as a result of participation in an NCAA team-related practice or competition and required medical attention or the athlete sought advice from a certified athletic trainer or other health care provider. *Lower extremity injuries* included all injuries to the hip and distal. *Noncontact* injuries were those injuries that occurred in the absence of contact with a player, ball, or equipment, as recorded by the evaluating athletic trainer. *Functional movement* was measured by the FMS and YBT-LQ tests. *High-risk* and *low-risk* categories were defined using the common cut scores for each functional movement test. For FMS, high-risk was defined as those individuals who scored a 14 or less (Kiesel et al., 2007). For YBT-LQ, high-risk was defined as those individuals who scored a 4.0 cm or higher normalized reach distance asymmetry in any direction (Gonell et al., 2015).

Instruments

Functional movement screen. The FMS is a screening tool used to evaluate functional movement in a physically active population. It consists of a battery of seven individual tests, each with a possible score ranging from 0-3 for a total possible score of 21 (Cook et al., 2006). A score of zero is assigned if pain was present at any time during that test or with any positive clearing tests. A score of one is given if the participant was unable to complete the movement pattern as instructed. A two is assigned if the movement was completed via compensatory movement strategies. And a score of three indicates correct completion of the movement pattern as instructed (Cook et al., 2006).

The most commonly accepted cutoff score for the FMS CS is 14, where those with an FMS CS of 14 or less are considered to be at a higher injury risk (Kiesel et al., 2007). Good interrater (ICC = .81 [95% CI, .70, .92]) and intrarater (ICC = .81 [95% CI, .69, .92]) reliability have been pooled and reported in military and athlete populations for the FMS (Bonazza, Dhawan, Smuin, Onks, & Silvis, 2017).

Y-balance lower quarter. The YBT-LQ is a tool used to assess single-leg dynamic balance. Derived from the star excursion balance tests, it assesses reach distance in cm of the non-stance foot in three directions: anterior, posteromedial, and posterolateral (See Figure 2 for diagram of directional excursions of non-stance foot). Normalized reach difference is calculated and recorded by dividing the reach distance by the limb length (Gonell et al., 2015; Lai et al., 2017). A validated cutoff score for right versus left normalized reach distance difference on the YBT-LQ is 4.0 cm, where those with a YBT-LQ of 4.0 cm or more left to right reach asymmetry are considered to be at a higher injury risk (Gonell et al., 2015). Good interrater test-retest reliability (ICC (2, 3) = .85-.93), measurement error (*SEM* = 2.0 - 3.5 cm and MDC values = 5.5 - 9.7 cm) have been demonstrated in an active adult (military) population for the YBT-LQ (Shaffer et al., 2013).

Procedures

Data collection. Each year the LVC athletic trainers collected baseline functional movement screen data via the YBT-LQ and FMS during the annual pre-participation examinations in August. The head athletic trainer and a collaborating physical therapy faculty member held certifications in movement screenings using the FMS. Together, the two members of the sports medicine team at LVC, held annual trainings for the assessors prior to data collection to learn, review, and practice the test protocols on live subjects. The test assessors consisted of clinical athletic trainers and physical therapy students. Before testing, each athlete completed a questionnaire consisting of demographics, current and recent injury history, and current medical restrictions.

The YBT-LQ protocol involves a limb length measurement from the inferior portion of the Anterior Superior Iliac Spine to the most inferior portion of the medial malleolus allowing for body relative calculations of right and left limb composite scores, or normalized scores. The YBT-LQ protocol requires each subject to maintain limb stance while performing three excursions with the non-weight bearing limb in the anterior, posteromedial, and posterolateral directions (Plisky et al., 2009). Reach distances in each direction were recorded for all participants.

Individual FMS tests were organized and administered in seven stations, one for each test: the deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. As per FMS protocol, three clearing tests (for shoulder mobility, trunk stability, and rotary stability) were scored as + or -, indicating if pain was present. If the clearing test accompanying the individual FMS test was scored as a + (pain present), the individual test was assigned a score of zero. Each tester administered and scored one movement screen.

The athletic trainers recorded all injuries that occurred during the subsequent season in ATS, the electronic health record used to record athlete data. Injuries were recorded by mechanism (contact/noncontact), location on the body (i.e., shoulder, knee, thigh), and type (i.e., sprain, strain, fracture).

Data extraction. Data extraction began by seeking athletes who met the inclusion and exclusion criteria. The official men's and women's soccer rosters for each year included in the study were obtained from the LVC athletics department. The rosters included only those athletes who remained on the team for the entirety of the regular season. Athletes who sustained a season-ending injury during the season but remained on the team were not removed from the official rosters and were included in the study. Any player not medically cleared for soccer at the time of testing was not included in the testing and therefore was not included in the study, even if they returned to play during the season.

The participant codes were cross-referenced with their paper and electronic records, using the codebook as a guide. The independent variable data were extracted and recorded in Excel. The dependent variable or injury data were extracted from ATS via ATS's data mining feature, which automatically populates selected injury data onto an Excel spreadsheet. The data was directly recorded onto one master Excel document.

Data management. Athlete names were initially deidentified using a numeric, random code generator. The names and codes were maintained in a password protected Excel document.

All athlete data were then entered into a separate master Excel document using the athlete numeric codes. While data were being extracted, electronic records were recalled on the primary investigator's encrypted and password-protected computer. All original paper charts were accessed and kept in their original locations. All information was entered into Excel directly from the original paper charts from their storage locations. The password-protected Excel file containing deidentified data mined from ATS was stored in the researcher's encrypted local drive to maintain an audit trail.

Data Analysis

Data analysis was completed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY). Normality of data was determined with the Shapiro-Wilk test. All tests were two-tailed, and a family-wise significance level of less than .05 was considered statistically significant. Descriptive statistics were conducted for the entire sample. Nominal data are reported as frequencies and percentages. Ordinal data and non-normally distributed interval and ratio data are reported with medians and interquartile ranges.

To determine if there were significant differences in functional movement scores by gender and by BMI, Mann-Whitney *U* tests were conducted on data that were not normally distributed (YBT-LQ) and for ordinal data (FMS CS scores). To determine if the pre-established "high-risk" and "low-risk" categories for the FMS and YBT-LQ were associated with whether or not a player sustained a lower extremity injury and a noncontact lower extremity injury, chi-square tests were conducted. Fisher exact tests are reported when any counts were less than five. Post-hoc tests were conducted using a Bonferroni correction as needed to determine pairwise differences. Odds ratios (OR) are reported for all two-sided chi-square and Fisher exact tests. To determine if athlete BMI or gender were associated with lower extremity injuries, Mann-

Whitney *U* (for BMI) and chi-square tests (for gender) were conducted. Recent injury history (yes/no) data were only available for 2015. Data from this subgroup of 39 athletes were explored using Fisher exact tests and odds ratios are reported to determine its role as a confounding variable. Three participants had isolated data points that were either missing or reflected suspected recording errors. These data were handled as missing data via the default removal of them by SPSS. Finally, two athletes scored a zero on the shoulder mobility test. To maintain three groups in cross tabulation, these two scores were collapsed into one group.

Results

Data were collected on 143 NCAA Division III soccer athletes. The percentage of male and female athletes was similar (49.7%, 50.3%, respectively). Basic descriptive statistics of study athletes included the following means (SD); age (years) 19.36 (1.23), height (inches) 67.36 (3.81), weight (pounds) 150.90 (22.99), BMI 23.27 (2.34). Of the 89 total lower extremity injuries, the most common types were muscle/tendon injuries $n = 59$ (34.3%), contusions $n = 45$ (26.2%), and sprains $n = 18$ (10.5%).

Functional Movement Categories and Injury

The primary research question asks, is there a significant difference in functional movement, as measured by the frequency of FMS CS and YBT-LQ injury risk categories among NCAA Division III soccer athletes who sustained a lower extremity injury versus those who did not sustain a lower extremity injury? Descriptive statistics and comparison results can be found in Table 1. When considering FMS CS and YBT-LQ risk categories, no differences existed between the injured and uninjured groups. Specifically, results indicated that the frequency of FMS CS injury risk categories did not differ statistically between those who were injured and those who were not injured at an alpha level of .008. For the YBT-LQ injury risk categories:

anterior risk, posterolateral risk, and posteromedial risk, no differences existed between the injured and uninjured groups at a family-wise alpha of .05. Confidence level of the statistical results was adjusted using Bonferroni correction to account for the 6 hypothesis tests. ($p = 1.00$, $p = .036$, $p = .728$, respectively). Overall, there was not a significant difference in functional movement among NCAA Division III soccer athletes who sustained a lower extremity injury versus those who did not sustain an injury.

Functional Movement Categories and Noncontact Injury

The first secondary research question asks, is there a significant difference in FMS CS categories among NCAA Division III soccer athletes who sustained a noncontact lower extremity injury versus those who did not sustain an injury? Functional movement and noncontact injury data can be found in Table 2. When considering FMS and YBT-LQ risk categories, no differences existed between the noncontact injury and not injured groups. Specifically, for the FMS CS, results indicated that the groups did not differ statistically at an alpha level of .008 ($p = .711$). For the YBT-LQ anterior high-risk group ($p = .557$), the YBT-LQ posterolateral high-risk group ($p = .036$), and the YBT-LQ posteromedial high-risk group ($p = .703$), results indicated that the groups did not differ significantly at an alpha of .008. There was not a significant difference in functional movement categories among NCAA Division III soccer athletes who sustained a lower extremity noncontact injury versus those who did not sustain an injury.

Athlete Factors and Injury

The second secondary research question asks, are athlete the factors body mass index (BMI) and history of recent injury associated with lower extremity injuries in NCAA Division III soccer athletes?

Body mass index. BMI between the injured and uninjured groups for all lower extremity injuries were compared. The median (interquartile range [IQR]) BMI was 22.93 kg/m^2 (3.26) for the uninjured group and 22.71 kg/m^2 (2.43) for the injured group indicating the groups did not differ statistically ($Z = -1.29$, $p = .196$) at an adjusted alpha of .008.

BMI between the injured and uninjured groups for noncontact lower extremity injuries was compared. The median BMI was 22.71 kg/m^2 (2.35) for the noncontact injuries group and 22.93 kg/m^2 (3.26) for the uninjured group. Results indicated that the groups did not differ statistically ($Z = -1.35$, $p = .179$) at an adjusted alpha of .008.

History of recent injury. An exploratory subgroup of 39 athletes was analyzed to determine whether recent injury history was associated with injury category. The analysis revealed that 5 of 8 (62.5%) athletes who reported previous recent injury were subsequently injured compared to 27 out of 39 (69.2%) who reported no recent injury history. The two-sided Fisher's exact test indicated no statistically significant difference ($p = .697$) in recent injury history and athletes who were injured or not injured at an alpha level .05. The OR was calculated to = 0.74; 95% CI [.15, 3.61]. This indicated that those who had a recent injury history were 1.4 times more likely to be injured than those who did not have a recent history of injury.

Presence of Lower Extremity Injuries by Gender

The third secondary research question asks, is there a significant difference in presence or no presence of lower extremity injuries between male and female NCAA Division III soccer athletes? For all lower extremity injuries, 44 of the 71 (62.0%) males were injured compared to 45 out of 73 (61.6%) females. The two-sided Fisher's exact test indicated no statistically significant difference ($p = 1.00$) between genders at a family-wise alpha level .05. The odds ratio (OR) was calculated to = 0.99; 95% CI [.50, 1.93]. This indicates that females were 1.01 times more likely to have a lower extremity injury than males in NCAA Division III soccer.

For noncontact lower extremity injuries, males were equally likely to have a noncontact injury, 30 of the 57 (52.6%), compared to 31 out of 59 (52.5%) females. The two-sided Fisher's exact test indicated no statistically significant difference (p = 1.00) between genders at a family-wise alpha level .05. The OR = 0.99; 95% CI [.48, 2.07]. This indicates that males were < 1.01 times more likely to have a noncontact lower extremity injury than females in NCAA Division III soccer.

Functional Movement and Gender

The final secondary research question asks, are there significant differences in functional movement as measured by the FMS CS, frequency of FMS individual test scores and the YBT-LQ reach difference scores for each direction between male and female NCAA Division III soccer athletes? The YBT-LQ anterior reach difference score, the YBT-LQ posterolateral reach difference score, YBT-LQ posteromedial reach difference score, results indicated that scores did not differ statistically by gender at a family-wise alpha of .05 (p = .699, p = .782, p = .489, respectively). Confidence level was adjusted using Bonferroni correction to account for the 4 hypothesis tests. For the FMS CS, it was determined that a significant difference did not exist between genders on FMS CS (p = .023) at a family-wise alpha of .05. There was not a significant difference in functional movement, as measured by FMS and Y-balance scores between male and female NCAA Division III soccer athletes.

An exploratory analysis of gender difference on each FMS component was completed. Two components, the ASLR and the trunk stability push-up, displayed differences between genders. For the ASLR, it was determined that females are significantly more likely to be in the higher category than males (p = .001) at an alpha of .05. Post-hoc pairwise group differences revealed that females were 19.8 times more likely than males to achieve a score of 3 versus a score of 1 ($p < .001$). Gender differences between scores of 1 and 2 ($p = .023$), and 2 and 3 ($p = .033$) were not significant at an adjusted alpha of .017. For the trunk stability push-up, it was determined that males were more likely to be in a higher category than females ($p < .001$) at an alpha of .05. Post-hoc pairwise group differences revealed that males were 10.9 times more likely than females to achieve a score of 2 versus a score of 1 ($p < .001$), males were 3.5 times more likely than females to achieve a score of 2 versus a score of 3 ($p = .005$), and females were 3.1 times more likely than males to achieve a score of 1 versus a score of 3 ($p = .013$). There was a significant difference in functional movement, as measured by the ASLR and trunk stability components of the FMS, between male and female NCAA Division III soccer athletes.

For the remainder of the FMS components, the deep squat ($p = .776$), hurdle step ($p = .145$), inline lunge ($p = .098$), shoulder mobility ($p = .095$), and rotary stability ($p = .224$), the data indicated that the groups did not differ statistically at an alpha of .05. There was not a significant difference in functional movement, as measured by the deep squat, hurdle step, inline lunge, shoulder mobility, and rotary stability components of the FMS, between male and female NCAA Division III soccer athletes. Data pertaining to functional movement and gender is displayed in Table 3.

Discussion

In this study, multiple research questions were explored to determine whether functional movement, as measured by the FMS and YBT-LQ, in junction with athlete demographics, is associated with lower extremity injury in NCAA Division III men's and women's soccer athletes. The questions sought to determine whether or not significant differences existed in: (1) functional movement, as measured by the FMS and YBT-LQ, between male and female soccer athletes, (2) the rate of lower extremity injuries between male and female soccer athletes, (3) athlete factors and injury categories, (4) functional movement test scores and injury categories, and (5) functional movement among soccer athletes who sustained a lower extremity noncontact injury versus those who did not sustain an injury.

Functional Movement Categories and Injury

With regard to functional movement and injury, this study sought to determine whether or not significant differences existed in functional movement test scores and lower extremity injuries. Functional movement, as measured by the FMS and YBT-LQ, was not associated with lower extremity injury in NCAA Division III men's and women's soccer athletes in this study. The FMS (Bonazza et al., 2017; Shultz, Anderson, Matheson, Marcello, & Besier, 2013) and YBT-LQ (Garrison et al., 2015; Plisky et al., 2009) are reliable tools. Further, it has been suggested that performance on functional movement tools such as the FMS and YBT-LQ are associated with increased injury incidence. Early studies showed promising findings with relation to the predictive ability of these tests (Butler, Contraras et al., 2013; Butler, Lehr, Fink, Kiesel, & Plisky, 2013; Chorba et al., 2010; Garrison et al., 2015). However, more recently published studies may suggest otherwise (Dorrel et al., 2018; Lai et al., 2017; Lisman et al., 2019; Mokha et al., 2016; Walbright et al., 2017; Wright et al., 2017). One limitation in early studies involves heterogony of sport. Since various sports have nuanced repetitive movements and subsequently varied injury epidemiology, it is plausible that including a variety of sports may not adequately capture sport-specific relationships that may exist between functional movement and injury. This study, with a specific soccer population, allowed for increased control of this type of extraneous variable in an attempt to better isolate sport-specific differences. The limitation in doing this is that it evaluated a homogeneous group who were engaging in similar training regimens. Thus, a group was created with little variation.

A debated factor in studies involving injury is the operationalizing of *injury*. Traditionally researches defined injury based on various levels of time-loss, reserving only injuries resulting in lost playing time for study inclusion (Butler, Contreras, et al., 2013; Garrison et al., 2015; Lai et al., 2017; Lisman et al., 2019; Mokha et al., 2016; Walbright et al., 2017). However, some authors have broadened the definition of injury to exclude time-loss as a factor in their definition of injury (Chorba et al., 2010; Lisman et al., 2013; Warren et al., 2015; Wright et al., 2017). Dompier et al. (2015) found non-time-loss injuries to account for over 80% of all reported injuries in high school sports. Accordingly, it can be inferred that, for an athletic trainer, non-time-loss injuries represent a majority of the workload. Similarly, it is possible that athletes continuing to play with an injury are not playing at full capacity. This study operationalized definition of injury was broad to represent a larger constituency of injured athletes. Nevertheless, the inclusion of minor injuries may have diluted any relationship between functional movement and more severe injuries resulting in time-loss.

Three interesting trends can be seen in previous studies concerning the role injury inclusion criteria play in the relationship between FMS and injury. First, studies that resulted in a positive relationship between FMS and injury existed whether the researchers defined injury through a broad or narrow definition considering time-loss. In four studies employing a broad injury definition (including all medically evaluated injuries regardless of time-loss), one reported a relationship between FMS score and injury (Chorba et al., 2010), and one reported no relationship (Warren et al., 2015). The third reported only a relationship where FMS, when added to their three-mile run time, strengthened the relationship found between run time and injuries (Lisman et al., 2013). The second trend was demonstrated in two studies that included three distinctive injury definitions in their samples and found similar relationships regardless of their definition (Dorrel et al., 2018; Lisman et al., 2013). Specifically, regardless of injury definition, FMS alone was not predictive of injury. The third trend was noted in a meta-analysis where it was determined that when all studies were included, the relative risk (RR) of those at "high-risk" was 1.51, 95% CI [1.35, 1.69]. Comparatively, for those studies that included time-loss as part of their injury definition, a slightly lower RR was calculated for those in the "high-risk" category, RR=1.44, 95%CI [1.05, 1.99] (dos Santos Bunn, Rodrigues, & da Silva, 2019). These differences would indicate that when less significant injuries are included in the study, the RR is higher, but it is unclear if the severity of injury included in the data affects the relationship between FMS score and injury.

For clinicians seeking guidance in making return to play decisions, standardized tools aimed at reducing the risk of reinjury are helpful and desired. Many field-expedient physical performance tests have strong construct validity regarding utility in discriminating between injured and uninjured limbs, aiding clinicians in making return to play decisions post-injury (Hegedus, McDonough, Bleakley, Baxter, & Cook, 2015). It is common practice amongst clinicians to seek bilateral symmetry as a measure of return to baseline for an injured extremity. Clinicians often compare segment or limb function bilaterally, when possible, to determine what is "normal" based on the contralateral segment or limb. However, this study found that a greater than 4 cm reach difference left to right on the YBT-LQ was not associated with increased injury occurrence. Though early studies identified and established the commonly used 4 cm cut-points as significant with relation to injuries, the lack of significant associations found in this study, are in agreement with more recent studies (Lai et al., 2017; Lisman et al., 2019; Wright et al., 2017). Therefore, it can be surmised that reach asymmetry alone may not be associated with increased injury incidence.

Further, Fousekis et al. (2011) found no increased incidence of hamstring injury in a similar group of soccer athletes with left to right asymmetries in flexibility, proprioception, mid-thigh girth, and knee laxity. Only asymmetrical functional leg length was positively associated with increased incidence of hamstring injuries. In many sports, such as soccer, left to right asymmetries are not only inherent but fostered simply by a dominant sided preference in the athlete or by nature of the sport, position, and sport movements. For example, in soccer, a majority of athletes are right foot dominant. As a result, they will often prefer to plant on the left foot while kicking with the right. The plant leg is subsequently likely to develop differences that affect the entire kinetic chain. The findings of this study support the idea that, while asymmetries are not protective, they may not be harmful to an athlete. The demands of the sport and common areas of injury for that sport should be considered when making injury prevention programs and return to play decisions rather than purely relying on achievement of bilateral symmetry.

Concerning clinical relevance, it is important to note that in both sport and occupational preventative medicine, clinicians should evaluate the common strains and demands of a particular sport, position, or occupation. Each one is likely to require an in-depth understanding of and unique approaches to injury prevention. Respectively, trends related to associations between various movement screens or other risk factors and injury should be sought. It is vital to the clinicians working with specific groups to have access to research or knowledge specific to their population.

Functional Movement Categories and Noncontact Injury

Finally, with regard to functional movement and noncontact injuries, this study sought to determine whether or not significant differences existed in functional movement among soccer athletes who sustained a lower extremity noncontact injury versus those who did not sustain an injury. In this study, functional movement, as measured by the FMS and YBT-LQ, was not associated with lower extremity noncontact injury in NCAA Division III men's and women's soccer athletes. Similar to the debate about inclusion of non-time-loss or less severe injuries in prior studies of injury incidence, is the decision to exclude contact injuries as they are less likely to be avoidable. Therefore, they are less likely to be modifiable via preventative intervention measures. Since contact injuries may be less preventable, noncontact injuries may have a more significant association with various modifiable risk factors.

On the contrary, it can be argued that contact injuries would be less likely to occur, or less severe, if an individual has quicker reaction time to avoid contact, and improved strength and dynamic stability to withstand the contact. The literature remains largely unclear about the association between functional movement and noncontact lower extremity injuries. While this study showed no significant difference between either test and injury, it is essential to view the literature concerning the relationship between FMS and YBT-LQ with injury individually.

In prior studies, the FMS CS was found to have no association with incidence of lower extremity noncontact injury (Smith & Hanlon, 2017; Warren et al., 2015) or overuse injury (Lisman et al., 2013). Only one study found a significant difference between FMS injury risk categories and injury incidence (Lehr et al., 2013). The YBT-LQ is potentially more promising than FMS when it comes to identification of an association between YBT-LQ scores and incidence of lower extremity noncontact injuries. Butler et al. (2013) reported an initial relationship in this area using a composite score cut-point. Similar findings were reported by Gonell et al. (2015), who specifically looked at both contact and noncontact injuries. Interestingly, in their sample of professional and amateur soccer athletes, the following components of the YBT-LQ were significantly different for the noncontact injuries groups but were not significantly different in the contact injuries groups: posteromedial reach difference, lower than average posteromedial reach distance, lower than average posterolateral reach distance, and lower than average composite reach scores. These findings, exclusive to the noncontact group, indicate that noncontact injuries may have a stronger relationship to specific components of the YBT-LQ than contact injuries.

In this study, no association was found between functional movement, as measured by FMS CS and YBT-LQ risk categories and noncontact injuries. This finding suggests that functional movement is not associated with contact nor noncontact mechanisms of injury in NCAA Division III soccer athletes.

Athlete Factors and Injury

The next research questions involved athlete characteristics and injury rate. Specifically, this study sought to determine whether or not significant differences existed between BMI and lower extremity injuries. In this study, BMI was not associated with lower extremity injury in NCAA Division III men's and women's soccer athletes. Lower BMI was previously identified as a risk factor for injuries in a group of Division I athletes (Warren et al., 2015). Since this study sampled multiple sports, it is possible that this finding was dependent on sport. For example, in a collision sport, such as football, a smaller player may be at increased risk of injury when colliding with a larger player. Of the 195 sampled in the study by Warren et al. (2015), the largest number of participants played football (*n* = 74). Wright et al. (2011) also surveyed a variety of sports, but did not include football and found no association between BMI or sport and injury. Therefore, it may be unlikely to see sport-specific relationships between BMI and injury when certain sports are included, and aggregate data is reported.

Given that BMI is composed of height and weight, it is possible that they could have a canceling effect when factored together. For example, Fousekis et al. (2011) found increased weight and decreased height to be risk factors for quadricep strains in a group of professional soccer athletes. However, others have reported no association between height, weight, or BMI and injury (Dauty et al., 2018; Wright et al., 2017).

One additional variable that was explored in this study due to its role as a possible confounding variable was previous injury history. In a subset sample (2016 data), self-reported injury history of the six months prior to testing was collected. The significance, type, or location of injury was unknown to the researchers. In this subsample group, previous injury history had no significant association with subsequent injury. It has been reported that previous injury history was associated with future injury (Chorba et al., 2010; Fousekis et al., 2011; Garrison et al., 2015; Warren et al., 2015). While injury is traditionally thought to increase the risk of future injuries (Garrison et al., 2015; Warren et al., 2015), Chorba et al. (2010) identified a protective effect between post ACLR patients and injury incidence. This protective effect was supported by Fousekis et al. (2011), who reported an increased incidence of hamstring injuries in soccer athletes who had no history of a hamstring injury. It is thought that this protective effect could be a result of rehabilitation undergone by the athlete after injury (Chorba et al., 2010). Unlike the studies mentioned above, we did not collect a detailed or extended injury history. Instead, only a recent patient-reported injury history was collected. These results revealed that recent injury history was likely not a confounding variable for the sample at large.

Injury Category by Gender

Concerning gender, this study sought to determine whether or not significant differences existed in the rate of lower extremity injuries between male and female soccer athletes. In this study, injury rate did not vary between gender groups. Prior studies have also shown a similar injury rate between male and female athletes (Roos et al., 2017; Wright et al., 2017). Similar to this study, both of the aforementioned studies included a broad definition of injury, which comprises all injuries evaluated by medical staff regardless of type, severity, or time-loss. Injury rate differences are noted in two studies looking at specific types of injuries. Tenan (2016) reported a higher rate of male emergency department (ED) visits as a result of sport and recreation. It is reasonable to conclude that injuries warranting an ED visit were more significant and were unlikely to resume normal activity the following day. In the second study, only noncontact injuries were included, and females were reported to have a higher injury rate than males (Warren et al., 2015). Thus, the definition of injury and inclusion criteria could directly affect injury rates for genders.

This study included a broad definition of injury; however, it was specific to location of the injury as it included all lower extremity injuries that occurred during practice or competition and for which medical attention was sought. Severity or time-loss was not used to differentiate significance of injuries. Non-time-loss injuries have been reported to account for approximately 81% of female and 83% of male high school soccer injuries (Dompier et al., 2015). A significant proportion of injuries that are evaluated in the athletic training clinic are non-time-loss injuries. Therefore, it may be important to include a broader injury definition to obtain a more comprehensive picture of the types and rates of injuries experienced across genders in future studies. In addition to severity or time-loss, rates between genders could vary based on sport. In the sport of soccer, researchers have found similar overall injury rates between genders, regardless of injury definition (DiStefano et al., 2018; Kerr et al., 2015; Kerr et al., 2018; Roos et al., 2017).

Functional Movement and Gender

This study sought to determine whether or not significant differences existed in functional movement, as measured by the FMS and YBT-LQ, between male and female soccer athletes. Composite scores on the FMS between males and females were not found to be significantly different in female versus male soccer athletes in this study. This finding is consistent with many prior studies showing no difference between genders (Agresta et al., 2014; Chimera et al., 2015; de la Motte et al., 2017). Only Teyhen et al. (2014) reported higher mean FMS-CS in females younger than 30 years of age as compared to males in the same age group. However, a paucity of data exists specific to the sport of soccer regarding differences between functional movement and gender. An exploratory analysis of components of these functional movement screening tools was conducted to give a more comprehensive picture of gender differences for this specific population.

While few previous studies have reported differences in the FMS-CS between genders, some have reported differences in components of the screen among physically active populations. The two significant differences between genders for components of the FMS supported in this study were for the ASLR and trunk stability push-up. First, these data revealed that the ASLR, a measure of range of motion, or flexibility about the hip, were significantly different between genders. Namely, more males scored in the lowest category of 1 on the ASLR compared to females while more females scored in the highest category of 3 compared to males. Agresta el al. (2014) reported a significantly higher Active Straight-Leg Raise (ASLR) score in a group of recreational female distance runners compared to their male counterparts. This higher female ASLR score was supported by Chimera et al. (2015) in a group of NCAA Division I athletes. In addition, Chimera et al. (2015) reported a higher shoulder mobility score and inline lunge score in females. However, in the Chimera et al. (2015) study, it is possible that sport differences accounted for some of the variability reported between genders as some of the athletes sampled did not have an opposite gender equivalent sport to control for that variable. The findings of significantly different female scores for tests involving mobility are consistent with researchers' suggestion that females generally exhibit more flexibility than males (Baechle & Earle, 2008).

Researchers of previous studies also reported significant differences between genders on the trunk stability push-up. Trunk stability push-up scores were reported as higher in males compared to females (Agresta et al., 2014; Chimera et al., 2015). In this study, significant differences were noted between genders. The post-hoc analysis revealed an interesting trend in the sample. While more females had a score of 1 than males and more males had a score of 2 than females, slightly more females had a score of 3 than males. This trend indicates that males had more symmetry in this test, while females had more disparity. While the trunk stability push-up is purported to be exclusively a measure of core stability, compromised upper body strength is listed as an implication (Cook, 2015). Another test of core stability, the rotary stability test, showed similar scores between genders in this study, indicating that male and female soccer athletes have similar core stability. Thus, the disparity in trunk stability push-up scores between genders may be related to upper body strength differences achieved by some females via strength training. While this finding of no difference in the rotary stability component was in agreement with one study (Agresta et al., 2014), it was inconsistent in another (Chimera et al., 2015). Due to the nature of the trunk stability push-up, upper body strength may play a more significant role in the test than previously thought. Females have a lower absolute strength compared to males (Bishop, Cureton, & Collins, 1987). Since the trunk stability push-up aims to measure core stability, the protocol accounts for these upper body strength differences between genders via a modification for females in an attempt to mitigate the role that upper body strength plays in this component. This modification may have been enough for some trained females to overcome the scores of their male counterparts but not enough for a majority of women. These findings indicate that modification for females made in the protocol for this component may not be enough to account for gender differences in upper body strength. It appears that gender differences in upper body strength may be a confounding variable for this component's utility as a measure of core stability.

This study showed no significant differences between genders when considering individual reach distances in the YBT-LQ three directions of left to right reach asymmetries. In each of the reach directions (anterior, posterolateral, and posteromedial), asymmetries were generally not found to be different between genders in prior studies. Only the anterior reach direction was found to be significantly lower in females in one study (Chimera et al., 2015). For the FMS, two of the test components are purported to assess dynamic stabilization: the hurdle step and inline lunge. In both of these components, male and female mean scores were not significantly different in this study. This finding of no significant relationship between genders on the YBT-LQ, along with the similar mean scores on the inline lunge and hurdle step, would suggest that dynamic balance is similar between male and female soccer athletes.

Limitations

There are some limitations of this study. While homogeneity of the sample group can add to the literature from the standpoint of sport-specific norms and relationships, it makes the results less generalizable to the physically active population at large. Previous discussion was made surrounding the operationalization of injury and its impact on study results. It is also important to highlight this study's inclusion of a broad injury definition, which has the potential to dilute the results if we had included only time-loss injuries. The data is unclear if a narrower inclusion criterion strengthens the relationship. As a retrospective study, we did not have access to severity or time-loss criteria in the data to include multiple definitions of injury. However, we were able to look at both noncontact and all injuries. In addition, adoption of a broad injury definition is not unusual.

Retrospective study designs come with inherent limitations due to various threats (Tofthagen, 2012). For example, in using retrospective data, we were bound by the data collected. In addition to severity and time-loss data not being recorded, limited information about injury history and the primary data collection methods is available to the researchers. In addition, retrospective data may not be free of bias. It is also unknown if historical or maturation threats were present. Huebner et al. (2019) demonstrated that injury risk category could be improved via an eight-week intervention program.

Similarly, Sprague et al. (2014) identified changes in FMS scores throughout the competitive season. In this study, it is not known if any intentional or unintentional interventions were present between August test date and injuries that occurred toward the end of the season in November. If an unknown intervention was present or an intervention in the form of a regular competitive season, such an intervention could have resulted in a change in functional movement and skewed the data collected closer to the end of the season.

This study only evaluated a relationship between functional movement and injury via previously established cut scores. A few researchers have established FMS CS cut-points other than 14 (dos Santos Bunn et al., 2019). In addition, researchers have selected various measures to evaluate relationships between YBT-LQ and injury (Butler, Lehr, et al., 2013; Gonell et al., 2015; Gribble, Hertel, & Plisky, 2012). Thus, even though we selected common cut-points, it is possible these were not optimal cut-points for these data.

Conclusion

Results of this study indicate that FMS and YBT-LQ scores are not related to injury in NCAA Division III soccer athletes. Additionally, the scores were not related to whether or not a noncontact injury occurred. Caution should be used in employing the FMS and YBT-LQ as injury screening tools or tools to determine return to play readiness after an injury. Further, gender, BMI, and recent injury history were not associated with whether or not an injury would occur in this sample. While no significant differences in YBT-LQ between males and females were found, some differences were noted in FMS scores between genders. No significant difference was found between genders on the FMS CS. However, significant differences between genders were noted on two components of the FMS: ASLR and trunk stability push-up. More research is needed to establish sport-specific norms for and clinical utility of the FMS and YBT-LQ.

References

Agresta, C., Slobodinsky, M., & Tucker, C. (2014). Functional Movement Screen – Normative values in healthy distance runners. *International Journal of Sports Medicine, 35*(14), 1203-1207. doi:doi:10.1055/s-0034-1382055

Armstrong, R. (2020). The relationship between the functional movement screen, star excursion balance test and the Beighton score in dancers. *The Physician and Sportsmedicine*, *48*(1), 1-10. doi:10.1080/00913847.2019.1624658

Armstrong, R., Brogden, C., Milner, D., Norris, D., & Greig, M. (2018). Functional movement screening as a predictor of mechanical loading and performance in dancers. *Journal of Dance Medicine & Science, 22*(4), 203-208. doi:10.12678/1089-313X.22.4.203

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength and conditioning*, (3rd ed.). Champaign, IL: Human Kinetics.

Bishop, P., Cureton, K., & Collins, M. (1987). Sex difference in muscular strength in equally-trained men and women. *Ergonomics, 30*(4), 675-687. doi:https://doi.org/10.1080/00140138708969760

Bonazza, N. A., Dhawan, A., Smuin, D., Onks, C. A., & Silvis, M. L. (2017). Reliability, validity, and injury predictive value of the Functional Movement Screen. *American Journal of Sports Medicine, 45*(3), 725-732. doi:10.1177/0363546516641937

Butler, R., Contreras, M., Burton, L., Plisky, P., Goode, A., & Kiesel, K. (2013). Modifiable risk factors predict injuries in firefighters during training academies. *Work (reading, Mass.), 46*(1), 11-17. doi:10.3233/WOR-121545

Butler, R. J., Lehr, M. E., Fink, M. L., Kiesel, K. B., & Plisky, P. J. (2013). Dynamic balance performance and noncontact lower extremity injury in college football players: An initial study. *Sports Health, 5*(5), 417-422. doi:10.1177/1941738113498703

Chimera, N. J., Smith, C. A., & Warren, M. (2015). Injury history, sex, and performance on the functional movement screen and y balance test. *Journal of Athletic Training, 50*(5), 475-485. doi:10.4085/1062-6050-49.6.02

Chorba, R. S., Chorba, D. J., Bouillon, L. E., Overmyer, C. A., & Landis, J. A. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy, 5*(2), 47-54. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953387/

Cook, G. (2015). Functional Movement Screen: Level 1. Retrieved from https://www.functionalmovement.com/files/Articles/717a_650a_FMS%20Level%201%20Online%20V1%203-21-2016.pdf

Cook, G., Burton, L., & Hoogenboom, B. (2006). Pre-participation screening: The use of fundamental movements as an assessment of function – Part 1. *North American Journal Sports Physical Therapy, 1*(2), 62-72. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953313/

Cosio-Lima, L., Knapik, J. J., Shumway, R., Reynolds, K., Lee, Y., Greska, E., & Hampton, M. (2016). Associations between functional movement screening, the y balance test, and injuries in Coast Guard training. *Military Medicine, 181*(7), 643-648. doi:10.7205/MILMED-D-15-00208

Dauty, M., Menu, P., & Fouasson-Chailloux, A. (2018). Cutoffs of isokinetic strength ratio and hamstring strain prediction in professional soccer players. *Scandinavian Journal of Medicine & Science in Sports, 28*(1), 276-281. doi:10.1111/sms.12890

de la Motte, S. J., Gribbin, T. C., Lisman, P., Beutler, A. I., & Deuster, P. (2017). The interrelationship of common clinical movement screens: Establishing population-specific norms in a large cohort of military applicants. *Journal of Athletic Training, 51*(11), 897-904. doi:10.4085/1062-6050-51.9.11

DiStefano, L. J., Dann, C. L., Chang, C. J., Putukian, M., Pierpoint, L. A., Currie, D. W., . . . Kerr, Z. Y. (2018). The first decade of web-based sports injury surveillance: Descriptive epidemiology of injuries in US high school girls' soccer (2005-2006 through 2013- 2014) and National Collegiate Athletic Association women's soccer (2004-2005 through 2013-2014). *Journal of Athletic Training, 53*(9), 880-892. doi:10.4085/1062-6050-143-17

Doherty, C., Bleakley, C. M., Hertel, J., Caulfield, B., Ryan, J., & Delahunt, E. (2015). Laboratory measures of postural control during the star excursion balance test after acute first-time lateral ankle sprain. *Journal of Athletic Training, 50*, 651-664. doi:http://dx.doi.org/10.4085/1062-6050-50.1.09

Dompier, T. P., Marshall, S. W., Kerr, Z. Y., & Hayden, R. (2015). The National Athletic Treatment, Injury and Outcomes Network (NATION): Methods of the surveillance program, 2011–2012 through 2013–2014. *Journal of Athletic Training, 50*(8), 862-869. doi:10.4085/1062-6050-50.5.04

Dorrel, B., Long, T., Shaffer, S., & Myer, G. D. (2018). The Functional Movement Screen as a predictor of injury in National Collegiate Athletic Association Division II athletes. *Journal of Athletic Training, 53*(1), 29-34. https://doi.org/10.4085/1062-6050-528-15

dos Santos Bunn, P., Rodrigues, A. I., & da Silva, E. B. (2019). The association between the functional movement screen outcome and the incidence of musculoskeletal injuries: A systematic review with meta-analysis. *Physical Therapy in Sport, 35*, 146-160. doi:10.1016/j.ptsp.2018.11.011

Dossa, K., Cashman, G., Howitt, S., West, B., & Murray, N. (2014). Can injury in major junior hockey players be predicted by a pre-season functional movement screen – A prospective cohort study. *The Journal of the Canadian Chiropractic Association, 58*(4), 421-427. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4262798/

Eckard, T. G., Kerr, Z. Y., Padua, D. A., Djoko, A., & Dompier, T. P. (2017). Epidemiology of quadriceps strains in National Collegiate Athletic Association athletes, 2009–2010 through 2014–2015. *Journal of Athletic Training, 52*(5), 474-481. doi:10.4085/1062-6050-52.2.17

Fousekis, K., Tsepis, E., Poulmedis, P., Athanasopoulos, S., & Vagenas, G. (2011). Intrinsic risk factors of noncontact quadriceps and hamstring strains in soccer: A prospective study of 100 professional players. *British Journal of Sports Medicine, 45*(8), 709-714.

Garrison, M., Westrick, R., Johnson, M., & Benenson, J. (2015). Association between the functional movement screen and injury development in college athletes. *International Journal of Sports Physical Therapy, 10*(1), 21-28. Retrieved from https://uindy.on.worldcat.org/oclc/5737748520

Gonell, A. C., Romero, J. A., & Soler, L. M. (2015). Relationship between the y balance test scores and soft tissue injury incidence in a soccer team. *International Journal of Sports Physical Therapy, 10*(7), 955-966. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26673848

Gribble, P. A., Hertel, J., & Plisky, P. (2012). Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: A literature and systematic review. *Journal of Athletic Training, 47*(3), 339-357. doi:10.4085/1062-6050-47.3.08

Hegedus, E. J., McDonough, S. M., Bleakley, C., Baxter, D., & Cook, C. E. (2015). Clinician-friendly lower extremity physical performance tests in athletes: A systematic review of measurement properties and correlation with injury. Part 2—the tests for the hip, thigh, foot and ankle including the star excursion balance test. *British Journal of Sports Medicine, 49*(10). doi:10.1136/bjsports-2014-094341

Huebner, B. J., Plisky, P. J., Kiesel, K. B., & Schwartzkopf-Phifer, K. (2019). Can injury risk category be changed in athletes? An analysis of an injury prevention system. *International Journal of Sports Physical Therapy, 14*(1), 127-134. doi:10.26603/ijspt20190127

Irick, E. (2018). Student-athlete participation 1981-82 - 2018-19: NCAA sports sponsorship and participation rates report. Retrieved from https://ncaaorg.s3.amazonaws.com/research/sportpart/2018-19RES_SportsSponsorshipParticipationRatesReport.pdf

Kerr, Z. Y., Dompier, T. P., Snook, E. M., Marshall, S. W., Klossner, D., Hainline, B., & J., C. (2014). National Collegiate Athletic Association Injury Surveillance System: Review of methods for 2004–2005 through 2013–2014 data collection. *Journal of Athletic Training, 49*(4), 552-560. doi:10.4085/1062-6050-49.3.58

Kerr, Z. Y., Marshall, S. W., Dompier, T. P., Corlette, J., Klossner, D. A., & Gilchrist, J. (2015). College sports-related injuries - United States, 2009-10 through 2013-14 academic years. *MMWR: Morbidity & Mortality Weekly Report, 64*(48), 1330-1336. doi:10.15585/mmwr.mm6448a2

Kerr, Z. Y., Putukian, M., Chang, C. J., DiStefano, L. J., Currie, D. W., Pierpoint, L. A., . . . Marshall, S. W. (2018). The first decade of web-based sports injury surveillance:

Descriptive epidemiology of injuries in US high school boys' soccer (2005-2006 through 2013- 2014) and National Collegiate Athletic Association men's soccer (2004-2005 through 2013-2014). *Journal of Athletic Training, 53*(9), 893-905. doi:10.4085/1062-6050-166-17

Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal Sports Physical Therapy, 2*(3), 147-158. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953296/

Lai, W. C., Wang, D., Chen, J. B., Vail, J., Rugg, C. M., & Hame, S. L. (2017). Lower quarter y-balance test scores and lower extremity injury in NCAA Division I athletes. *Orthopaedic Journal of Sports Medicine, 5*(8), 1-5. doi:10.1177/2325967117723666

Lehr, M. E., Plisky, P. J., Butler, R. J., Fink, M. L., Kiesel, K. B., & Underwood, F. B. (2013). Field-expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury. *Scandinavian Journal of Medicine & Science in Sports, 23*(4), e225-e232. Retrieved from http://proxy-lvc.klnpa.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=89023931&site=ehost-live

Lisman, P., Hildebrand, E., Nadelen, M., & Leppert, K. (2019). Association of functional movement screen and y-balance test scores with injury in high school athletes. *Journal of Strength and Conditioning Research.* Advance online publication. doi:10.1519/JSC.0000000000003082

Lisman, P., O'Connor, F. G., Deuster, P. A., & Knapik, J. J. (2013). Functional movement screen and aerobic fitness predict injuries in military training. *Medicine & Science in Sports &*

Exercise, 45(4), 636-643. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5675370/

Mokha, M., Sprague, P. A., & Gatens, D. R. (2016). Predicting musculoskeletal injury in National Collegiate Athletic Association Division II athletes from asymmetries and individual-test versus composite functional movement screen scores. *Journal of Athletic Training, 51*(4), 276-282. doi:10.4085/1062-6050-51.2.07

Orchard, J., Seward, H., McGivern, J., & Hood, S. (2001). Intrinsic and extrinsic risk factors for anterior cruciate ligament injury in Australian footballers. *The American Journal of Sports Medicine, 29*(2), 196-200. Retrieved from https://uindy.on.worldcat.org/oclc/118788976

Plisky, P. J., Gorman, P. P., Butler, R. J., Kiesel, K. B., Underwood, F. B., & Elkins, B. (2009). The reliability of an instrumented device for measuring components of the star excursion balance test. *North American Journal Sports Physical Therapy, 4*(2), 92-99. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953327/

Roos, K., Wasserman, E., Dalton, S., Gray, A., Djoko, A., Dompier, T., & Kerr, Z. (2017). Epidemiology of 3825 injuries sustained in six seasons of national collegiate athletic association men's and women's soccer (2009/2010-2014/2015). *British Journal of Sports Medicine, 51*(13), 1029-1034. doi:10.1136/bjsports-2015-095718

Shaffer, S. W., Teyhen, D. S., Lorenson, C. L., Warren, R. L., Koreerat, C. M., Straseske, C. A., & Childs, J. D. (2013). Y-balance test: A reliability study involving multiple raters. *Military Medicine, 178*(11), 1264-1270. doi:10.7205/MILMED-D-13-00222

Shultz, R., Anderson, S. C., Matheson, G. O., Marcello, B., & Besier, T. (2013). Test-retest and interrater reliability of the Functional Movement Screen. *Journal of Athletic Training,* *48*(3), 331-336. doi:http://dx.doi.org/10.4085/1062-6050-48.2.11

Smith, C. A., Chimera, N. J., & Warren, M. (2015). Association of y balance test reach asymmetry and injury in Division I athletes. *Medicine & Science in Sports & Exercise, 47*(1), 136-141. doi:10.1249/MSS.0000000000000380

Smith, P. D., & Hanlon, M. P. (2017). Assessing the effectiveness of the functional movement screen in predicting noncontact injury rates in soccer players. *Journal of Strength and Conditioning Research, 31*(12), 3327-3332. doi:10.1519/JSC.0000000000001757

Sprague, P. A., Mokha, G. M. & Gatens, D. R. (2014). Changes in Functional Movement Screen scores over a season in collegiate soccer and volleyball athletes. *Journal of Strength and Conditioning Research, 28*(11), 3155-3163. doi:10.1519/JSC.0000000000000506

Tenan, M. S. (2016). Quantifying emergency department visits from sport and recreation: Focus on the lower extremity and knee, 1997–2009. *Journal of Athletic Training, 51*(4), 309-316. doi:10.4085/1062-6050-51.4.12

Teyhen, D. S., Riebel, M. A., McArthur, D. R., Savini, M., Jones, M. J., Goffar, S. L., Kiesel, K. B., & Plisky, P. J. (2014). Normative data and the influence of age and gender on power, balance, flexibility, and functional movement in healthy service members. *Military Medicine, 179*(4), 413-420. doi:https://doi.org/10.7205/MILMED-D-13-00362

Tofthagen, C. (2012). Threats to validity in retrospective studies. *Journal of the Advanced Practitioner in Oncology, 3*(3), 181-183. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/

Walbright, P. D., Walbright, N., Ojha, H., & Davenport, T. (2017). Validity of functional screening tests to predict lost-time lower quarter injury in a cohort of female collegiate athletes. *International Journal of Sports Physical Therapy, 12*(6), 948-959. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5675370/

Warren, M., Smith, C., & Chimera, N. (2015). Association of the functional movement screen with injuries in division I athletes. *Journal of Sport Rehabilitation, 24*(2), 163-170. doi:10.1123/jsr.2013-0141

Wright, A. A., Dischiavi, S. L., Smoliga, J. M., Taylor, J. B., & Hegedus, E. J. (2017). Association of lower quarter y-balance test with lower extremity injury in NCAA division 1 athletes: An independent validation study. *Physiotherapy, 103*(2), 231-236. doi:10.1016/j.physio.2016.06.002

Table 1

Comparison of FMS-CS and YBT-LQ Injury Risk Categories by Injury (N = 143)

	Injured	Not injured				
	n = 89	*n* = 54				
Variable	*n* (%)	*n* (%)	χ2	OR	95% CI	*p*
FMS CS						
high-risk	38 (63.3%)	22 (36.7%)	0.05	0.92	[0.46, 1.83]	.818
low-risk	51 (61.4%)	32 (38.6%)				
YBT Ant						
high-risk	27 (62.8%)	16 (37.2%)	0.03	0.94	[0.45, 1.97]	.874
low-risk	62 (61.4%)	39 (38.6%)				
YBT Plat						
high-risk	30 (51.7%)	28 (48.3%)	4.59	2.12	[1.06, 4.23]	.032
low-risk	59 (69.4%)	26 (30.6%)				
YBT Pmed						
high-risk	35 (60.3%)	23 (39.7%)	0.15	1.15	[0.58, 2.28]	.700
low-risk	54 (63.5%)	31 (36.5%)				

Note. FMS CS = Functional Movement Screen Composite Score; YBT = Y-balance test lower quarter Ant = anterior reach difference 4 cm cut point; Plat = posterolateral reach difference 4 cm cut point; Pmed = posteromedial reach difference 4 cm cut point;

Alpha level adjusted to .008 using Bonferroni correction to account for the six hypothesis tests

Table 2

Comparison of Frequency of FMS-CS and YBT-LQ *Injury Risk Categories Between Noncontact Injury and No Injury*

Variable	Noncontact Injury n = 61	No Injury n = 54	$\chi2$	OR	95% CI	p
	n (%)	n (%)				
FMS CS						
high-risk	27 (55.1%)	22 (44.9%)	0.15	0.87	[0.41, 1.82]	.703
low-risk	34 (51.5%)	32 (48.5%)				
YBT Ant						
high-risk	21 (56.8%)	16 (43.2%)	0.38	0.78	[0.36, 1.72]	.538
low-risk	40 (50.6%)	39 (49.4%)				
YBT Plat						
high-risk	19 (40.4%)	28 (59.6%)	5.08	2.38	[1.11, 5.09]	.024
low-risk	42 (61.8%)	26 (38.3%)				
YBT Pmed						
high-risk	23 (50.0%)	23 (50.0%)	0.28	1.23	[0.58, 2.59]	.593
low-risk	38 (55.1%)	31 (44.9%)				

Note. FMS CS = Functional Movement Screen Composite Score; YBT = Y-balance test lower quarter Ant = anterior reach difference 4 cm cut point; Plat = posterolateral reach difference 4 cm cut point; Pmed = posteromedial reach difference 4 cm cut point

Alpha level adjusted to .008 using Bonferroni correction to account for the 6 hypothesis tests

Table 3

Comparison of FMS-CS scores, FMS Component Test Score Frequency, and YBT-LQ Direction Scores by Gender

	Males $n = 71$	Females $n = 72$		
Test	*Mdn* (IQR)	*Mdn* (IQR)	*Z* value	*p*
FMS CS	14 (3)	15 (3)	-2.27	.023
YBT Ant	2.30 (3.20)	2.40 (3.50)	-0.39	.699
YBT Plat	3.30 (4.70)	3.25 (3.70)	-0.28	.782
YBT Pmed	3.10 (4.10)	3.55 (4.50)	-0.69	.489
	n (%)	*n* (%)	χ2	*p*
FMS Component Test Score Frequency				
Deep Squat			0.51	.776
1	33 (50.8%)	32 (49.2%)		
2	35 (50.0%)	35 (50.0%)		
3	3 (37.5%)	5 (62.5%)		
Hurdle Step			3.86	.145
1	6 (85.7%)	1 (14.3)		
2	58 (47.5%)	64 (52.5%)		
3	7 (50.0%)	7 (50.0%)		

	n (%)	*n* (%)	χ2	*p*
Inline Lunge			4.65	.098
1	3 (33.3%)	6 (66.7%)		
2	46 (57.5%)	34 (42.5%)		
3	22 (40.7%)	32 (50.3%)		
Shoulder Mobility			4.70	.095
1	6 (7.05%)	2 (25.0%)		
2	25 (58.1%)	18 (41.9%)		
3	40 (43.5%)	52(56.5%)		
ASLR[a]			14.91	.001*
1	12 (92.3%)	1 (7.7%)		
2	30 (56.6%)	23 (43.4%)		
3	29 (37.7%)	48 (62.3%)		
Trunk Stab P/U[b]			29.49	< .001*
1	11 (22.4%)	38 (77.6%)		
2	41 (75.9%)	13 (24.1%)		
3	19 (47%)	21 (52.5%)		
Rotary Stability[c]			1.48	.224
1	13 (61.9%)	8 (38.1%)		
2	58 (47.5%)	64 (52.5%)		

Note. FMS CS = Functional Movement Screen Composite Score; YBT = Y-balance test lower quarter Ant = anterior reach difference 4 cm cut point; Plat = posterolateral reach difference 4 cm cut point; Pmed = posteromedial reach difference 4 cm cut point; IQR = interquartile range; ASLR = active straight leg raise; Trunk Stab P/U = trunk stability push up

*$p < .05$

[a] Significant difference ($p < .017$) between genders on pairwise post-hoc analysis between scores 1 and 3 with the Fisher exact test ($p < .001$).

[b] Significant difference ($p < .017$) between genders on all pairwise post-hoc analysis: between scores 1 and 2 $\chi2$ (1) = 29.39, $p <.001$, between scores 1 and 3 $\chi2$ (1) = 6.19, $p = .013$, between scores 2 and 3 $\chi2$ (1) = 8.04, $p = .005$. No counts were less than 5.

[c] No scores of 3 were achieved.

Figure 1. Data Collection Sources

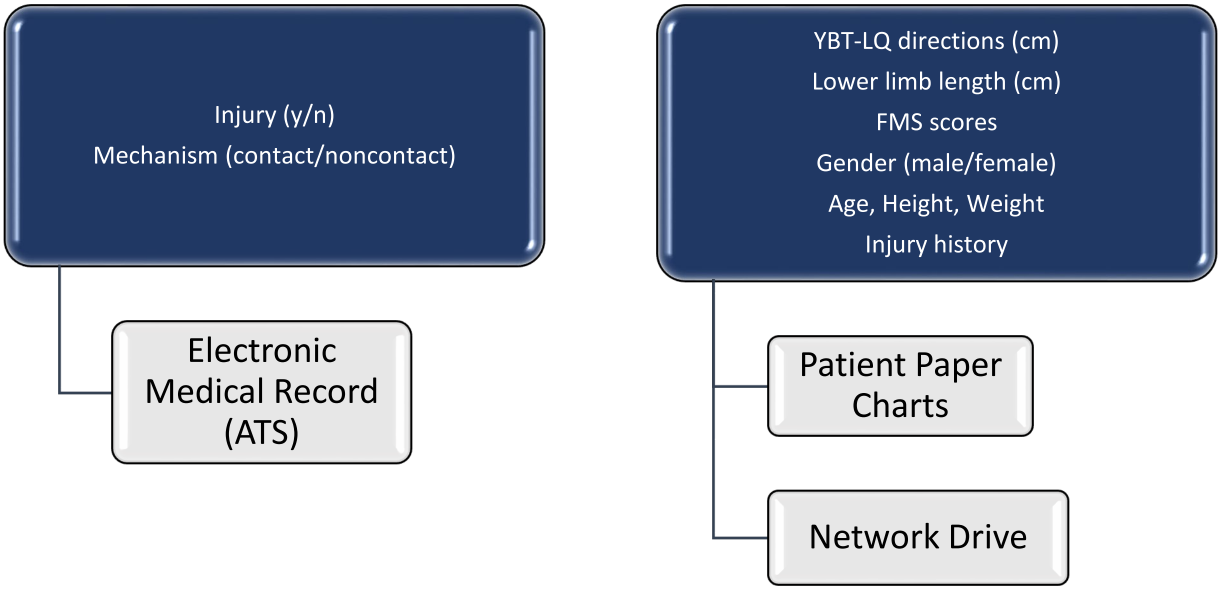
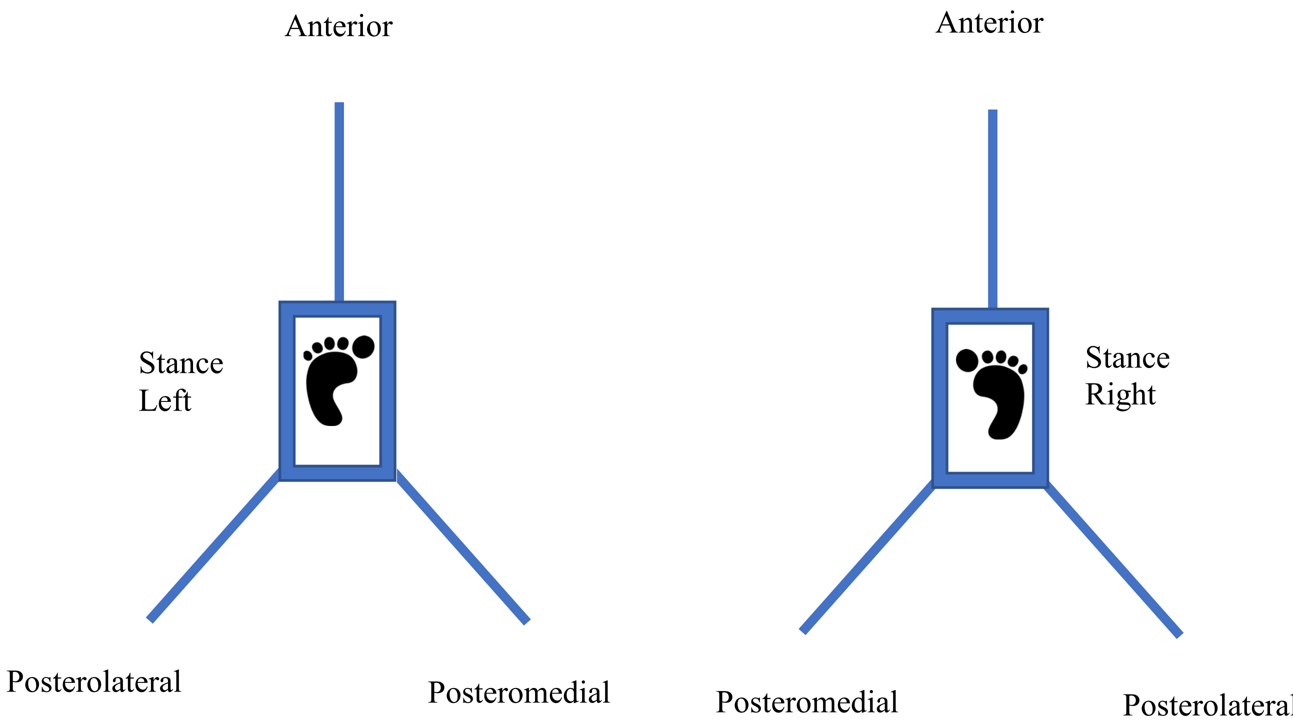


Figure 2. Diagram of Y-Balance Test Lower Quarter Non-Stance Foot Excursions



Appendix A

Lebanon Valley College Institutional Review Board Approval

AUTHOR: ERIN ULRICH, MATTHEW WECK, & SAMUEL GRILLO
TITLE: FUNCTIONAL MOVEMENT AND INJURY RISK

LVC INSTITUTIONAL REVIEW BOARD

RESEARCH CERTIFICATION FORM

In accordance with the compositional requirements of section 46.107 of the 45 CFR 46, this institution has established an IRB (as listed in the attached roster). This IRB is responsible for the continuing review of the research project.

I certify that this institution endorses the above project and abides by the principles set forth in Parts I and II of this Assurance of Compliance:

IRB Chairperson
Signature ______________________ **Date** 1/2/20

Name and Title: Ann Berger-Knorr, Ph.D., Associate Professor Education

Address: Department of Education, Lebanon Valley College

101 N. College Avenue, Annville, PA 17003 **Phone: 717-867-6596**

Authorized Institutional Official
Signature ______________________ **Date** 1/2/20

Name and Title: Marc Harris, Ph.D., Dean of the Faculty & Deputy Title IX Coordinator

Address: Lebanon Valley College

101 N. College Avenue, Annville, PA 17003 **Phone: 717-867-6146**

This project (check all that apply):

poses minimal risk.	X
poses greater than minimal risk.	
is exempt from Continuing Review.	
is accepted for Expedited Review.	X
required full IRB Review.	
IS APPROVED TO PROCEED	X
IS DISAPPROVED TO PROCEED	

Appendix B

Lebanon Valley College and University of Indianapolis Reliance Agreement

Version Date: 03/31/2011

Sample text for an Institution with a Federalwide Assurance (FWA) to rely on the IRB/IEC of another institution (institutions may use this sample as a guide to develop their own agreement).

Institutional Review Board (IRB) Authorization Agreement

Name of Institution or Organization Providing IRB Review (Institution/Organization A):
Lebanon Valley College IRB

IRB Registration #: ________________ Federalwide Assurance (FWA) #, if any: ________________

Name of Institution Relying on the Designated IRB (Institution B):
University of Indianapolis

FWA #: 000027197

The Officials signing below agree that the University of Indianapolis may rely on the designated IRB for review and continuing oversight of its human subjects research described below: (*check one*)

(___) This agreement applies to all human subjects research covered by Institution B's FWA.

(X) This agreement is limited to the following specific protocol(s):

Name of Research Project: Functional Movement and Injury Risk
Name of Principal Investigator: Elizabeth Moore, Ph.D and Erin Ulrich
Sponsor or Funding Agency: n/a Award Number, if any: n/a

(___) Other (*describe*): ________________

The review performed by the designated IRB will meet the human subject protection requirements of Institution B's OHRP-approved FWA. The IRB at Institution/Organization A will follow written procedures for reporting its findings and actions to appropriate officials at Institution B. Relevant minutes of IRB meetings will be made available to Institution B upon request. Institution B remains responsible for ensuring compliance with the IRB's determinations and with the Terms of its OHRP-approved FWA. This document must be kept on file by both parties and provided to OHRP upon request.

Signature of Signatory Official (Institution/Organization A):
[signature] Date: 1/24/2020

Print Full Name: Ann Berger-Knorr Institutional Title: LVC IRB Chair

NOTE: The IRB of Institution A may need to be designated on the OHRP-approved FWA for Institution B.

Signature of Signatory Official (Institution B):
[signature] Date: 1/21/2020

Print Full Name: Yvonne Wakeford for Ellen Miller Institutional Title: Director HRPP for Ass Provost