Using the Functional Movement Screen® and Y-Balance Test to Predict Injury in Division III Volleyball Players

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Using the Functional Movement Screen® and Y-Balance Test to Predict Injury in Division III Volleyball Players

Kaycee Rowe

Submitted to the School of Human Movement, Sport, and Leisure Studies
Bowling Green State University
In partial fulfillment of the requirements for the degree of

MASTERS OF EDUCATION
In
Kinesiology

May 1, 2020

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Abstract

Volleyball participation has increased over the years; therefore, injury rates have also increased (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007). An accurate pre-participation screening tool would be important to help reduce the risk of injury. **Purpose:** The purpose of this study was to use the Functional Movement Screen® (FMS®) and Y-Balance Test (YBT) to predict injury risk of Division III volleyball players during the competitive season. The FMS® and YBT identify functional movement limitations and imbalances that might predispose an athlete to injury (Bonazza, Onks, Silvis, & Dhawan, 2016; Cook, 2010; Cook, 2012; Lehr et al., 2013).

**Method:** Twenty-two female volleyball players (Mean ± S.D. Age: 19.5 ± 0.9 years) were recruited for this study. Quantitative data were collected from each athlete prior to the beginning of the competitive season and included administration of the FMS® and the YBT. Throughout the season, any injuries reported were recorded by the certified athletic trainer at the time of the injury. A one-way, between measures ANOVA was calculated to determine the significant differences between the injured (n = 10) and non-injured (n = 12) groups and their FMS® and YBT scores. To evaluate a composite score threshold for the development of injury, 2 × 2 contingency tables were created. These tables were also used to determine sensitivity, specificity, 1-specificity, and odds ratio for injury using each composite score, 13 through 18. **Results:** There were no significant differences between FMS® scores of those players injured and not injured (Mean ± S.D.: 15.5 ± 1.4 and 15.7 ± 2.5, respectively; p = .85). A score of 15 maximized both sensitivity (0.40) and 1 – specificity (0.17). Odds ratio indicated that individuals who had a composite threshold of ≤15 had 3.33 greater odds of becoming injured. There were no significant differences between the injured group and the uninjured group when comparing dominant and non-dominant YBT composite scores (p = .339, p = .326, respectively) or reach
differences in the anterior, posteromedial, and posterolateral directions ($p = .384$, $p = .333$, $p = .463$, respectively). Athletes with an FMS® composite score of $\leq 15$ in this small sample had a higher risk of becoming injured than those with scores $> 15$.

*Keywords:* Functional Movement Screen®, Y-Balance Test, injury, volleyball athletes
Introduction

Volleyball is a team sport that involves two teams of either six players (indoor volleyball) or two players (beach volleyball) (NCAA, 2020). Volleyball consists of many sport-specific skills including passing, setting, spiking, blocking, digging and serving. In indoor volleyball, positions on the court include front row (left front, middle front, right front), back row (libero, defensive specialist) and setter. The college indoor volleyball season lasts about four months from August to November. NCAA Division III volleyball teams play approximately 30 games, not including post-season tournaments (NCAA, 2020).

Participation in collegiate volleyball has grown over the years and like many sports, injury rates for volleyball players have also increased (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007). Injuries can impact teams’ performances and athletes’ performances. Approximately 40.6 injuries per 1,000 athlete-exposures have been reported in women’s collegiate volleyball between all three divisions (Division I, Division II, Division III) (Reeser, Gregory, Berg, & Comstock, 2015). Over the years of 1988-2004, there were more than 7,000 injuries reported between 50,000 practices and 90,000 games (Agel et al., 2007), with this number increasing due to increasing participation rates. Those injuries reported included head/neck, upper extremity, trunk/back, and lower extremity, with over half of these injuries to the lower extremity (Agel et al., 2007; Lehr et al., 2013; Walbright, Walbright, Ojha & Davenport, 2017).

Agel et al. (2007) investigated the epidemiology of women’s volleyball injuries from 1988-2004. Agel et al. (2007) researched injury rate by participation, division, and season. In Division III, 25% of injuries came from no apparent contact and 54% of those injuries occurred during practice (Agel et al., 2007). Player position also was a significant predictor of injuries,
with 67.3% of injuries happening in front row players (Agel et al., 2007). Hootman, Dick and Agel (2007) found that 50% of those injuries occurred to the lower extremities including ankle and anterior cruciate ligament (ACL) injuries.

Risk of injury can be measured by the probability of an incident and the consequences. Risk factors can include extrinsic and intrinsic factors. Extrinsic factors might include weather, temperature, or altitude. Extrinsic factors are less likely to contribute to injury in volleyball players compared to intrinsic factors. Intrinsic risk factors include previous injury; low or high body mass index; core motor control deficits; poor motor patterns; lack of flexibility, strength, and range of motion; poor balance; and poor functional movements (Frost, Beach, Callaghan, & McGill, 2012; Gonell, Pina Romera & Soler, 2015; Lehr et al., 2013).

Functional movement is defined as the ability to move the body with proper muscle and joint function to produce a pain-free movement (Stenger, 2018). Functional movements relative to volleyball include jumping, short sprints, multi-directional movements, and overhead movements. Excessive jumping and repetitive overhead movements are two of the main causes of injury in volleyball players (Eerkes, 2012). Imbalances and poor body mechanisms in these movements can further contribute to the incidence of injury.

**Functional Movement Screen®**

The Functional Movement Screen® (FMS®) was designed to identify functional movement limitations that might predispose an individual to injury (Bonazza, Smuin, Onks, Silvis & Dhawan, 2016; Cook, Burton, Hoogenboom, & Voight, 2006; Lehr et al., 2013). The screening includes seven functional tests and three clearing tests to grade whole body movement quality. The functional tests include deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability (Cook, 2010). Tests are
scored on a four-point system (0-3) and a cumulative score is determined with a maximum of 21 (Cook, Burton, Hoogenboom, & Voight, 2006). A score of 0 is given if pain occurs during test, a score of 1 is given if participant cannot perform the movement, a score of 2 is given if the subject compensates in any way to complete the movement, and a score of 3 is given if the participant performs the movement correctly without any compensations (Cook, Burton, Hoogenboom, & Voight, 2006).

The clearing tests include shoulder flexion, trunk flexion and trunk extension. These tests are scored with a positive (+), indicating pain, or a negative (-), indicating no pain. If any of these tests are scored positive, the corresponding functional test results in a score of zero.

Any score less than 21 on the FMS® indicates a compensatory movement. A compensatory movement is considered any movement used to achieve a functional motor skill when a normal movement pattern is unavailable (Beardsley & Contreras, 2014). Such compensatory movements can increase the risk of injury and reduce performance in an athlete (Beardsley & Contreras, 2014). Some athletes might be asymptomatic when performing a movement. The FMS® was designed to identify these compensatory movements and musculoskeletal imbalances that might be overlooked in an athlete with no symptoms (Chorba, Chorba, Bouillon, Overmeyer, & Landis, 2010; Parchmann & McBride, 2011). With the assessment of functional movements, intervention programs consisting of corrective exercises can be put in place for athletes who score lower and who fall in the high-risk category in order to reduce injury.

Previous research regarding a cut-off value for composite scores on the FMS® has been diverse. Most researchers suggest a cut-off value of 14 (Chorba et al., 2010; Garrison, Westrick, Johnson, & Benenson, 2015; Kiesel, Plisky & Voight, 2007). This means that a composite score
of less than 14 puts an athlete at a higher risk for injury. According to a meta-analysis completed by Bunn, Rodrigues, and Bezerra da Silva (2019), athletes who were in the “high-risk” category with a score < 14 were 51% more likely to sustain an injury. Chorba et al. (2010) and Garrison et al. (2015) agreed with this finding and also found a composite score of less than 14 indicated a higher risk of injury. Chorba et al. (2010) conducted a study on 38 female student-athletes who participated in Division II soccer, volleyball and basketball. The average FMS® score was 14.3 ± 1.77. Out of 38 participants, 18 injuries were reported with 17 injuries to the lower extremity and one injury to the lower back. Those who sustained an injury had a mean FMS® composite score of 13.9 ± 1.29 and those who did not report an injury scored an average of 14.7 ± 1.29 on the FMS®. Chorba et al. (2010) found volleyball players scored an average of 15.3 on the FMS® and reported five injuries of the 18 total injuries. In all, 69% of those athletes who scored < 14 were at a 4-fold increased risk of injury.

Garrison et al. (2015) also reported that a lower score on the FMS® increased the risk for injury. They studied 168 collegiate and club athletes in order to explore the association between FMS® scores and development of injury. Garrison et al. (2015) found those who were injured scored an average of 13.6 and those who were not injured scored an average of 15.5 on the FMS®. With this data, researchers concluded that athletes with a score < 14 on the FMS® combined with a previous injury were 15 times more likely for an injury (Garrison et al., 2015).

**Y-Balance Test**

The Y-Balance Test (YBT) can be used like the FMS® for identifying imbalances in functional movements (Cook, 2010; Cook, 2012). The YBT is used to measure motor control abilities (Cook, 2010; Cook, 2012) and requires strength, flexibility, neuromuscular control, stability, range of motion, balance, and proprioception (Gonell, Pina Romera, & Soler, 2015;
Hudson, Garrison, & Pollard, 2016). Single-leg balance is assessed when completing the YBT and absolute reach distance is measured in three directions: anterior, posteromedial, and posterolateral. The test is performed on each leg, and comparisons between leg distances can be used to assess any asymmetry or balance deficits.

For the YBT, the maximal reach distance is recorded where the most distal part of the foot (i.e., toe) reaches on the measurement stick. This is measured for all three directions and for each leg. Failed attempts occur when a person loses balance, places the foot on the top of the measurement indicator, or kicks the indicator to improve the score. The composite score is calculated by adding the measured anterior, posteromedial, and posterolateral directions, then dividing the sum by three times the participant’s limb length, and multiplying that number by 100 in order to calculate a percentage. Limb length is measured from the most noticeable portion of the greater trochanter and the floor while in a standing position. Reach difference for each direction can be calculated by subtracting the non-dominant limb from the dominant limb in that direction (Walker, 2016).

Hudson et al. (2016) studied YBT in Division I collegiate volleyball players to determine normative values. These researchers studied 90 female collegiate volleyball players from eight different universities. Of these 90 players, 24 were middle blockers, 18 defensive specialist/liberos, 26 outside hitters, 7 right side hitters, and 15 setters. The dominant leg composite score was 94.1% ± 6.6% and non-dominant leg composite score was 93.9% ± 6.2%. Hudson et al. (2016) also explored mean composite scores for each position. They found right side hitters to have the highest composite score in both the dominant (95.7%) and non-dominant (94.9%) legs. Setters had the second highest composite score with 94.7% dominant leg and 94.1% non-dominant leg. Overall, there were no significant mean differences for the reach
differences between any positions in this study. However, other researchers have suggested that a reach difference $> 4$ cm between dominant and non-dominant legs increases the risk for injury (Smith, Chimera, & Warren, 2014).

Smith, Chimera, and Warren (2014) conducted a study to examine the association of the YBT and noncontact season injury with Division I college athletes from a variety of sports. The study included 200 athletes playing men’s and women’s basketball, men’s and women’s cross-country, men’s football, women’s golf, men’s and women’s track and field, men’s and women’s tennis, women’s volleyball, women’s soccer, and women’s swimming/diving. A total of 81 participants reported a noncontact injury. However, composite scores did not significantly differ from those who were injured (101.3% ± 7.8%) and those not injured (101.2% ± 7.1%). Smith, Chimera, & Warren (2014) compared all reach directions (anterior, posteromedial, posterolateral) and found an asymmetry greater than or equal to 4 cm between dominant and non-dominant legs had greater odds of injury compared to those with less than 4 cm asymmetry.

Injury prevention is important in helping athletes achieve their training goals, as well as keeping them safe and healthy. Predicting injury risk can aid in injury prevention programs. Therefore, the purpose of this study was to use the FMS® and YBT to predict injury risk in Division III volleyball players. The functional movement of female volleyball players and their risk of injury was assessed during their competitive season.

**Methods**

**Participants**

Female collegiate volleyball athletes ($N=23$) at a small, Midwestern private Division III university participated in this study. The mean age of the total group was $19.5 \pm 0.9$ years with six freshmen, seven sophomores, four juniors and four seniors. The mean height was $67.3$ in. $\pm 3.4$ in. and the mean body mass index (BMI) value was $22.9$ kg/m$^2$ $\pm 1.9$ kg/m$^2$. Nine athletes
were strictly front row players, eight athletes played only back row, two athletes played front and back row, two athletes played back row and setter and two athletes played setter.

**Research Design**

This was an experimental research design with athletes tested using the Functional Movement Screen® and Y-Balance Tests prior to their competitive season. Any injuries that were reported during the season were collected by the certified athletic trainer and used for interpretation of the composite scores from the FMS® and Y-Balance Tests (Cook, 2010; Cook, 2012; Hudson, Garrison, & Pollard, 2016; Walker, 2016).

**Equipment, Materials, & Measures**

The FMS® tool kit and Y-Balance Test (YBT) kit were used to assess the athletes. The seven tests of the FMS® included deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, and rotary stability, as well as the three clearing tests: shoulder clearing, extension clearing and flexion clearing (Appendix A). Each individual test is scored on a 0 – 3 scale. A score of 0 is given if pain occurs during test, a score of 1 is given if participant cannot perform the movement, a score of 2 is given if the subject compensates in any way to complete the movement, and a score of 3 is given if the participant performs the movement correctly without any compensations. Total (composite) FMS® scores were out of a maximum score of 21. The YBT was completed in three directions: anterior, posterolateral, and posteromedial on each leg (Appendix B). YBT composite scores were calculated by taking the sum of each direction reach divided by three times the limb length times 100 and expressed as a percentage for both the dominant and non-dominant leg.
**Interrater Reliability of the FMS and YBT**

Interrater reliability has been reported to be acceptable for the FMS®; interclass correlation coefficients (ICC) have ranged from 0.76 to 0.98. Bonazza, Smuin, Onks, Silvis and Dhawan (2017) supported this by reporting that nine of 10 studies found the FMS® reliable. Bonazza, Smuin, Onks, Silvis and Dhawan (2017) also found that the level of experience administering the FMS® did not consistently affect this reliability. The YBT has also been reported to have high interrater reliability with ICC of 0.80-0.85 and interrater reliability of 0.99-1.00 (Walker, 2016).

The FMS® tests were completed in the following order:

**Deep Squat Test**

The individual stands with feet shoulder-width apart with toes pointing forward. A rod is in both hands and placed on top of their head with elbows at 90 degrees. The rod is then pressed straight above head and the individual squats as low as possible, maintaining an upright torso and keeping heels and toes in position. The individual holds the bottom position for one second and returns to starting position. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010).

**Hurdle Step Test**

The individual stands tall with feet together and toes touching test kit. The rod is in both hands and placed across the back of the shoulders. While maintaining an upright position, the individual raises right leg and steps over the hurdle. The individual should attempt to raise the foot towards the shin and maintain foot alignment with hip, ankle, and knee. The individual will touch the floor with their heel on opposite side of test kit and return to starting position maintaining alignment. The test is repeated on the left side. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010).
In-Line Lunge Test

The individual steps onto center of the board with left toes on the zero mark. The right heel should be placed at tibial height measurement. The rod is placed along spine in contact with head, upper back, and tailbone. While maintaining an upright posture, the individual will descend into a lunge position so left knee makes contact with center of board and returns to starting position. The test is repeated on the opposite side with the individual’s right toes at the zero mark and their left heel at their tibial height measurement. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010).

Shoulder Mobility Test

The individual starts standing tall with feet together and arms hanging comfortable at their side. A fist is made by placing their thumb into their fingers. In one motion, they will reach their right fist over their head and down their back while their left fist reaches up their back as far as possible. The individual should make sure not to “creep” their fists together after initial placement. The test is repeated on the opposite side. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010).

Shoulder Clearing Test

Individual places one hand on opposite shoulder and lifts elbow while maintaining contact on shoulder. This test is completed on both sides of the body. If pain occurs, a score of zero is given for the shoulder mobility test.

Active Straight Leg Raise Test

The individual lies flat on their back with knees against the board, feet together and toes pointing up. The rod is placed halfway between the anterior superior iliac spine (ASIS) and
kneecap. With the left leg remaining straight and maintaining contact with the board, the right leg will be raised as high as possible. The test is repeated on the left side. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010). Scoring is based on the endpoint of the raised ankle: between ASIS and rod (3); between rod and kneecap (2); between kneecap and ankle (1).

**Trunk Stability Push-Up Test**

The individual lies face down with arms extended overhead and shoulder-width apart. The individual will pull thumbs down in line with their chin (for women) or forehead (for men). Individual will make sure legs are together and toes pulled towards their shins. While maintaining a rigid torso, the individual will push their body up as one unit into a push-up position. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010).

**Extension Clearing Test**

Individual lies on their stomach and place their hands under their shoulders. With no lower body movement, the individual will press their upper body off the ground until elbows are straight. If pain occurs, a score of zero is given on the trunk stability push-up test.

**Rotary Stability Test**

The individual gets down on their hands and knees, straddling the FMS® board with thumbs, knees and toes touching the sides of the board. Their hands will be aligned with their shoulders and knees aligned with their hips. In one movement, he or she will lift their arm and leg on the same side, extending the leg backward and arm forward. The individual then touches their elbow to knee and then return to starting position. This movement is performed while keeping the arm and leg in-line with board. If this movement cannot be completed, the individual completes the same movement with opposite arm and leg, touching knee to elbow directly over
the board. The test is performed on each side and scored. The individual’s lateral and anterior views during the movement are compared to the FMS® pictures with ratings (Cook, 2010).

*Flexion Clearing Test*

In the same starting position as the rotary stability, the individual will rock their hips back towards their heels. They will lower their chest to their knees and reach their hands out in front of their body. If pain occurs, a score of zero will be given on the rotary stability test.

**Rater Reliability**

For the present study, a certified Level I examiner completed all FMS® testing. The rater reliability of this tester was assessed by comparing the tester’s ratings to two other FMS® Level I Certified examiners to establish interrater reliability. Twelve subjects were recruited and evaluated in all seven tests and three clearing tests by all three raters. An Intraclass Correlation Coefficient (ICC) for the total FMS® scores was calculated to determine interrater reliability among three raters. The Krippendorff’s alpha (KALPHA) test was used (Hayes & Krippendorff, 2007) to estimate the interrater reliability for each individual FMS® test. A KALPHA score of .8 or above indicates acceptable reliability, where 1.00 indicates perfect reliability and 0.00 indicating no reliability (Hayes and Krippendorff, 2007).

ICC was 0.952 with the lower and upper 95% Confidence Intervals (CI) of .879 and .985, respectively. This indicates that there was high reliability among the raters. KALPHA was calculated on each of the FMS® test scores. The interrater reliability was high (Kα > .80) for all single FMS® tasks with the exception of the right inline lunge, left inline lunge, left hurdle step, and squat (Kα = .55, Kα = .44, Kα = .78, Kα = .78, respectively; see Table 1). The probability that the Kα would not be acceptable is interpreted from the q values (i.e., < .67 if 10000 participants were tested). Both the squat and left hurdle step have a 9% chance of being < .67;
therefore, the squat and left hurdle step were moderately reliable. The left and right inline lunge tests had a 97% chance and an 82% chance, respectively, of being < .67; therefore, the ratings for these two tests would not be reliable.

**Table 1**
*Krippendorff Alpha statistics for each FMS task*

<table>
<thead>
<tr>
<th>Assessment</th>
<th>$\text{K} \alpha$</th>
<th>LL 95%</th>
<th>UL 95%</th>
<th>$q$ at 0.6700</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite Score</td>
<td>0.9579</td>
<td>0.929</td>
<td>0.9817</td>
<td></td>
</tr>
<tr>
<td>Right Rotary</td>
<td>0.8958</td>
<td>0.7396</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Left Rotary</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Trunk Stability</td>
<td>0.9469</td>
<td>0.8672</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right ASLR</td>
<td>0.9128</td>
<td>0.782</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Left ASLR</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right Shoulder</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Left Shoulder</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right Inline Lunge</td>
<td>0.5544</td>
<td>0.3316</td>
<td>0.7772</td>
<td>0.8241</td>
</tr>
<tr>
<td>Left Inline Lunge</td>
<td>0.442</td>
<td>0.1616</td>
<td>0.6652</td>
<td>0.9793</td>
</tr>
<tr>
<td>Right Hurdle Step</td>
<td>0.8542</td>
<td>0.7326</td>
<td>0.9514</td>
<td></td>
</tr>
<tr>
<td>Left Hurdle Step</td>
<td>0.784</td>
<td>0.5679</td>
<td>0.946</td>
<td>0.0942</td>
</tr>
<tr>
<td>Squat</td>
<td>0.784</td>
<td>0.5679</td>
<td>0.946</td>
<td>0.0942</td>
</tr>
</tbody>
</table>

$\text{K} \alpha$ = Krippendorff Alpha; $q$ = probability of failure to achieve an alpha; LL = Lower Level Confidence Interval; UL = Upper Level Confidence Interval
Procedures

After approval of the study from the Institutional Review Board at the two midwestern higher education institutions, participants were recruited from the women’s volleyball team at a Division III university. An information session was held at a team meeting with all team members in attendance. A description of the study, research protocol, benefits, and risks were presented to all team members. All questions were answered and team members had the opportunity to sign-up to volunteer for the study. Volunteers selected available testing times. The day prior to testing, individuals were sent a text message with a reminder of their testing times.

Each testing session was done individually to protect the privacy of the participant and was completed prior to the competitive season. During the testing session, participants completed the informed consent document (see Appendix C), and a Health Insurance Portability and Accountability Act (HIPAA) document (see Appendix D). Five participants were asked to fill out a consent document for pictures to be taken during testing procedures and used in publications.

Height and weight was self-reported by participants and BMI was calculated by researcher. Each individual’s hand length, tibia length, and leg length were measured. All measurements were taken on the individual’s dominant side. The hand length was measured from the tip of the middle finger to the bottom of the palm. The tibia length was measured from the individual’s tibial tuberosity to the floor. Leg length was measured from the anterior superior iliac spine (ASIS) to the floor. Cook (2010) testing protocol for the FMS® was followed and tests were administered in the order of deep squat, hurdle step, inline lunge, shoulder mobility, shoulder clearing test, active straight-leg raise, trunk stability push-up, extension clearing test, rotary stability, and the flexion clearing test. The participant had a maximum of three attempts for each test.
Following the FMS®, the YBT was administered using the recommended protocol (Walker, 2016). The right foot was used to push the indicator box three times, or until the last attempt was shorter than the longest attempt and this procedure was repeated for the left foot. The order of the procedure was completed in the anterior, posteromedial, and posterolateral directions. Each direction was completed on each foot before moving on to the next direction.

During the competitive season, all injuries were documented by the volleyball team’s certified athletic trainer using SportsWare software (Computer Sports Medicine; Stoughton, Massachusetts). After the competitive season, all injuries reported during the season were collected by the researcher in partnership with the certified athletic trainer. This information included type of injury, if an athlete received treatment, if an athlete lost participation time, and if so, for how long. All participants who completed the study had their name placed in a drawing for a $15 Chipotle gift card and the gift card was awarded.

**Statistical Analysis**

All data were analyzed using IBM SPSS Statistics 26 software (IBM Corporation; Armonk, New York). The mean was utilized as a measure of central tendency. To evaluate differences in composite FMS® scores and YBT scores between the injured and uninjured groups, a one-way, between measures ANOVA (Injury Status: Injured, Not Injured) was calculated to determine if there were significant differences between these two groups. Significance of \( p \leq .05 \) was set *a priori* for all analyses.

To evaluate a composite score threshold for the development of injury, \( 2 \times 2 \) contingency tables were created. Sensitivity is the probability that the clinical test results, in this study the FMS® cut-off test score, identifies those people who are positive (i.e., injured; who actually have the condition; true positive; see Figure 1) (Kuzma, 1998). Specificity is the probability that the
clinical test, in this study the FMS® cut-off test score, identifies those people who are negative (i.e., noninjured; who are in reality without the condition; true negative; see Figure 1) (Kuzma, 1998). For this study, odds ratio quantifies the strength of the association between an exposure and an outcome, where the exposure is an FMS® score less than the cut-off score and the outcome is an injury (Kuzma, 1998). If the odds ratio is > 1 there is a significant correlation between the FMS® score below the cut-off score and the presence of injury. Thus meaning, the presence of an FMS® score below the cut-off score increases the odds of having an injury. If the odds ratio is < 1 there would be a negative correlation and the presence of the exposure (i.e., FMS® score below the cut-off score) would reduce the odds of having an injury (Kuzma, 1998).

Figure 1 shows the table for True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). Sensitivity is calculated by \( \frac{TP}{TP + FN} \); specificity can be calculated by \( \frac{TN}{FP + TN} \); 1-specificity is calculated by \( \frac{1 - TN}{FP + TN} \); odds ratio is calculated by \( \frac{(TP)(TN)}{(FP)(FN)} \) (ACSM, 2018).

**Figure 1**
*Sample 2 × 2 Contingency Table*

<table>
<thead>
<tr>
<th>“Test Result”</th>
<th>“True Situation”</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
<td>Not Injured</td>
</tr>
<tr>
<td>≤ FMS® Cut-off Score</td>
<td>a (TP)</td>
<td>b (FP)</td>
</tr>
<tr>
<td>&gt; FMS® Cut-off Score</td>
<td>c (FN)</td>
<td>d (TN)</td>
</tr>
</tbody>
</table>

\( a = \text{True Positive- classifying a person with condition when condition is present; } \)
\( b = \text{False Positive- classifies person with condition when condition is not present; } \)
\( c = \text{False Negative- classifies person without the condition when condition is present; } \)
\( d = \text{True Negative- classifies person without condition when condition is not present (Kuzma, 1998; ACSM, 2018)} \)
A receiver-operator characteristic (ROC) curve was calculated plotting sensitivity versus 1-specificity to show how sensitivity and specificity varied for each cut-off score. The area under the curve gives a graphic representation of using the various cut-off scores. A significant cut-off score will maximize sensitivity (probability of TP) and specificity (probability of TN) as compared to the other possible cut-off scores.

Results

There were 23 female volleyball players at a Division III university who were tested using the FMS® and YBT. There was one dropout; therefore, 22 players completed the study. Demographic data for the athletes are shown in Table 2. A frequency table with the athletes characteristics is shown in Table 3.

Table 2
Demographics of the Female Volleyball Athletes (N=22)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.5 ± .9</td>
</tr>
<tr>
<td>Height (in)</td>
<td>67.3 ± 3.4</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>150.5 ± 19.3</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>23.3 ± 2.3</td>
</tr>
<tr>
<td>Dominant Hand Length (cm)</td>
<td>16.0 ± 1.0</td>
</tr>
<tr>
<td>Dominant Tibia Length (cm)</td>
<td>43.3 ± 2.1</td>
</tr>
<tr>
<td>Dominant Leg Length (cm)</td>
<td>96.8 ± 5.1</td>
</tr>
</tbody>
</table>

S.D. = Standard Deviation
Table 3
Frequency Table for Athletes’ Characteristics (N=22)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n of players</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Position</strong></td>
<td></td>
</tr>
<tr>
<td>Front Row</td>
<td>8</td>
</tr>
<tr>
<td>Back Row</td>
<td>8</td>
</tr>
<tr>
<td>Setter</td>
<td>2</td>
</tr>
<tr>
<td>Back &amp; Front Row</td>
<td>2</td>
</tr>
<tr>
<td>Back Row &amp; Setter</td>
<td>2</td>
</tr>
<tr>
<td><strong>Year in Collegiate Volleyball</strong></td>
<td></td>
</tr>
<tr>
<td>First</td>
<td>6</td>
</tr>
<tr>
<td>Second</td>
<td>7</td>
</tr>
<tr>
<td>Third</td>
<td>5</td>
</tr>
<tr>
<td>Fourth</td>
<td>4</td>
</tr>
<tr>
<td><strong>Leg Dominance</strong></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>19</td>
</tr>
<tr>
<td>Left</td>
<td>3</td>
</tr>
</tbody>
</table>

Of the 22 players, 10 players were injured during the course of the competitive season with a total of 15 injury occurrences (see Table 4). One player was injured three times and three players were injured twice. Seven of the 15 injuries (47%) occurred in the lower limb, five injuries (33%) occurred to the trunk (back/abdominal), and three injuries (20%) occurred in the upper limb. Fifty percent of those injured players were front row (n = 5), 40% were back row (n = 4), and 10% were setter (n = 1) (see Table 5). Those players who were injured had a mean
FMS® score of 15.5 ± 1.4 and the players who were not injured had a mean FMS® score of 15.7 ± 2.5 (see Table 6). There was no significant difference between FMS® scores for injured versus non-injured players ($p = .85$).

**Table 4**  
*Number of volleyball players injured (N = 22) during the 12-week season*

<table>
<thead>
<tr>
<th>Injured</th>
<th>n of Players</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>No</td>
<td>12</td>
</tr>
</tbody>
</table>

**Table 5**  
*Number and percentage of injuries by position (N = 10)*

<table>
<thead>
<tr>
<th>Position</th>
<th>$n$ injured</th>
<th>% injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Row</td>
<td>5</td>
<td>50%</td>
</tr>
<tr>
<td>Back Row</td>
<td>4</td>
<td>40%</td>
</tr>
<tr>
<td>Setter</td>
<td>1</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Table 6**  
*Means and standard deviations of total FMS® scores of injured and non-injured volleyball players (N=22)*

<table>
<thead>
<tr>
<th></th>
<th>Injured (n = 10) (Means ± S.D.)</th>
<th>Not Injured (n = 12) (Means ± S.D.)</th>
<th>$p$ value</th>
<th>Effect size (partial Eta squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS® scores</td>
<td>15.5 ± 1.4</td>
<td>15.7 ± 2.5</td>
<td>.852</td>
<td>.002</td>
</tr>
</tbody>
</table>

FMS® = Functional Movement Screen® (Cook, 2010); S.D. = Standard Deviation
There were approximately 180 hours of playing time between all practices and the competitive season of 31 games. About 50 total hours of playing time was missed for those injured players. Six players missed one to three days of participation, one player missed seven to nine days and one player missed more than 10 days of participation due to their injuries (see Table 7). Other injuries resulted in limited repetitions in practice.

**Table 7**

*Number of Days of Participation Missed by Injured Volleyball Players*

<table>
<thead>
<tr>
<th>Number of Days of Participation Missed</th>
<th>Number of Athletes (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 days</td>
<td>2</td>
</tr>
<tr>
<td>1 – 3 days</td>
<td>6</td>
</tr>
<tr>
<td>4 – 6 days</td>
<td>0</td>
</tr>
<tr>
<td>7 – 9 days</td>
<td>1</td>
</tr>
<tr>
<td>10+ days</td>
<td>1</td>
</tr>
</tbody>
</table>

Participation = games or practices

Five of the seven individual FMS® tasks can identify asymmetries between the left and right sides of the body (hurdle step, inline lunge, shoulder mobility, active straight leg raise, and rotary stability). There were no significant differences found between left and right sides (see Table 8). The lowest score (scale of 0-3) of the two sides was included in the composite FMS® score. Athletes (N = 22) scored the highest on the active straight leg raise test with a mean FMS® task score of 2.9 ± 0.3 (ASLR-left = 3.0 ± 0.2 and ASLR-right = 2.9 ± 0.3; see Table 8). Athletes who were injured (n = 10) scored the lowest on the trunk stability test with a mean FMS® task score of 1.1 ± 0.3 (see Table 8). Athletes who were injured (n = 10) had a mean FMS® task score
of 3.0 ± 0.0 on the shoulder mobility-right, while those athletes who were not injured \( (n = 12) \) had a lower average FMS\(^\circledR \) task score of 2.4 ± 0.8 on the shoulder mobility-right (see Table 8).

**Table 8**

*FMS\(^\circledR \) Individual Test Scores*

<table>
<thead>
<tr>
<th>FMS(^\circledR ) Test</th>
<th>FMS(^\circledR ) Score (( N = 22 )) Mean ± S.D. Range (0-3)</th>
<th>FMS(^\circledR ) Score of Injured (( n = 10 )) Means ± S.D. Range (0-3)</th>
<th>FMS(^\circledR ) Score of Non-Injured (( n = 12 )) Means ± S.D. Range (0-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squat</td>
<td>2.5 ± .6</td>
<td>2.6 ± .5</td>
<td>2.3 ± .7</td>
</tr>
<tr>
<td>Hurdle Step- Left</td>
<td>2.2 ± .4</td>
<td>2.2 ± .4</td>
<td>2.2 ± .4</td>
</tr>
<tr>
<td>Hurdle Step- Right</td>
<td>2.2 ± .43</td>
<td>2.1 ± .3</td>
<td>2.3 ± .5</td>
</tr>
<tr>
<td>Inline Lunge- Left</td>
<td>2.7 ± .5</td>
<td>2.7 ± .5</td>
<td>2.7 ± .5</td>
</tr>
<tr>
<td>Inline Lunge- Right</td>
<td>2.7 ± .5</td>
<td>2.7 ± .5</td>
<td>2.8 ± .5</td>
</tr>
<tr>
<td>Shoulder Mobility- Left</td>
<td>2.4 ± .7</td>
<td>2.6 ± .5</td>
<td>2.2 ± .8</td>
</tr>
<tr>
<td>Shoulder Mobility- Right</td>
<td>2.8 ± .7</td>
<td>3.0 ± .0</td>
<td>2.4 ± .8</td>
</tr>
<tr>
<td>ASLR- Left</td>
<td>3.0 ± .2</td>
<td>2.9 ± .3</td>
<td>3.0 ± .0</td>
</tr>
<tr>
<td>ASLR- Right</td>
<td>2.9 ± .3</td>
<td>2.8 ± .4</td>
<td>3.0 ± .0</td>
</tr>
<tr>
<td>Trunk Stability</td>
<td>1.5 ± .9</td>
<td>1.1 ± .3</td>
<td>1.9 ± 1.0</td>
</tr>
<tr>
<td>Rotary Stability- Left</td>
<td>2.0 ± .3</td>
<td>2.0 ± .0</td>
<td>2.0 ± .4</td>
</tr>
<tr>
<td>Rotary Stability- Right</td>
<td>2.0 ± .4</td>
<td>2.1 ± .3</td>
<td>2.0 ± .4</td>
</tr>
</tbody>
</table>

FMS\(^\circledR \) = Functional Movement Screen\(^\circledR \) (Cook, 2010); S.D. = standard deviation
Two, $2 \times 2$ contingency tables for $\leq 14$ and $\leq 15$ thresholds (see Tables 9 and 10, respectively) are shown because these scores have been reported to be typical cut-off scores for injury for athletes (Chorba et al., 2010; Garrison et al., 2015; Kiesel et al., 2007). Composite score thresholds of $\leq 13$, $\leq 16$, $\leq 17$ and $\leq 18$ were also calculated, as well as the calculations of sensitivity, specificity, $1 - $ specificity, and odds ratio at these thresholds (see Table 11). A composite FMS® score of 15 or below had the highest probabilities for sensitivity (.40) and specificity (.83) (see Table 11). This indicates there is a probability that using a cut-off score of $\leq 15$ will identify 40% of injured athletes and 84% of those not injured. The odds ratio (OR) in Table 11 indicates that individuals with a composite threshold of 15 had a 3.33 greater odds of becoming injured than those who had a score $> 15$.

The predictive values of positive (+) and negative (-) tests were calculated for each FMS® cut-off score (see Table 11). The predictive value for positive tests indicates the percentage of positive FMS® tests (i.e., less than the cut-off threshold) that correctly identify a player with an injury. The predictive value of negative tests indicates the percentage of negative FMS® tests (greater than cut-off threshold) that correctly identifies players without an injury. A cut-off threshold of $\leq 15$ has a predictive value for positive tests at 67% and a predictive value for negative tests at 63% (see Table 11; ACSM, 2018).

**Table 9**

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Not Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS® Score $\leq 14$</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>FMS® Score $&gt; 14$</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

FMS® = Functional Movement Screen® (Cook, 2010)
### Table 10
2 × 2 contingency table for a cut-off FMS score of ≤ 15 for all volleyball players (N=22)

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Not Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS® Score ≤ 15</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>FMS® Score &gt; 15</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

FMS® = Functional Movement Screen® (Cook, 2010)

### Table 11
Sensitivity and specificity of various composite FMS® cut-off scores

<table>
<thead>
<tr>
<th>FMS® Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>1-Specificity</th>
<th>Predictive Value (+ test)</th>
<th>Predictive Value (- test)</th>
<th>Odds Ratio (ad/bc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 13</td>
<td>.10</td>
<td>.83</td>
<td>.17</td>
<td>33%</td>
<td>53%</td>
<td>.56</td>
</tr>
<tr>
<td>≤ 14</td>
<td>.30</td>
<td>.83</td>
<td>.17</td>
<td>60%</td>
<td>59%</td>
<td>2.14</td>
</tr>
<tr>
<td>≤ 15</td>
<td>.40</td>
<td>.83</td>
<td>.17</td>
<td>67%</td>
<td>63%</td>
<td>3.33</td>
</tr>
<tr>
<td>≤ 16</td>
<td>.70</td>
<td>.33</td>
<td>.67</td>
<td>47%</td>
<td>50%</td>
<td>.88</td>
</tr>
<tr>
<td>≤ 17</td>
<td>1.00</td>
<td>.17</td>
<td>.83</td>
<td>50%</td>
<td>100%</td>
<td>0</td>
</tr>
<tr>
<td>≤ 18</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
<td>55%</td>
<td>0%</td>
<td>0</td>
</tr>
</tbody>
</table>

FMS® = Functional Movement Screen® (Cook, 2010); Sensitivity- probability that the FMS® cut-off test score identifies those people who will become injured; Specificity- probability that the FMS® cut-off test score identifies those people who will not become injured; Odds ratio- quantifies the strength of the association between the FMS® cut-off score and injury: (ad/bc) = ((TP)(TN)/(FP)(FN)) (Kuzma, 1998); Predictive value (+ test)- the percentage of positive tests that correctly identify a player with an injury; Predictive value (- test)- the percentage of negative tests that correctly identify a player without an injury (ACSM, 2018)
Figure 2 shows the Receiver Operating Characteristic curve (ROC) curve between sensitivity and 1-specificity for FMS® composite scores at 14, 15, and 16. The accuracy of each cut-off score depends on how well the test identifies the “true situation” for the athletes into the injured (True Positive, TP) and non-injured groups (True Negative, TN) based on their composite FMS® score. A score of 15 maximized both sensitivity (True Positive) and 1–specificity (.40 and .17, respectively; see Figure 2) and had the greatest area under the ROC curve.

The area under the curve is a numerical summary of the ROC curve and represents the accuracy of the FMS® test cut-off score to predict injury or not. The variable on the X-axis, 1-specificity, is the rate of FP (false positives among all cases that should be negative (FP + TN). As the values on the ROC curve increase, the curve represents more TP values, but also more FP values (which is not desirable). The area under the curve (AUC) can vary between .5 (poor cut-off for injury classification) and 1.0 (excellent cut-off for injury classification). Based on this very small sample size, the FMS® cut-off score is a rather poor cut-off for predicting injury (AUC = .617; see Table 12), but nonetheless is what was found for these Division III volleyball players.
**Figure 2**

ROC Curve (Sensitivity vs. 1-Specificity). A FMS score of 15 maximized both sensitivity (True Positive) and 1–specificity and accounted for the greatest area under the curve.

![ROC Curve](image)

An FMS\textsuperscript{a} score of 15 maximized both sensitivity (True Positive) and 1–specificity and accounted for the greatest area under the curve.

**Table 12**

*Area under the curve and confidence intervals for cut-off composite FMS scores of 14-16*

<table>
<thead>
<tr>
<th>Test Result Variable(s)</th>
<th>Area</th>
<th>Std. Error\textsuperscript{a}</th>
<th>Asymptotic 95% Lower Bound</th>
<th>Confidence Interval Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS 14</td>
<td>.567</td>
<td>.126</td>
<td>.320</td>
<td>.814</td>
</tr>
<tr>
<td>FMS 15</td>
<td>.617</td>
<td>.124</td>
<td>.374</td>
<td>.860</td>
</tr>
<tr>
<td>FMS 16</td>
<td>.517</td>
<td>.126</td>
<td>.269</td>
<td>.764</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Under the nonparametric assumption;\textsuperscript{b} Null hypothesis: true area = .05

**Y-Balance Test Results**

There were no significant differences between the injured group and the non-injured group when comparing dominant and non-dominant leg YBT composite scores ($p = .339, p =$
.326, respectively; see Table 13) or for reach differences between the dominant and non-
dominant legs in the anterior, posteromedial, and posterolateral directions ($p = .384$, $p = .333$, $p$
$= .463$, respectively; see Table 14).

**Table 13**

*Average YBT Composite Score of Injured and Not Injured*

<table>
<thead>
<tr>
<th></th>
<th>Injured ($n = 10$) (Means ± S.D.)</th>
<th>Not Injured ($n = 12$) (Means ± S.D.)</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>YBT Dominant Composite Score</td>
<td>90% ± .08</td>
<td>90% ± .06</td>
<td>.339</td>
</tr>
<tr>
<td>YBT Non-Dominant Composite Score</td>
<td>90% ± .08</td>
<td>90% ± .04</td>
<td>.326</td>
</tr>
</tbody>
</table>

*YBT = Y-Balance Test (Walker, 2016); YBT composite score is the sum of the reach distance in each direction (anterior, posteromedial, posterolateral) divided by limb length times 100*

**Table 14**

*YBT Reach Difference Between Dominant and Non-Dominant Legs of Injured and Not Injured*

<table>
<thead>
<tr>
<th></th>
<th>Injured ($n = 10$) (Means ± S.D.)</th>
<th>Not Injured ($n = 12$) (Means ± S.D.)</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>3.0 ± 3.1</td>
<td>4.2 ± 3.0</td>
<td>.384</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>5.2 ± 3.8</td>
<td>3.8 ± 2.6</td>
<td>.333</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>6.3 ± 5.3</td>
<td>4.8 ± 3.7</td>
<td>.463</td>
</tr>
</tbody>
</table>

*YBT = Y-Balance Test (Walker, 2016); Reach difference = difference in reach distance (cm) between dominant and non-dominant leg. n = 4 were left leg dominant; n = 18 were right leg dominant; S.D. = Standard Deviation*
Discussion

The purpose of this study was to use the FMS® to predict injury risk in Division III volleyball players during the competitive season. The probability of injury can depend on a variety of factors. A history of injury, muscle ratio, structural abnormalities, core instability, repetitive use, and female gender are a few factors that could increase the risk of injury (Chorba et al., 2010; Warren, Smith, Chimera, 2015). The injury definition for this study was any injury that was reported to the athletic trainer and required treatment or intervention. A broad injury definition allowed for the capture of injuries that may not have resulted in a significant loss of playing time, but may have affected movement patterns and peak performance (Garrison et al., 2015).

Ten of the 22 players were injured during their competitive season (45%). Sixty percent of the injured players reported a history of injuries. A history of injuries has been reported to increase risk of injury according to Chorba et al. (2010). The highest percentage of those players injured played in the front row (50%), which can also be supported by Agel et al. (2007), who found 67% of injuries occurring in volleyball players playing the front row. Hootman et al. (2007) found that 50% of injuries were to the lower extremity and that was supported by the present study which found seven of the 15 injuries occurring in the lower extremities (47%). Overall, there were no significant differences between the players who were injured and not injured when comparing the FMS® and YBT scores.

Functional Movement Screen® (FMS®)

The researcher was FMS® Level I certified. The ICC value and KALPHA value indicated high interrater reliability for FMS® composite scores and most individual FMS® test scores among three independent raters; therefore, it was determined that the rater for this study was capable of making judgements similar to other certified FMS® Level I raters.
There were no significant differences between FMS® composite scores in those players who were injured and those players who were not injured. Warren, Smith and Chimera (2015) also did not find differences between scores of those players who were injured and not injured. One hypothesis of this study was that an FMS® composite score of \( \leq 14 \) would increase the likelihood of becoming injured during the competitive season. Kiesel et al. (2007) determined a cut-off score of \( \leq 14 \) increased the likelihood of injury; therefore \( \leq 14 \) was initially used in this study to determine the validity of using this as the cut-off threshold.

In the present study, it was found that one score higher (\( \leq 15 \)) may be a better cut-off score for predicting injury. A threshold of 15 had the highest values for sensitivity and specificity. Thus, the players who had a lower FMS® composite score (\( \leq 15 \)) were more likely to become injured (sensitivity) and those players who had a higher FMS® composite score (\( > 15 \)) were less likely to become injured (specificity) (Kuzma, 1998). Dorrel, Long, Shaffer, and Myer (2018) also found a cut-off score of \( \leq 15 \) to have higher sensitivity and specificity compared to a cut-off of \( \leq 14 \) reported in many other studies. A threshold score of 15 also had a higher odds ratio. A threshold score of 14 resulted in a lower odds ratio (2.14) compared to a threshold score of 15 (3.33). A higher odds ratio indicates an increased chance of becoming injured.

For the cut-off threshold of \( \leq 15 \), positive and negative predictive values were 67% and 63%, respectively. This means that 67% of positive FMS® tests (\( \leq 15 \)) correctly identified a volleyball player with an injury and 63% of negative FMS® tests (\( > 15 \)) correctly identified a volleyball player without an injury. The closer the predictive values are to 100%, the more accurate the performance of the diagnostic test is in this study, the FMS® screen. Positive and negative predictive values are similar to sensitivity and specificity in that they identify the
likelihood of an outcome; however, positive and negative predictive values do not include false positives or false negatives.

Nine out of 10 players who were injured scored a one for the trunk stability, indicating poor core stability. Five of the 12 who were not injured scored a three on this test. The average score on the trunk stability for those athletes who were injured was 1.1, whereas all other FMS® task scores had an average of 2.0 or higher. Chorba et al. (2010) discussed how females are likely to have decreased upper body strength and shoulder laxity which may cause a lower score on trunk stability; however, a majority of their subjects (74%) also scored a 3 on the shoulder mobility test. Results from the current study also resulted in higher scores on the shoulder mobility test compared to the trunk stability test. These results can indicate a lower score on trunk stability being associated with core instability. Chorba et al. (2010) also reported core instability to increase risk of injury.

Warren et al. (2015) also examined the FMS® movement patterns that assess asymmetry (i.e., hurdle step, inline lunge, shoulder mobility, active straight leg raise, and rotary stability) and did not find any significant findings. Asymmetry can be defined as a difference between patterns of FMS® movements that are scored separately. The results of the current study also were not significant for movement patterns assessing asymmetry.

The finding of a low FMS® composite score associated with injury risk is somewhat consistent with other studies. The results of the current study resulted in a cut-off threshold score of 15 to maximize both sensitivity (True Positive) and 1-specificity and had the greatest area under the curve of the ROC. The area under the curve represents the accuracy of the FMS® cut-off score of 15 to predict injury or not. On a scale of 0.5 (poor) to 1.0 (excellent), a cut-off threshold score of 15 was approximately 0.6 indicating a poor cut-off score for predicting injury.
However, the results of this study are not generalizable, as these are only applicable to Division III female volleyball players.

**Y-Balance Test (YBT)**

Researchers have suggested that a reach difference between dominant and non-dominant legs of > 4 cm increases the risk for injury (Smith, Chimera, & Warren, 2014). There were no significant differences in YBT reach difference between those injured and not injured. The average reach difference in the anterior, posteromedial, and posterolateral directions in those players injured were 3.0 cm, 5.2 cm, and 6.3 cm, respectively, compared to those players not injured with 4.2 cm, 3.8 cm, and 4.8 cm, respectively. Therefore, posteromedial and posterolateral reach differences could potentially indicate a higher risk for injury, although the anterior and posterolateral directions were also > 4 cm in the uninjured athletes.

Y-balance test composite scores were analyzed for dominant and non-dominant legs. Hudson, Garrison and Pollard (2016) found females who had a composite score less than 94% were 6.5 times more likely to become injured. A composite score of 100% indicates a very small risk of becoming injured and the reach differences in all directions (anterior, posteromedial, and posterolateral) between dominant and non-dominant legs were 0 cm. The mean composite scores for those athletes who were injured were 90% for both dominant and non-dominant legs, supporting Hudson, Garrison and Pollard (2016) findings. However, there were no significant differences between dominant legs for injured or non-injured athletes ($p = 0.339$). There were also no significant differences between non-dominant legs for those injured or not injured ($p = 0.326$). Hudson, Garrison and Pollard (2016) also did not find significant differences between composite scores of dominant ($p = 0.867$) and non-dominant ($p = 0.989$) legs.
Hudson, Garrison and Pollard (2016) researched a larger sample size of female volleyball players and reported normative data for composite scores. They showed a mean composite score of 94.1% for the dominant leg and 93.9% for the non-dominant leg. In the present study, mean composite scores of 90% for both dominant and non-dominant legs were calculated for both injured and non-injured players. The results indicate a lower mean YBT score and an increased risk of injury if 94% is used as a cut-off for injury.

It is interesting to note that one player had > 4 cm reach differences in all three directions (anterior = 7 cm; posteromedial = 12 cm; posterolateral = 17 cm) and she was not injured during the competitive season. All other injured players had only one or two directions with a reach difference > 4 cm. With no significant differences found for the YBT in those injured and not-injured, it is difficult to conclude that the YBT would be a valid assessment in determining injury risk for this group of athletes.

Future Studies

Future research should explore the idea of corrective exercises and how these might improve FMS® and YBT scores in the hopes of preventing injury. Although all individuals are different and may require diverse corrective exercises, it would be beneficial to understand how corrective exercises might coincide with imbalanced functional movements to prevent injury. Further research should identify how movement limitations in specific FMS® tests, rather than the composite FMS® score, may lead to injury.

Limitations

One of the limitations of this study was that it was a small sample size (N = 22). A small sample size over one season may limit the conclusions, and the results of this study should be interpreted carefully. Additional work with a larger sample size may be required to further
investigate the FMS® and YBT to identify functional movement limitations and imbalances that might predispose an athlete to injury. Another limitation of the present study was that individual playing time was not taken into consideration when analyzing the reported injuries. Players who are exposed to more minutes in games and/or practices may have had an increased risk of becoming injured.

**Conclusion**

Functional movement limitations and imbalances can increase the risk for injury in athletes and can be identified by using the Functional Movement Screen® and Y-Balance Test. The results of this study do not support the widespread use of an FMS® score of 14 as a cut-off threshold for injury. However, this study adds to the current research literature and indicated a cut-off threshold of ≤15 as a risk for injury. The YBT mean composite scores were similar between injured and non-injured players and therefore, were not used as a screen for injuries. Future research to determine FMS® and YBT normative scores for volleyball players is necessary.
References


  https://www.ncaa.com/sports/volleyball-women/d.


Appendix A

Images are from data collection for the Functional Movement Screen for Deep Squat, Hurdle Step, Inline Lunge, Active Straight Leg Raise, Trunk Stability, Rotary Stability, and Shoulder Mobility. All of the seven tests and clearing tests with scoring criteria and the scoring sheet can be retrieved from Cook (2010) or online from [http://www.functionalmovement.com](http://www.functionalmovement.com).
Appendix B

Images are from data collection for Y-Balance Test in the anterior, posterolateral, and posteromedial directions.
INFORMED CONSENT FORM

Title: USING THE FUNCTIONAL MOVEMENT SCREEN AND Y-BALANCE TEST TO PREDICT INJURY IN DIVISION III VOLLEYBALL PLAYERS

BGSU Principle Investigator: Kaycee Rowe (419) 953-3212

Key Information: The Functional Movement Screen (FMS; Cook, 2010) is an assessment designed to screen for fundamental movement limitations that might predispose an individual to injury. If the FMS is deemed valid and reliable, it can be included in a pre-participation examination to reduce risk of injury. In order to determine if the FMS is a valid and reliable test, we will be comparing FMS scores with reported number of and severity of injuries from the competitive volleyball season. As a participant in this study, you will complete seven functional movement tests, three clearing tests and a series of Y-balance tests. You will also be asked to complete the Athletic Identity Measurement and Sports Motivation Scale II questionnaires. The total duration of this testing will be approximately 1 hour. Following the season, your reported injuries will be collected from your athletic trainers.

Why is this study being done?
The purpose of this study is to assess the relationship of Functional Movement Screen (FMS) scores and Y-Balance Test (YBT) scores with injury occurrences in women’s Division III collegiate volleyball players during their competitive season. Functional movement is the ability to move the body with proper muscle and joint function for a pain-free movement. Poor functional movement habits and asymmetries may lead to injuries. We are investigating the functional movement of members of your team and their risk for injury.

You have been asked to be a participant in this study because you are a Division III collegiate volleyball player.

Prerequisites to being in the study. You must be a member of the Bluffton University women’s volleyball team between the ages of 18-22 years. The recruitment goal for this study is to recruit 30 participants. Any participant cannot have a current injury. This will be determined by self-report. Please inform the researcher if you do not meet criteria to participate in the study.
What will happen if you take part in this study? (Procedures and Duration)
If you chose to participate in this research, all involvement will be for research purposes only and not for diagnostic or treatment purposes. You will be asked to complete a demographic and injury history form asking for your name, age, player position and history of injuries. You will also participate in screening activities and functional testing at Bluffton University.

If you meet the eligibility requirements, you will participate in a one-time screening visit. The visit will include signing an informed consent form and Health Insurance Portability and Accountability Act of 1996 (HIPPA) authorization form, as well as the FMS and YBT testing. The visit to collect all data and your participation in this study will take approximately 1 hour. The FMS and YBT are tests designed to screen fundamental movement limitations that might predispose an individual to injury. During this screening, participants will complete 7 functional tests including deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability; 3 clearing tests to assess pain, and single leg reach tests in 3 directions on both the dominant and non-dominant leg. Each test will take approximately 3-5 minutes. Participants will be scored based on their ability to complete the tests and their reach distance. Following the season, information related to injuries occurring during the season will be received from your athletic trainers.

Risks and discomforts you may experience if you take part in this research

- By agreeing to take part in this research study, you give to Bowling Green State University, the Principal Investigator and all personnel associated with this research study your permission to collect information on your health conditions and health history. Names will be used to link FMS, YBT data and injury data. Once all data is collected you will be assigned a unique identification code by BGSU researchers. The data collected from the FMS, YBT, and athletic trainers will be labeled with this code. All data storage is password-secured and only I, the researcher and my advisor, will have access to your information. All data will be coded by a number and not your name or personal information. Any eventual research report will NOT include names or any information that could allow someone to determine which participant produced a given score.
- Participating in this study will yield no risk greater than everyday exercise. However, to minimize the risk of injury, prior to each test, thorough instructions will be given on how to perform the test. In case of emergency or injury, an athletic trainer will be on site and nearby.
What are the benefits to participating?
Specific benefits to benefits to being in this study: Your participation will allow you to become aware of your own injury risk and be able to take preventative steps to decrease your risk. Following the study, you will receive your FMS composite score and will have the opportunity to receive corrective exercises, if needed, to decrease your risk of injury. Norms for the FMS score will also be provided to you.

General benefits of being in this study: Your participation will benefit science by increasing our knowledge of the relationship between the FMS and YBT scores and predicting injury. This knowledge could lead to future interventions to decrease injury.

Will I receive payment or compensation for taking part in this research?
At the end of participation, you will be placed in a drawing with all other participants to win a $15 Chipotle gift card for your time. Your chance of winning the giftcard is approximately 1 in 30.

What other choices do you have if you do not take part in this study?
You may choose not to participate in this research study. If you do not decide to participate in this study, it will not affect your position on the team or your relationship with Bluffton Athletics or Bowling Green State University. Furthermore, if you begin participation in the study, you may also choose to withdraw from participation at any time. If you choose to withdraw from the study, your name will not be entered into the drawing for the Chipotle gift card. However, there will be no other consequences to you for withdrawal either as a student or as an athlete. Early withdrawal will not affect your position on the team or your relationship with Bluffton Athletics or Bowling Green State University.

CONFIDENTIALITY
By agreeing to take part in this research study, you give recruiting site Bowling Green State University (BGSU) and FMS testing site, Bluffton University and all personnel associated with this research study your permission to collect information we obtain in connection with this study. We will use this information solely for conducting the present research study as described in the research consent form.

The information that we will use includes all data collected during FMS testing and injury records from the season. In summary, we are collecting information regarding your functional ability based on the FMS and your reported injuries during your competitive season.
Appendix C (cont.)

Your data will be stored in a computer program but not any personal information (i.e., your identity). Any system used for data storage is password-secured—only the researchers will have access to your data. Names will be included during data collection to link FMS data with injury data. Any paper forms containing personal information will be stored in a locked file cabinet in the PI’s office on Bowling Green State University’s campus. Following data collection, all data will be coded by a number and not your name or personal information. Data from this study may be used in medical publications or presentations, but any information identifying you will be removed.

**What are the costs of taking part in this study?**
If you decide to take part in this research, you will not be charged for any study-related procedures.

**Who can answer your questions about the study?**
Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think this over. If you have any questions concerning this study or consent form beyond those answered by the investigator, including questions about the research, your rights as a research subject or research-related injuries, please contact myself at rowek@bgsu.edu or 419-953-3212; Dr. Lynn Darby at ldarby@bgsu.edu or 419-372-6903; Bowling Green State University’s Office of Research Compliance at orc@bgsu.edu or 419-372-7716.
Signatures:
You are making a decision whether or not to participate in this study. Your signature indicates that you have read and understood the information provided above, have had all your questions answered, and have decided to participate.

By signing this document, you authorize us to use or disclose your protected health information as described in this form.

Printed Name of Subject (18 years or older)

Signature of Subject (18 years or older)  Date

YOU WILL BE GIVEN A SIGNED COPY OF THIS CONSENT FORM TO KEEP
Appendix D

HIPPA Authorization to Use and Disclose Protected Health Information for Research Purposes

**Title of Study:** Using the functional movement screen and Y-balance test to predict injury in Division III volleyball players

**Principal Investigator:** Kaycee Rowe

**Investigator’s Contact Information:** Phone: 419-953-3212  Email: rowek@bgsu.edu

HIPPA is the Health Insurance Portability and Accountability Act of 1996, a federal law related to privacy of health information.

**What is the purpose of this form?** You have been asked to take part in a research study. The consent form for this study describes your participation and all that information still applies. The purpose of this form is to obtain your permission to use health information about you that is created by or used in conjunction with this research.

**What if I don’t want my personal health information (PHI) to be used in a research study?** You do not have to give this permission. Your decision to sign this form will not change your ability to get health care outside of this research study. However, if you do not sign this form you will not be allowed to participate in the study.

**What PHI am I allowing to be used for this research?** PHI used for this study will be any injury acquired during the competitive season. This includes what the injury was, if the athlete received treatment for injury, if athlete had a loss in playing time and how long.

**Where will the researchers go to find my PHI?** We will ask for specific details regarding any injury during the season, including type of injury, any treatment received for injury and if any playing time was lost and how long. PHI will be released by the athletic trainer through the SportsWare software.

**Who will be allowed to see my PHI?** The researcher named above and staff members of this research team will be allowed to see and use your health information for the research study. Your records may also be viewed by representatives of Bowling Green State University’s Institutional Review Board.

**Will my information be used in any other way?** Your information will only be used in this research study. Data in this research study may be published, but your personal information will be unidentifiable. All information and data will be deleted upon completion of this study.
Appendix D (cont.)

**What if I change my mind after I give this permission?** You can change your mind and withdraw this permission at any time by informing the Principal Investigator. If you withdraw this permission, the researcher will not use your information already collected. No other additional health information about you will be collected by or given to the researcher for the purposes of this study.

**What are the privacy protections for my PHI used in this research study?** HIPAA regulations apply to personal health information in the records of health care providers and other groups that share such information. Unique number codes will be given to participants so PHI cannot be traced back to individuals.

**How long does this permission allow my PHI to be used?** If you decide to be in this research study, your permission to access and use your health information will only last the duration of the study. No other health information will be accessed except for new health information acquired during the competitive volleyball season. Following the season, we will not be able to access any of your health information.

I am the research participant. By signing this form, I am giving permission for my personal health information to be used in research as described above.

_________________________  __________________________  ____________
Name of Research Participant    Signature                  Date

_________________________  __________________________  ____________
Name of Researcher              Signature                  Date

YOU WILL BE GIVEN A SIGNED COPY OF THIS CONSENT FORM TO KEEP