Function Movement Screening Used as a Predictor for Rowing Injuries

Honors Thesis

March 2015

Tori Torrisi

Dr. Megan Colas, Advisor

Dr. Elizabeth Swann, Co-Advisor

Nova Southeastern University

Farquhar College of Arts and Sciences

Undergraduate Honors Program

Division of Math, Science, and Technology

Undergraduate Honors Thesis

of

Tori Torrisi

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Approved:

Honors Thesis Committee

Dr.Don Rosenblum, Dean, Farquhar College of Arts and Sciences

Dr.Matthew He, Director, Division of Math, Science, and Technology

Dr. Megan Colas, Thesis Advisor, Division of Math Science and Technology

Tori Michelle Torrisi, Undergraduate Honors Research Student

Nova Southeastern University

March 2015

Preface

I was fortunate enough to be recruited by Nova Southeastern University's rowing team and was immersed in an incredible group of athletes and sports medicine staff. We were a strong willed and athletic team but like many rowing teams across the country we had a problematic number of injuries. We completed Functional Movement Screening (FMS) as a part of our pre-participation examination before every season but had not yet analyzed those scores to determine their ability to predict injury. Our athletic trainer Zevon Stubblefield began emphasizing injury prediction and prevention in the athletic training room. He took a proactive approach to keeping student athletes healthy which I aspire to emulate as a future clinician.

I began learning about research methods in my clinical classes and discovered the value of using evidence based practices. I enjoyed sifting through research to find new techniques and treatment plans. When I heard about the honors thesis option, I was thrilled. I could finally take the skills I learned in class and utilize them to help my team solve their injury problem.

Our sports medicine staff was dedicating days to Function Movement Screening as well as spending time and money to become certified to use FMS testing. I choose to explore the effectiveness of FMS on a Division Two women's rowing population so that my findings could be utilized by Nova Southeastern University's rowing team in the future. If FMS was effective in predicting injuries, then those resources allocated to FMS testing were well spent. However, if FMS testing is not effective in predicting injuries in the rowing population, then perhaps other prediction models should be considered.

When I told Dr. Swann, who would later become my faculty advisor about my intention to complete an honors thesis, she was extremely supportive. She encouraged me to speak to the other faculty and staff in order to learn as much as I could about FMS, research methods, and their experiences with injury prediction. I have been fortunate to have such an incredible support system which included my professors, the sports medicine staff, and my peers. When Dr.Swann had the opportunity to further her career and go on sabbatical, Dr. Colas made a seamless transition to the role of faculty advisor and helped me complete my honors thesis.

This experience has given me a greater appreciation for the work that goes into conducting research. It has reinforced my desire to question common clinical practices and be open minded to newer, more effective clinical practices. My honors thesis made me a more competitive applicant for graduate school and helped me secure a spot at my top choice. I am so grateful to have had this opportunity and hope that many future honors students explore this option.

Abstract

Function Movement Screening (FMS) has been successfully used to predict injuries in Cadets, professional football players, division two women's volleyball and basketball but there has been no FMS research done on the rowing population (Cosio-Lima et al., 2013; Kiesel et al., 2007;Chorba et al., 2010). Since the implementation of title IX, the number of intercollegiate women rowing teams has doubled. (US Rowing, Personal Communication, 2011). According to the National Collegiate Athletic Association (NCAA) there has been a steady increase in the number of female collegiate rowers with that number now reaching over 7,000 athletes. With an increase in participation, there is also an increase in the number of rowing injuries.

Purpose: to explore FMS as an injury predictor in a division two collegiate rowing team.

Null Hypothesis: FMS scores will have no relationship with the presence of injury in a rowing population

Alternate Hypothesis: FMS score of 14 or below or the presence of a score of "1" will be a predictor for rowing injuries

Participants: Retroactive data from the 2012 rowing team was acquired after receiving IRB approval. Data from 28 division two rowing athletes was used in the study.

Results: An FMS score of 14 or below was not found to be a statistically significant predictor for rowing injuries. The Pearson Chi-Square number was found to be .827. The percentage of athletes who sustained injuries in the "low" group (42.9%) was not larger than the percent of injuries sustained in the "high" group (47.6%). The score of a "1" on

any FMS test was also not statistically significant in predicting an injury. The Pearson Chi-Square number was found to be .283. The percent of injuries in the group of who received a "1" (38.9%) was not larger than the percent of injuries (60.0%) in the group who did not receive any "1"s. These results suggest that FMS is not an effective injury predictor for division two rowing athletes.

Acknowledgments

My Divisional Honors research project was made possible through the combined efforts and support of my faculty advisors, Dr. Colas and Dr. Swann. Thank you for fostering my independence as well as guiding me through the research process with reassurance and confidence. I regard you as both my mentors and appreciate the time you took to help me achieve my goals. I would also like to thank Dr. Mokha and Dr. Doeringer for helping me with my statistical analysis. Without your guidance SPSS would have been incredibly difficult to navigate. I would like to thank the entire sports medicine staff for their relentless encouragement and support. I aspire to reach the level of commitment which Zevon Stubblefield, Dustin Gatens, and Dr. Peter Sprague has demonstrating towards implementing evidence based practices to improve their patient outcomes. Thank you for allowing me to participate in preseason FMS testing and granting me access to the retroactive 2012 data. I would also like to thank Dean Rosenblum and President Hanbury for making this opportunity available to the undergraduate honors students.

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I. Literature Review

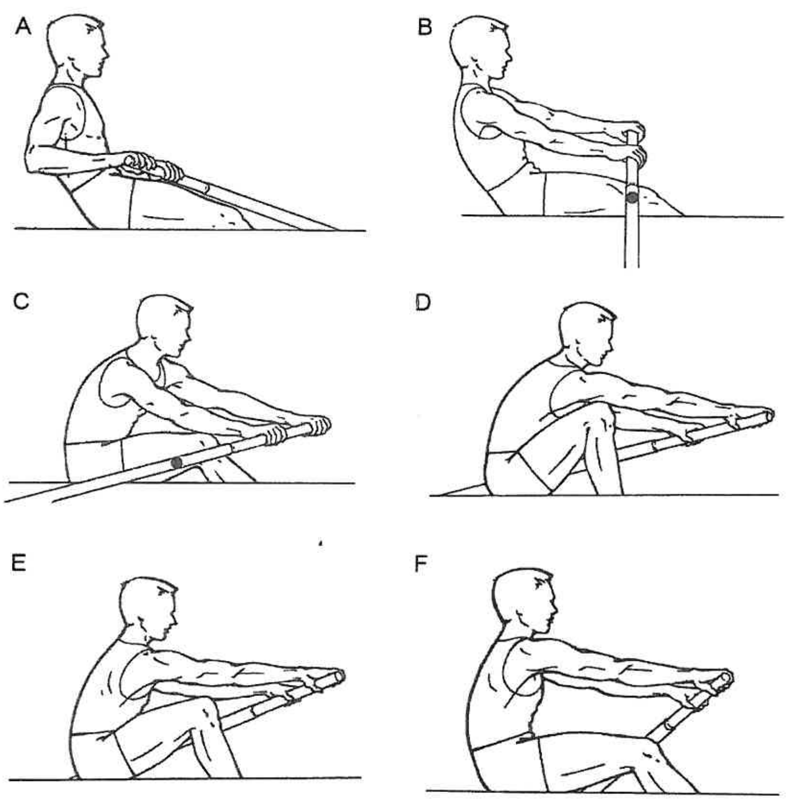
A. Rowing Biomechanics

Rowers sit in boats ranging from 60ft to 41ft long facing the stern of the boat. The goal of the rowing stroke is to put the blade of an oar into the water and use the water as resistance to propel the boat forward. According to the US Rowing level one coaches manual, the rowing motion starts at the "finish" where the knees are fully extended, the spine tilted back, hips extended, and elbows flexed to just below the nipple line. From here, the elbows are extended, the body rocks forward, and the knees are fully flexed. Once the knees are fully flexed with the torso tilted forward and elbows extended the blade of the oar can enter the water. This is the "catch" or entry position. The portion of the stroke where the rower approaches the catch position is the recovery.

Once the blade is buried in the water the knees are forcefully extended against the resistance of the water. When the legs are partially extended the torso swings back and the arms are fully flexed and brought into the body. This is the "drive" portion of the stroke. (Figure 1)

During the drive phase, when the oar is in the water force is transferred from the legs and body through the shoulders to the oar. The rectus femoris muscle provides power to the stroke while the paraspinal muscles stabilize the spine to make a transfer of power to the oar possible (Hosea, 2012). The torso acts like a lever to swing the boat up and forward through the water. In sweep rowing the rower has one oar and must laterally flex their spine as well as rotate towards their side of the boat. This puts repeated compressive and sheer forces on the spine in a rotated position. The rowing motion is repeated thousands of times each practice.

Figure one: The rowing sequence



(US Rowing level one coaches manual)

The finish position, B-C is the recovery, D is the catch position where the blade enters the water, and E-F is the drive where the rower places the blade of the oars into the water and applies pressure through the legs, back, then arms.

B. Rowing Injuries

Rowing biomechanics put repetitive stress on the back, knees, wrists, and ribs of rowing athletes. This predisposes rowing athletes to a high number of overuse injuries (Wilson, 20121; Smoijavic, 2009; Perich, 2011; Hosea, 2012; Karlson, 2012; McDonnel, 2011). Smoljanovic et al. investigated rowing injuries in elite junior rowers and found that 73.8% of reported injuries involved overuse while only 26.2% of reported injuries were caused by a single event. The study also found that although rowing has a low individual injury risk per exposure time, the high number of training sessions made the likelihood of injury throughout the year significantly higher. Teams that practiced more than 7 sessions per week had a significantly larger number of injuries. The most frequently injuries site was the lower back, knee, and the forearm and wrist. (Smolijanovic, 2009)

Wilson et al. (2012) conducted a 12 month study on rowing injury incidences associated with type and volume of training. The study demonstrated a high number of injuries in a rowing population. The average number of injuries per rowing athlete was 2.2 over a 12 month period. The majority of these injuries (31.8%) were to the lumbar spine followed by the knee at 15.9 percent. Similar to Smolijanovic et al the large number of injuries was attributed to the high training volume. Training time on an ergometer had a significant impact on the number of injuries. (Wilson 2012) This is particularly important when considering teams who practice in climates where the waterways freeze causing them to train on ergometers.

The types and mechanism of injury are important considerations when assessing the effectiveness of injury predicting models. Currently there is evidence supporting the use of FMS as an injury predictor for populations that sustain a high percent of acute injuries (Cosio-Lima et al., 2013; Kiesel et al., 2007;Chorba et al., 2010) but there is a lack of research on populations with a high percent of chronic or overuse injuries. The high number of overuse injuries in the sport of rowing makes rowing athletes the ideal population to test the effectiveness of FMS in predicting injuries in endurance athletes. If FMS can detect poor movement patterns in the rowing population and predict injury prone athletes, then it could be possible to prescribe an intervention program to susceptible athletes before injuries occur. Being able to identify injury prone athletes is a necessary component of injury prevention.

C. Rowing Injury Prediction

Due to the repetitive nature of rowing, poor biomechanics can put excessive stress on the knees and back. (Hosea, 2012; Perich, 2011) Proper knee biomechanics has an effect on the patellar compression and knee flexion at the catch. Toe in or toe out position while rowing can create valgus and varus forces on the knees. (Hosea, 2012) FMS testing is designed to detect poor knee biomechanics during the deep squat test. The deep squat replicates the large range of motion necessary at the knee, hip, and ankle joint in order to sit at the catch position. (Cook, 2006)

Stretching may be an important component to injury prevention. Rowers who stretched more than 10 minutes a day were found to have less traumatic injuries and those who stretch more than 15 minutes a day had lower incidences of overall injuries. (Smolijanovic, 2009). Hypomobility may contribute to overuse injuries such as stress fractures (McDonnel, 2011). FMS tests mobility through the shoulder mobility test and the active straight leg raise test. Hypomobility would also cause a compensatory movement pattern which would be detected in other FMS tests (Cook, 2006).

The rowing stroke requires bilateral coordination in order to place the blade in the water, apply pressure through the water, and feather the blade. It also requires coordination of the upper and lower extremities. Lumbo-pelvic coordination was found to be a vital component to the rowing stroke. Poor lubo-pelvic control can increase the likelihood of lumbar and thoracic injury (McDonnel, 2011). FMS could detect a lack of coordination in the hurdle step test, active straight leg raise text, rotary stability test, as well as the deep squat test (Cook, 2006).

Perich et al found that a multi-directional intervention program was found to decrease low back pain in female high school rowers. The intervention included a screening to evaluate lumbo-pelvic control and range of motion. Each athlete in the intervention group then received individual exercises, an off water conditioning program, and a back management educational seminar. Athletes in the intervention group had a lower incidence of lower back pain and also had better aerobic fitness. (Perich, 2011) This study reinforces the value of detecting poor movement patterns in order to prevent rowing injuries.

D. Functional Movement Screening

Functional movement screening consists of seven movement tests that are designed to expose imbalances, instability, hypomobility, compensatory movements, and poor biomechanics. The tests are scored from zero to three. A score of zero signifies that there was pain observed in a clearing test. A score of three is earned when the movement pattern was completed within the FMS criteria which vary from test to test (Cook, 2006).

FMS has also been found to have good test-retest reliability. According to Shultz, test-retest reliability had an intra-class correlation coefficient (ICC) of 0.6. Interrater reliability was found to be poor with a Krippendorffa of .38. This varied from (Frohm et al., 2012) who used a slightly varied version of FMS and found an interrater correlation coefficient to be 0.8. Gulgin et al investigated the inter-rater reliability of FMS when the raters had varying levels of experience. They found, the total FMS scores were similar among raters of varying level of experience. The majority of individual test scores had strong agreement although three tests only had slight agreement. This study demonstrated that overall test scores can be reliable with raters of varying levels of experience but individual test scores are less reliable (Gulgin et al, 2014).

There have been recent studies which use Functional Movement Screening as a predictor for injuries. One study found that an FMS score lower than 14 was a predictor of serious injury with a specificity of .91 in Professional football players (Kiesel et al. 2007). A serious injury was defined as any injury requiring membership on the injured reserve for at least three weeks. Players with scores lower than 15 out of a possible 21 had an eleven-fold increased chance of serious injury as compared to a player with a score greater than 14 at the beginning of the season. This research found that athletes with dysfunctional movement patterns, lower FMS scores are more likely to suffer a time loss injury although no cause affect relationship could be established (Kiesel et al., 2007). A similar study found that an FMS score or 14 or lower could also predict injury in female collegiate athletes. Thirty-eight division two female athletes from soccer, volleyball, and basketball participated in the study. Athletes with a score of 14 or lower were four times more likely to sustain an injury. Sixty-nine percent of low scoring athletes sustain an injury during their competitive season (Chorba et al, 2010). FMS scores were also successfully used to predict injuries for male and female freshman cadets entering the Summer Warfare Basic (SWAB) training at the U.S. Coast Guard Academy (Cosio-Lima et al., 2013).

FMS has been shown to be effective in predicting injuries in populations who participate in contact sports or activities which can lead to acute injuries (Cosio-Lima et al., 2013; Kiesel et al., 2007; Chorba et al., 2010). However, there has been a lack of research on the effectiveness of FMS to predict injuries in a population of endurance trained athletes with a low percent of acute injuries.

Methods:

The data from the fall preseason FMS testing for the 2012-2013 Nova Southeastern University rowing team was retroactively acquired and evaluated after receiving IRB approval. Scores of 14 or below were considered "low" and scores above 14 were considered "high". A Pearson Chi Square test will be used to determine if the high or low FMS scores are significantly related to the presence an injury. The injury percentage in group with "low" scores versus the group who received "high" scores will also be calculated. Individual test scores will also be considered. We will determine of the presence of a score of "1" in any FMS test can predict injuries in the rowing population. The Pearson Chi-Square test will be used to determine if the presence of a "1" is significantly related to the presence of injury. The percent of injured athletes in the group who received a score of "1" and those in the group who did not receive any "1"s will be calculated.

An injury was defined as any injury which required an appointment with a physician and time away from practice or racing. This is not inclusive of illness or cutaneous injuries.

This study will use all seven FMS tests described by (Cook et al., 2006) to determine a score out of a possible twenty-one points. The exercises are as follows (Figure 2):

A. Functional Movement Screening tests

Deep Squat Test

The deep squat is a sport specific movement pattern that assesses bilateral, symmetrical, and functional mobility of the knees, hips, and ankles. The dowel assesses bilateral mobility of the shoulders and thoracic spine.

Description: The athlete places feet about shoulder width apart. The hands should be placed on the dowel so that the elbows are at 90 degrees with the dowel resting on the athletes head. Toes are pointing forward. The dowel is then pressed overhead and the individual descends into a deep squat position. The heels must remain on the floor head and chest facing forward and the dowel pressed overhead with elbows in full extension. If the athlete does not meet the criteria to receive a score of three, the athlete must repeat the test with a 2x6 block under their heels.

Criteria for a three:

A. keep upper torso parallel with the tibia or toward vertical

B. the femur must be below the horizon

C. knees are aligned over the feet

D. the dowel must be aligned over the feet

E. Heels must remain on the floor

Hurdle Step Test

The hurdle step was designed to asses proper stride mechanics. The movement requires single leg stance stability, coordination, and stability between the hips and torso. It assesses bilateral mobility and stability of the knees, ankles, and hips.

Description: The athlete begins by standing on one side of the hurdle with feet together and toes touching the side of the hurdle. The height of the hurdle is adjusted to be the height of the athlete's tibia tuberosity. The athlete places a dowel across their shoulders below the neck. The athlete is the asked to step one leg over the hurdle, tap the floor with their heel and return to the starting position. The test can be completed up to three times on each side.

Criteria for earning a three:

A. Hips, knees, and ankles remain aligned in the sagittal plane

B. Minimal to no movement is noted in the lumbar spine

C. Dowel and the string must remain parallel

D. There is no loss of balance

E. The foot does not make contact with the string

Inline Lunge Test

The inline lunge places the athlete into a split stance position on a narrow base. This required bilateral stability and dynamic control of the core muscles with an asymmetrical hip position as well as hip, knee, and ankle mobility. The test is designed to replicate the stresses of deceleration and lateral movements.

Description: First, the height of the tibial tuberosity from the floor is measured. The toes of the back foot are placed on the start line of the FMS board. The back of the front heel is placed on the board at the same distance away as the height of the tibial tuberosity. The dowel is then introduced. It is placed behind the athletes back making contact with the head, thoracic spine, and lumbar spine. The hand opposite to the front foot grabs the dowel at the cervical spine level. The other hand grabs the dowel at the lumbar spine. The individual then lowers their back knee to touch the board behind their front foot and returns to the starting position. The test may be completed up to three times on each side.

Criteria for earning a three:

A. The dowel remains in contact with all three points throughout the movement

B. The dowel remains perpendicular with the floor

C. The back knee touches the board behind the front foot

D. There is no loss of balance

E. No movement in the torso is noted

Shoulder Mobility Test

The Shoulder mobility test asses bilateral shoulder range of motion. It combines internal and external rotation with adduction. This test also requires normal scapular function and thoracic extension.

Description: The tester first measures hand length from the distal wrist crease to the tip of the third digit. The athlete will stand with feet together and make their hands into fists with the thumbs tucked in. The athlete simultaneously reaches one hand behind the back and the other behind the neck. The hands are brought as close together as possible in a smooth motion with no "inching". This distance is then measured. A clearing test must be performed after this test. In the clearing exam, the athlete must place his or her hand on the opposite shoulder and then attempt to point the elbow upward. This is done bilaterally. If there is any pain the athlete receives a score of zero regardless of their score on the shoulder mobility test.

Criteria for earning a three:

A. Fists are within one hand length

B. A score of two will be given if hands are within one and a half hand lengths

C. A score of three will be given if hands are more than one and a half hand lengths apart

Strait Leg Raise Test

This test identifies the active mobility of the flexed hip as well as flexibility of the hamstrings, gastrocnemius and soleus. It required core stability while the legs are dissociated as well as pelvic control.

Description: The client lays supine with their arms at their sides, palms facing up. The FMS board is then placed under the knees. The soles of the feet should be perpendicular to the floor. The point between the anterior superior iliac spine (ASIS) and the joint line of the knee is identified and the dowel is placed in line with this point perpendicular to the floor. The client then lifts the test limb while maintain the original start position of the ankle and knee. During the test the opposite knee should remain in contact with the board, head should remain flat on the floor, and the toes should be pointing up. Once the leg reaches end range, the location of the malleolus as compared to the dowel is noted. If the malleoli does not reach the dowel, the dowel is moved to be in line with the malleoli perpendicular to the floor. This test can be taken up to three time on each side.

Criteria for earning a three:

A. The ankle/ dowel resides between mid-thigh and asis. (the malleoli reaches at least the dowels start position)

B. A score of two is earned if the ankle/dowel reaches between mid-thigh and the joint line of the knee

C. A score of 1 is earned if the ankle/dowel reaches below the knee joint line

Trunk Stability Pushup Test

The purpose of the trunk stability push up is to test the athlete's ability to stabilize the spine in an anterior and posterior plane. This is not a test of upper body strength. Extension and rotation are the two most common compensatory movements. These compensations suggest that the primary movers are firing before the stabilizers can engage.

Description: The athlete lies prone with the arms extended overhead. For this test, men and women have different starting positions. Men begin with their thumbs in line with the top of their forehead. Women begin with thumbs at chin level. Knees are fully extended and the sole of the feet are perpendicular to the floor. The athlete is then asked to push up their body moving as one unit. There should be no sway in the spine as the athlete pushes up. If the athlete cannot perform the pushup, men can lower their hands to chin level and women lower their hands to shoulder level. The test can be completed up to three times. This test includes a clearing exam to check for the presence of pain. The athlete lays prone the hands at shoulder height. Then they press up there torso leaving there legs in place to reach full spinal extension. This is similar to a cobra stretch. If the athlete experiences pain, they receive a score of zero for the trunk stability push up.

Criteria for earning a three:

A. Males can perform the movement with thumbs aligned with the top of their forehead

B. Females can perform the moment with thumbs aligned with their chin

C. The chest and stomach come off the floor at the same instance

D. The body moves as one unit

E. There is no sag in the back

Rotary Stability Test

The rotary stability test requires proper neuromuscular coordination as well as core, shoulder and pelvis stability. It is a complex movement in which the athlete must balance and weight shift in the transverse plane.

Description: The athlete assumes a quadruped position with the FMS board between both hands and knees. The board should be parallel with the spine with the shoulders and hips 90 degrees to the torso. The soles of the feet should be perpendicular to the floor. Thumbs, knees, and feet should all be touching the board. The client flexes the shoulder while also extended the same side hip and knee. They must touch elbow to knee and then return to the starting position. There should be no contact with the floor until the movement is complete and the athlete resumes the start position. If the movement cannot be completed, the athlete resumes the start position and flexes the shoulder and extends the hip and knee oppose to one another. This test is done bilaterally. The upper moving limb indicates the side being tested.

Criteria for earning a three:

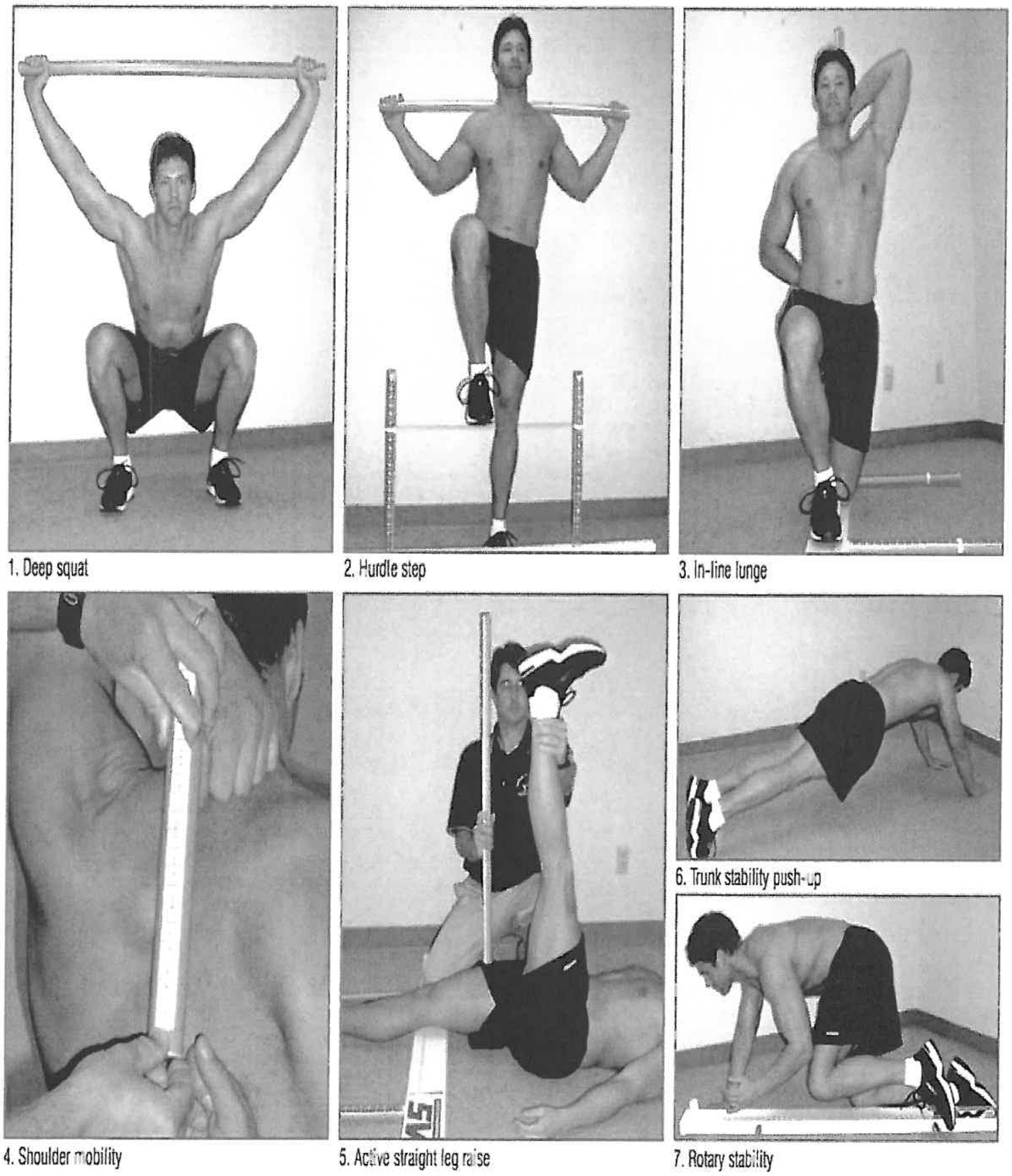
A. The athlete can perform the movement with same side limbs.

B. The spine stays parallel to the floor

C. The knee and elbow touch

Figure 2. Functional Movement Screening Tests

Figure 1. The seven movements of the Functional Movement Screen.



(Kathryn Schwartzkopf-Phifer, 2014)

Participants:

IRB approval was attained prior to accessing retroactive data from the 2012-2013 rowing team at Nova Southeastern University. There were 28 participants (n=28) who were included in the statistical analysis. FMS scores were collected on September 13th 2012. Any athletes who joined the team after September 13th were not included in this study. This study excluded our novice or "learn to row" team because they began practicing in November and predominately focused on learning the rowing motion. The novice team allows a group of non-rowers to learn about the sport in a low pressure environment before they can attempt to join the competitive NCAA team. The novice team focuses on general fitness, learning the rowing sequence, attaining "boat feel" or the ability to balance in the boat, and learning to move together. Their training plan varies greatly from NCAA division two rowing teams. For this reason, the Novice team results would be incomparable to other division two women rowing teams. All scores were de-identified upon retrieval. Table one displays the demographics of the participants.

Table One: Participant Information

Number of Subjects (n)	27
Average age (years)	20.22
Average weight (pounds)	153
Average FMS score	16
Athletes sustained injuries	13
Percent of athletes who sustained injuries	42.9%

Results:

There were a high number of injuries throughout the team in the fall 2012 season. 46.4% of the athletes on Nova Southeastern University's rowing team sustained a time loss injury or an injury which required a physician appointment during the Fall 2012 season.

An FMS of 14 or below was not found to be a statistically significant predictor for rowing injuries. The Pearson Chi-Square number was found to be .827. (Table 3) The percentage of athletes who sustained injuries in the "low" scoring group (42.9%) was not larger than the percent of injuries sustained in the "high" scoring group (47.6%). This would suggest that "high" FMS scores versus "low" FMS scores are not an effective tool for predicting injuries. (Table 2)

The score of a "1" on any FMS test was also not statistically significant in predicting an injury. The Pearson Chi-Square number was found to be .283. (Table 5) The percent of injuries in the group of who received a "1" (38.9%) was not larger than the percent of injuries (60.0%) in the group who did not receive any "1"s. (Table 4)

The null hypothesis for this experiment was supported by the statistical analysis of both "high" versus "low" FMS scores as well at the presence of a "1" versus no score of "1". The evidence from this study suggests the functional movement screening may not be an effective tool to predict rowing injuries.

Table 2. Percent injured in the "high" and "low" FMS score groups

	"high" group	"low" group
Total number in group	21	7
Number of athletes who sustained injuries	10	3
% of athletes in the group who sustained injuries	47.6%	42.9%

Table 3: High v. Low Score Person Chi-Square Test

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.048[a]	1	.827		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.048	1	.827		
Fisher's Exact Test				1.000	.588
N of Valid Cases	28				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.25.

Table 4: Percent injured in the group with and without a score of "1"

	No score of "1"	Score of "1"
Total number in group	10	18
Number of athletes who sustained an injury	6	7
% of athletes in the group who sustained an injury	60.0%	38.9%

Table 5: Presence of a "1" Pearson Chi-Square Test

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.152[a]	1	.283		
Continuity Correction[b]	.459	1	.498		
Likelihood Ratio	1.156	1	.282		
Fisher's Exact Test				.433	.249
N of Valid Cases	28				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 4.64.

b. Computed only for a 2x2 table

Discussions and Conclusions:

This study suggests that Functional Movement Screening is not an effective tool for predicting injuries in a Division Two female rowing population. The presence of a "low" score did not increase the percent of injuries in the group as compared to the "high" group. The presence of a "1" and any one test also did not increase the likelihood of sustaining an injury. This was not the hypothesized result. It was suspected that a "low" score would indicate an overall poor movement pattern which would predispose rowing athletes to injury. It was also hypothesized that a score of "1" on any test would also predict injury because it would indicate a weak point in the athlete's movement pattern. However, neither hypothesized indicator was an effective injury predictor. This is significant because it discredits the common clinical practice of using FMS as an injury predictor for rowing athletes. It is clinically significant because this practice is not supported by this study.

These results may be attributed to the small sample size (n) which was studied. Even under ideal conditions, it would be unlikely to find statistical significance using Pearson's Chi-Squared using a sample size of 28. The small sample size also could have skewed the percentage of injuries in all the groups. For example, there were only seven athletes who scored 14 or lower. Even the presence of a single injury would increase the overall percent of the group by almost 15%.

Another factor which could have affected the study's results was the time of data collection. This data was collected on September 13th, 2012. It was done in conjunction with the rowing team's pre-participation examination for the fall season. Despite the fact that fall is a racing season, it is considered an off season due to the fact that the NCAA championship is at the end of the spring season. Since the NCAA National Championship was the team's priority, the team's injury treatment may have been more conservative in the fall than it would have been in the spring. If someone was experiencing discomfort they might have been taken out of practice more freely than they would have closer to NCAAs. This could explain the high number of overall injuries.

Despite the good inter-rater reliability of FMS, the varying graders might have caused error in the scores. Not all of the graders had been certified to grade FMS. This might have led to inaccurate scoring.

Rowing has very unique demands on the body. There are very few acute injuries the rowing population. The repetitive trauma which causes most rowing injuries may not be detectible through FMS. This may be due to the non-weight bearing nature of rowing. Four out of the seven FMS tests are done standing. Rowing requires the athlete to be seated while both the upper and lower extremity are working in a closed kinetic chain. The body weight is supported by the buoyancy of the water. These differences may explain why FMS cannot predict rowing injuries. It is possible that a screening tool which placed the athletes in a position more similar to rowing may be more effective.

The mechanism of injury for the rowing population is also an important consideration.. McDonnell et al. suggested that exercise induced muscle fatigue is the cause of altered movement patterns which cause injury (2011). If this is the case, then testing rowing athletes when they are not fatigued would not reveal a problematic compensatory pattern. This may also contribute to why athletes experience more injuries when the training volume is increased. It increases the level of fatigue.

These finding are significant because they discredit a common practice. This study suggests that FMS is not an effective injury predictor for division two rowing athletes. Therefore, the time, money, and effort spent conducting FMS testing on Nova Southeastern University's rowing team may be put to better use exploring a different injury predicting model.

More research should be conducted to determine if FMS is an effective injury predictor for rowing athletes as well as other endurance athletes. Rowing athletes have a high incidence of injury. If these injuries can be predicted and prevented, the rowing population could be healthier and more effective. If FMS is not an effective injury predicting tool, then other predicting models should be explored. The effectiveness of FMS scores taken from fatigued athletes should also be explored in endurance athletes. FMS is both costly (due the necessary certification) and time consuming. If FMS is not an effective predicting tool, then resources should be conserved for a more useful prediction model.

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