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Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes

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LOWER EXTREMITY FUNCTIONAL SCREEN FOR BIOMECHANICAL FAULTS IN FEMALE ATHLETES

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ABSTRACT

Background and Purpose:
Injuries resulting from athletic participation have been extensively researched in an attempt to identify causative factors. Lower extremity injuries account for the greatest proportion of athletic participation injuries. Traditional medically based pre-participation screening lacks a performance assessment from which to determine athletic preparedness. The purpose of this study was to develop a reliable functional screen in order to identify biomechanical faults in a female athletic population.

Methods:
Twenty-two female subjects (25.05 ± 3.88 years) were recruited from the St. Catherine University Doctor of Physical Therapy, class of 2011. Hand-held dynamometry was used to assess hip strength. The modified Star Excursion Balance Test (mSEBT) was used to assess single-leg balance. The Lower Extremity Functional Screen was developed based on clinical expertise and included the following tasks: double-leg squat (DLS), double-leg jump (DLJ), single-leg squat (SLS), single-leg hop (SLH), and a leap (LP). Each participant was videotaped performing the functional screen following a description and demonstration of each task. Recorded videotapes of all subjects were viewed and scored independently by five testers. The graded task was scored on a zero to three scale. Component scores were added to obtain a total possible score of 21 points with a higher score hypothesizing better leg mechanics and a lower risk of injury.

Results:
Inter-rater reliability for five raters was calculated using interclass correlation coefficient (ICC). Reliability for each task ranged from moderate to good (ICC=0.63-0.84): DLS=0.835; DLJ=0.691; right SLS=0.812; left SLS=0.802; right SLH=0.745; left SLH=0.627; LP=0.716. Reliability for the total score was also identified as good (ICC=0.88). Weak to moderate correlations were found between single-leg squat tasks and either hip abduction or hip external rotation strength (p=0.016-0.088).

Conclusion:
These results indicate that the Lower Extremity Functional Screen developed for this study is a reliable tool. The data did not show a strong correlation between the functional screening tool, hip strength, and balance. This may suggest additional factors are involved beyond strength and balance during these functional tasks.

ACKNOWLEDGEMENTS

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The undersigned certify recommendations for approval of the research project entitled…

LOWER EXTREMITY FUNCTIONAL SCREEN FOR BIOMECHANICAL FAULTS IN FEMALE ATHLETES

Submitted by:

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In partial fulfillment of the requirements for the Doctor of Physical Therapy Program

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4/28/11
Date

TABLE OF CONTENTS

LIST OF TABLES AND GRAPHS

CHAPTER I:

INTRODUCTION

Athletic participation continues to increase in frequency among females across all age groups. Between 1995 and 2005 collegiate participation increased by more than 25,000 female athletes.[1] Such increases have presented a disparity between male and female athletes with females sustaining a significantly higher overall injury rate per athletic exposure.[2,3] The greatest proportion of athletic injuries occur in the lower extremity with associations established between lower extremity muscle deficits and increased injury risk.[2,4,5,6,7]

Three-dimensional motion analysis is the gold standard for kinematic evaluation. However, this technique is inappropriate for use across the vast athletic population because it is time consuming, costly, and there is limited equipment availability.[8] Therefore, there is a need for a simple and reliable screening tool that has the capability to identify athletes at risk for injury that may be implemented in any athletic venue and can demonstrate multiple-rater consistency.

Current evidence regarding pre-participation athletic screening and the ability to accurately predict athletic injury is limited in today's literature. For the past 30 years the pre-participation physical examination (PPE) has played a significant role in athletic eligibility. The current screening standards recommended by the United States Preventative Services Task Force (USPSTF) are medically based with the goal of ensuring athletic participation does not unnecessarily increase injury risk.[9] The musculoskeletal component is fulfilled with the recommended 90-second orthopedic screen. Although this examination may serve as a good screening tool, it does not provide enough baseline information when assessing athletes' preparedness for activity.[10]

The lack of evidence for the PPE was highlighted in a systematic review from Medline literature between 1966 and 2002 that examined the effectiveness of the medical PPE. The USPSTF's description of a preventive screen was used as the standard to evaluate the current activity screens.[11] A total of 176 articles were found and subsequently limited to eleven articles selected for further review. This review concluded that evidence is lacking to support the use of a PPE that satisfies the basic requirements of medical screening. Studies included in this review used only self-selected samples of athletes and lacked a control group. Thus, the effectiveness of the PPE in detecting physical abnormalities serious enough to limit or restrict athletic participation could not be established.

A growing number of musculoskeletal lower extremity injuries have led to heightened interest regarding mechanism of injury as well as biomechanical, structural, and neuromuscular differences between male and female athletes. With a growing body of research recognizing risk factors associated with injury from athletic participation, great benefit would result from the ability to identify athletes at an increased risk of injury prior to athletic participation. This literature review focuses on the prevalence of lower extremity injury in female athletes as well as the relationship between injury and strength of the core, hip, knee, and ankle. The primary research articles reviewed examine a number of factors that have been associated with lower extremity injury throughout the literature.

CHAPTER II:

REVIEW OF LITERATURE

Current Assessment Protocols

Despite the increasing prevalence of pre-participation physical examinations in athletic participation, research regarding the reliability and validity of their use is limited.[12] Cook et al[10] introduced the Functional Movement Screen (FMS) in 2006. The tasks included in the FMS were created based on fundamental proprioceptive and kinesthetic awareness principles.[10,12] The tasks place the subject in extreme positions where weakness or imbalance might be noticeable if mobility or appropriate stability are not utilized. There are seven movement tasks for the FMS including the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability.

Cook et al suggested that if the FMS could be used to identify athletes at risk for injury then prevention strategies could be instituted. Kisel et al[13] tested this hypothesis on professional football players by analyzing the reliability of the FMS. These authors suggested that athletes with poor dynamic balance or asymmetrical strength and flexibility were more likely to be injured. A relationship between the score on the FMS and the likelihood of serious injury was analyzed. The results of this study indicate that the FMS can identify risk factors for injury in a professional football population with a sensitivity of 0.54 and a specificity of 0.91.

In a reliability study conducted by Tabor et al, [14] the Lower Extremity Functional Test (LEFT) was introduced as a functional performance measure. The LEFT simulated movements that are commonly performed during athletic participation. It is a comprehensive, timed test consisting of eight multi-directional skills performed continuously in a standardized 16-step sequence between targets. The eight skills include forward running, retro running, side shuffling, carioca, figure-8 running, 45-degree crossover cutting, and 90-degree crossover cutting. To test for reliability research was conducted over a three week period. Each subject was provided a demonstration of the LEFT and sub-maximal practice trials. Reliability was assessed following the maximal effort timed trials of weeks two and three. An analysis of reliability between weeks two and three were calculated with Interclass Correlation Coefficients (ICC) of 0.95 and 0.97. These results indicate exceptional reliability with ICCs similar or greater than those reported for other functional performance tests.

In 2006, Plisky et al[15] carried out a study to determine if the Star Excursion Balance Test (SEBT) could be associated with a risk of lower extremity injury. The SEBT is an inexpensive and quick method of measuring balance. The study prospectively followed subjects from seven high schools. Subjects completed a baseline questionnaire at the beginning of the season and viewed an instructional video demonstrating the SEBT. Subjects were allowed six practice trials prior to final testing of the SEBT. Subjects were followed during the 2004-2005 basketball season in which 54 of the 235 subjects reported a lower extremity injury. Results of the study demonstrated that the SEBT could be incorporated into a pre-participation physical examination of high school basketball players to help identify neuromuscular deficits.

Epidemiology

Injuries resulting from athletic participation have been extensively researched in an attempt to identify causative factors.[3,16,17] In a study conducted by Conn et al[16] in 2003, demographic and health data from a nationally representative sample of United States civilian, non-institutionalized members was obtained from the National Health Interview Survey (NHIS). Approximately seven million sports and recreation-related injuries required medical attention between 1997 and 1999 across the United States. Although injuries cannot, at this time, be pre-determined based upon personal characteristics, populations with greater risk have been identified through a number of studies.[3,16,17] Between 1997 and 1999, 64% of all injuries occurred between the ages of five and twenty-four years.[16] This was further narrowed to isolate the 15-24 year age range as the second most frequently injured group with approximately 56.4 of every 1,000 injuries having occurred within this age bracket.

With increased athletic participation, the number of athletes at risk for injuries has also increased.[3] Female participation in intercollegiate athletics has grown by approximately 25,000 athletes between the seasons of 1995-1996 to 2004-2005 with more than 4,000 of these participants being active in the sport of soccer.[1] A 2005 study confirmed an 875% increase in female sport participation levels in American high school athletics and a 435% increase in college athletics since 1975.[1] A 15-year longitudinal study of 3,233 high school cross-country runners identified a significantly higher female overall injury rate per athletic exposure (F: 16.71/1,000; M: 10.9/1,000). This study also demonstrated that females have a significantly higher initial and subsequent injury rate.[3] However, female injuries are not isolated to cross-country participation. Hootman et al[17] identified soccer to prevail as the women's sport with the highest injury rate during games and the second highest rate for practice injuries. Trends of increasing female athletic participation have mounted concern for increasing injury rates within this population.

According to data collected by the National Collegiate Athletic Association (NCAA), nearly 182,000 injuries occurred amongst collegiate athletes between 1988-2004.[17] Lower extremity injuries accounted for the greatest proportion of participation-related injuries occurring predominantly within the knee and ankle. [3,16,17] The NCAA identified approximately 313 anterior cruciate ligament (ACL) injuries and roughly 1,700 ankle ligament sprains per year among their collegiate athletes.[17] Rauh et al[3] identified female cross-country runners to have higher initial injury rates in the hip, shin, and feet; in comparison, re-injuries were greatest for the knee, calf, and foot.

Core and Hip

Well-established within the literature are the structural differences existing between males and females. Research efforts are continuing in an attempt to establish whether or not these structural differences either lead to, or contribute to, the disproportionate number of injuries in females as compared to males. Leetun et al[2] reported that kinematic differences place greater demands on the female lumbo-pelvic musculature which is also referred to as the core. Researchers have investigated these increased muscle demands at the site of injury as well as the structures both above and below the injury to determine whether a relationship exists. Considering the closed-chain nature of many athletic activities, motion at one segment will influence all other structures within that chain.

The impact of diminished core stability remains to be established. However, considering the movement demands required in athletics, athletes must possess sufficient strength in the hip and trunk muscles in order to provide stability in all planes of motion. Active muscle force of contractile tissues, including the abdominals and lumbar extensors, provide the primary form of stability to the vertebral column through adjustments in both the magnitude and timing of contraction.[18] Despite this knowledge, the literature supporting the inclusion of core stability on a pre-participation athletic screen is varied.

Associations have been established between lower extremity muscle deficits and increased injury risk in athletic performance among collegiate athletes.[2,4,5,6,7] Each muscle group plays an important role in lower extremity alignment. Therefore, weakness in any particular group could lead to muscle imbalance and subsequent injury.[18] Many studies have focused on involvement of the hip abductors and rotators.[2,6,7] In 2004, a study by Leetun et al[2] concluded that core stability has an important role in injury prevention. Athletes, free from injury, had significantly stronger hip abduction and hip external rotation measures in comparison to injured athletes. The literature also reports that women demonstrate a greater pattern of hip adduction and hip internal rotation during jumping and landing tasks contributing to a knee valgus position and potentially pre-disposing females to injury.[8,19] Additional studies have identified pain and injury correlation with weakness in the hip abductors and hip external rotators.[7,19,20,21]

Not only have deficits been identified when comparing injured and un-injured athletes, but strength deficits have additionally been recognized between extremities within subjects.[4,6,22] Niemuth et al[6] tested for differences in strength of 6 hip muscle groups between thirty injured recreational runners and thirty non-injured recreational runners. Muscle strength data identified no significant side-to-side differences in non-injured runners. In comparison, injured runners demonstrated significant unilateral strength deficits of the hip abductors and hip flexors, as well as a trend toward significant weakness of the hip external rotators on the involved side. These muscle imbalances may be associated with an inability to balance the biomechanical forces placed on the body therefore increasing the risk of injury.

Knee

Current literature has noted a high susceptibility to non-contact knee injuries in female athletes as compared to males.[19,23] Research has proposed that muscle strength may serve as a protective mechanism due to its contribution to joint stability.[19] However, deficits in strength and neuromuscular control lead to difficulty controlling the hip musculature during dynamic movement and may predispose a position of valgus knee alignment during both hip and knee flexion.[8,19,21,23,24]

The single-leg squat has been analyzed for knee valgus and its relationship with hip and knee strength.[19,20] Claiborne et al[19] determined gender differences between fifteen healthy men and fifteen healthy women in frontal plane motions during the single-leg squat as well as differences between hip and knee strength. Males demonstrated significantly greater absolute peak torque for all strength values, excluding hip internal rotation. This study identified muscle weakness existing within the hip abductors, knee flexors, and knee extensors as significant predictors of frontal plane knee motion during the single-leg squat. In addition, significant negative correlations between these strength variables and movement in the valgus direction demonstrated that as strength increased, particularly hip abductor strength, the degree of motion in the valgus direction decreased.

Zeller et al[20] kinematically and electromyographically analyzed the single-leg squat in nine male and nine female healthy intercollegiate athletes. Female athletes demonstrated significantly more hip adduction, hip flexion, and hip external rotation during performance of the single-leg squat relative to male athletes. This was associated with a decreased ability to maintain a varus knee position during the single-leg squat. These authors found that intermittent periods of knee valgus were associated with losses of knee control and greater hip adduction. This study additionally found significantly increased activation of the rectus femoris during the single-leg squat which could increase strain on knee structures and amplify injury risk.

Lower limb muscle activity and kinematics of an unanticipated cutting maneuver were analyzed by Beaulieu et al.[21] Fifteen female and fifteen male elite soccer players performed five unanticipated cutting tasks. During an unanticipated cutting maneuver, females demonstrated greater knee abduction and hip external rotation via greater muscle activity of the rectus femoris, lateral gastrocnemius, and transverse abdominus when compared to their male counterparts. This combination of neuromuscular control strategies may clarify the reasons for which women strike the ground with a more abducted knee during a cutting task.

The literature analyzing factors contributing to valgus knee alignment has grown substantially over the last few years. Although increased dynamic knee valgus has been identified as a risk factor for lower extremity injury, no absolute value has been identified as the cut-off that predisposes an individual for injury. Early identification of such risk factors, combined with appropriate training, have the potential to prevent, if not eliminate, a significant number of athletic injuries.

Ankle

Ankle injuries are very common in athletic participation with ankle sprains accounting for 12-20% of all sport-related injuries.[25] Sports which involve large components of running and jumping forces, such as soccer, place athletes at greater risk for ankle injury.[25,26] Numerous studies have analyzed balance, flexibility, strength, and proprioception as risk factors for ankle sprains. Trojian et al[25] investigated the ability of the single-leg balance (SLB) test to predict an ankle sprain in 230 high school athletes.

The inability of athletes to perform a 10-second SLB was significantly associated with ankle sprains. Furthermore, data identified athletes with a positive SLB test that did not participate in ankle taping were at increased risk regardless of previous ankle injury history.

Payne et al[26] assessed the ankle muscular strength, flexibility, and proprioception of 42 collegiate basketball players in order to determine if these factors could accurately predict ankle injuries. This study did not identify ankle muscle strength or heel cord flexibility as predictors of injury. However, proprioceptive deficits as measured with an electric goniometer at the ankle joint were found to be accurate predictors of ankle injury. Payne et al further identified that the instability of the involved limb places additional proprioceptive demands on the uninvolved limb. An unstable limb may affect an athlete's situational reaction resulting in increased stress on the opposite limb in order to decrease use of the unstable limb.

During performance of a single-leg squat, Zeller et al[20] found that females demonstrate significantly more ankle dorsiflexion and pronation as compared to their male counterparts. The literature terms this ankle arrangement as the position of no return, which is a loss of control at the hip and pelvis, internal rotation of the femur, valgus knee angulation, and external tibial rotation on a pronated, externally rotated foot. This position is a synergy of motions which place an athlete at an increased risk for injury.

PURPOSE

Injuries resulting from athletic participation have been extensively researched in an attempt to identify causative factors. Lower extremity injuries account for the greatest proportion of athletic participation injuries. Traditional medically based pre-participation screening lacks a performance assessment from which to determine athletic preparedness. The primary purpose of this study was to develop a reliable functional screen in order to identify biomechanical faults in an athletic population. The secondary purpose of this study was to determine validity of the functional screen in relationship to strength and balance testing. The foundation for this study was initially developed in clinical practice by Paul Solie PT, SCS. Solie created an observational screening tool for athletes to determine their readiness to return to sport following injury. However, no data had been collected to support this clinical screening tool. This descriptive study was designed to formulate a screening tool to provide supporting psychometric measurements.

CHAPTER III:

METHODS

Ethical Considerations

The Institutional Review Board of St. Catherine University granted approval for this study protocol. Consent was obtained from all volunteer subjects prior to their participation in the study. Confidentiality of the subjects' information was maintained.

Design

A descriptive study was initiated to investigate biomechanical faults in female athletes. This study was initially developed in clinical practice by Paul Solie PT, SCS. Solie created an observational screening tool for athletes to determine their readiness to return to sport following injury. However, no data had been collected to support this clinical screening tool. This case study was designed to formulate a screening tool to provide supporting psychometric measurements.

Doctor of Physical Therapy, class of 2011

Subjects

Female subjects were recruited from St. Catherine University Doctor of Physical Therapy (DPT), class of 2011. Participation in this study was voluntary and did not affect academic standing. Twenty-two female DPT students volunteered for this research study. Subjects' ages ranged from 22-40 years. Subjects were excluded if they had a current lower extremity injury creating pain and/or a limp which would not allow them to perform jumping and hopping activities, or if they were pregnant. All subjects were provided a letter of consent which described the details of the study including their responsibilities as a participant, risks and benefits, and study confidentiality (Appendix A). Subjects also completed a questionnaire regarding past and current lower extremity injuries and current levels of activity (Appendix D). Each participant was assigned a subject number to maintain confidentiality of their data.

Testing Procedures

Testing took place in a large classroom. Each subject's testing sequence was recorded with a video camera to be viewed later for scoring. The testing sequence included watching a demonstration of the task, practicing the task three times, asking any questions about the task, and then performing the graded task three times. The screen consisted of five graded tasks that followed this testing sequence. The total testing sequence took five to ten minutes. Each subject was read a standardized script introducing the testing sequence and each individual task (Appendix F).

The five tasks in the testing sequence included a double-leg squat, double-leg jump, single-leg squat on the right and left, single-leg hop on the right and left, and six dynamic leaps.

<u>Double-leg squat:</u> Subjects stood on both legs with their feet shoulder-width apart and their arms raised to 90-degrees of flexion. Subjects were asked to squat down until their thighs were parallel with the ground.

<u>Double-leg jump:</u> Subjects stood on both legs with their feet shoulder-width apart and both their arms extended behind. Subjects were asked to jump vertically from a partial squat position while raising their arms overhead.

Single-leg squat: Subjects stood on their stance leg with their opposite knee flexed. Subjects were asked to squat down until their flexed knee dropped below mid-shin of their stance leg while using a reciprocating arm swing.

Single-leg hop: Subjects stood on their stance leg with their opposite knee flexed and both their arms extended behind them. Subjects were asked to jump vertically from a partial single-leg squat position while raising their arms overhead.

Leap: Subjects stood on their right leg with their left knee flexed and their left arm flexed forward. Subjects were asked to leap at a 45 degree angle onto their left leg using a reciprocating arm swing and next leaping onto their right leg using a reciprocating arm swing. This sequence continued through six total leaps.

Subjects completed all five tasks in the sequence regardless of success.

Scoring of Subjects

Recorded videotapes of all subjects were viewed by the five testers. Testers watched the entire sequence and scored the trial that was indicated as the graded task. The graded task was scored on a zero to three scale.

0= cannot complete movement or loss of balance

1= completed with two or more faults

2= completed with one fault

3= perfect technique

Each tester scored the subjects individually with no discussion regarding scoring. Component scores were added to obtain a total possible score of 21 points with a higher score hypothesizing better leg mechanics and a lower risk of injury (Appendix F).

Prior to testing, researchers developed criteria for the five tasks in the testing sequence through consultation with an expert clinical physical therapist, Paul Solie, PT, SCS. The criteria identified biomechanical faults in the lower extremities while performing each specific task (Appendix F). The following are criteria for the five tasks:

Double-leg squat: 1) Equal weight bearing. 2) Maintain knee control in all three planes. 3) Must squat with thighs parallel to the floor or knee flexion to 90-degrees.

Double-leg jump: 1) Equal weight bearing at take-off and landing. 2) Maintain knee control in all three planes at take-off and landing. 3) Upon landing, must squat with knee flexion between 45-degrees to 90-degrees.

Single-leg squat on the right: 1) Maintain hip control and balance with no visible hip hike, drop, or rotation. 2) Maintain knee control in all three planes. 3) Must squat so the left knee drops below half the height of the right leg shin length.

Single-leg squat on the left: 1) Maintain hip control and balance with no visible hip hike, drop, or rotation. 2) Maintain knee control in all three planes. 3) Must squat so the right knee drops below half the height of the left leg shin length.

Single-leg hop on the right: 1) Maintain hip control and balance with no visible hip hike, drop, or rotation at take-off and landing. 2) Maintain knee control in all three planes at take-off and landing. 3) Upon landing, must squat so the left knee drops below half the height of the right leg shin length.

Single-leg hop on the left: 1) Maintain hip control and balance with no visible hip hike, drop, or rotation at take-off and landing. 2) Maintain knee control in all three planes at take-off and landing. 3) Upon landing, must squat so the right knee drops below half the height of the left leg shin length.

Leap: 1) Maintain hip control and balance with no visible hip hike, drop, or rotation. 2) Maintain knee control in all three planes. 3) Upon landing, maintain foot position.

Strength and Balance Testing

Hand-held dynamometry was used to assess hip strength. Training was conducted by the research advisor prior to testing. Utilizing standard testing procedures described by Reese,[27] the subjects were positioned in side-lying for hip abduction, prone with knee flexion for hip extension, and seated for hip external rotation. The subjects performed all tests resisting gravity and the examiner's manual resistance. The hand-held dynamometer was positioned proximal to the lateral knee for hip abduction testing, proximal to the posterior knee with knee flexion for hip extension testing, and proximal to the ankle malleoli for external rotation testing. Subjects performed a maximal isometric contraction into the hand-held dynamometer. The subjects performed two trials of each testing position. The highest measurement for each testing position was used for data analysis (Appendix E).

The modified Star Excursion Balance Test (mSEBT) was used to assess single-leg balance. This test was developed by the University of Minnesota Department of Orthopedics. The mSEBT was adapted from the SEBT which has been shown to have good to excellent reliability.[28,29,30] Use of the mSEBT was considered beneficial because it involved fewer testing positions, the use of upper and lower extremities, as well as a shorter testing period. Training was conducted by the research advisor prior to testing.

The mSEBT required the subject to reach along a previously marked ruled line while maintaining a single-leg stance. Four reaching tasks were performed along two diagonal lines coming from a central point at a 90-degree angle. The reaching tasks included right single-leg stance while reaching to the right with the left hand, right single-leg stance while reaching to the left with the left hand, left single-leg stance while reaching to the left with the right hand, and left single-leg stance while reaching to the right with the left hand. The subjects performed two trials of each testing position. The distance reached for each trial was recorded in centimeters. The trial was discarded and repeated if the subject was unable to maintain single-leg stance during the reach or moved the stance foot during the reach. The highest reach distance for each testing position was used for data analysis (Appendix E).

Female Athletes

Subjects

Pilot trials were performed using the Lower Extremity Functional Screen with an athletic population. Female athletes were recruited from St. Catherine University

Women's Varsity Soccer team and Hamline University Women's Varsity Soccer team. An informational letter describing the study design was sent to the aforementioned Varsity Women's Soccer coaches (Appendix C). Both coaches expressed a willingness to recruit their players for this study. Researchers presented the study design to players at team meetings. Participation in this study was voluntary and did not affect athletic standing. Twenty-three female collegiate athletes volunteered for this research study. Subjects' ages ranged from 18-26 years. Subjects were excluded if they had a current lower extremity injury, creating pain and/or a limp which would not allow them to perform jumping and hopping activities, or if they were pregnant. All subjects were provided a letter of consent which described the details of the study including their responsibilities as a participant, risks and benefits, and study confidentiality (Appendix B). Subjects also completed a questionnaire regarding past and current lower extremity injuries and current activity levels (Appendix D). Each participant was assigned a subject number to maintain confidentiality of their data.

Testing Procedures

Testing took place in two locations: St. Catherine University Women's Varsity Soccer female athletes were tested in a hallway and Hamline University Women's Varsity Soccer female athletes were tested on an outdoor soccer field. The testing sequence included watching a demonstration of the task, practicing the task three times, asking any questions about the task, and then performing the graded task three times. There were five graded tasks that followed this testing sequence. The total testing sequence took five to ten minutes. Each subject was read a standardized script introducing the testing sequence and each individual task (Appendix F).

The five tasks in the testing sequence included a double-leg squat, double-leg jump, single-leg squat on the right and left, single-leg hop on the right and left, and six dynamic leaps. Subjects completed all five tasks in the sequence regardless of success. A detailed description of each task can be found in the Doctor of Physical Therapy, class of 2011 testing procedure section.

Scoring of Subjects

Each subject was graded by one tester. The tester watched the entire sequence and scored the trial that was indicated as the graded task. The graded task was scored on a zero to three scale.

0= cannot complete movement or loss of balance

1= completed with two or more faults

2= completed with one fault

3= perfect technique

Component scores were added to obtain a total possible score of 21 points with a higher score hypothesizing better leg mechanics and a lower risk of injury (Appendix F). A detailed description of the criteria for each task can be found in the in the Doctor of Physical Therapy, class of 2011 scoring of subjects section.

DATA ANALYSIS

All data were analyzed using the Number Crunchers Statistical Software (2004, Kaysville, UT). Descriptive statistics were used to summarize data including age range, previous lower extremity injury, and activity / sports participation. Interclass Correlation Coefficient (ICC) was used to determine interrater reliability among five raters on the Lower Extremity Functional Screen. Spearman correlation coefficient was used to determine correlations between the Lower Extremity Functional Screen and hip strength/balance. For all tasks a p-value of 0.05 was used to determine statistical significance.

CHAPTER IV:

RESULTS

Significant Results

Participants

The average age of DPT, class of 2011 subjects was 25.05 years ± 3.88. The average age of St. Catherine University and Hamline University Women's Varsity Soccer female athletes was 20.04 years ± 1.97. Six of the twenty-two DPT students self-reported a previous lower extremity injury. Nineteen of the twenty-three student athletes self-reported a previous lower extremity injury. DPT students self-reported an average of three to four days of activity per week. Student athletes self-reported an average of five or more days of activity per week. DPT students self-reported an average of 30-60 minutes of physical activity per session. Student athletes self-reported an average of 60 or more minutes of physical activity per session. Table 1 shows a comparison of the average demographic values between the DPT students and student athletes.

Table 1. Subject Demographics (Average)

	DPT Subjects	Female Student Athletes
Age (years)	25.05 ± 3.88	20.04 ± 1.97
Previous LE injury	6/22	19/23
Days of Activity per Week	3-4	5
Minutes of Activity per Session	30-60	60+

Interrater Reliability

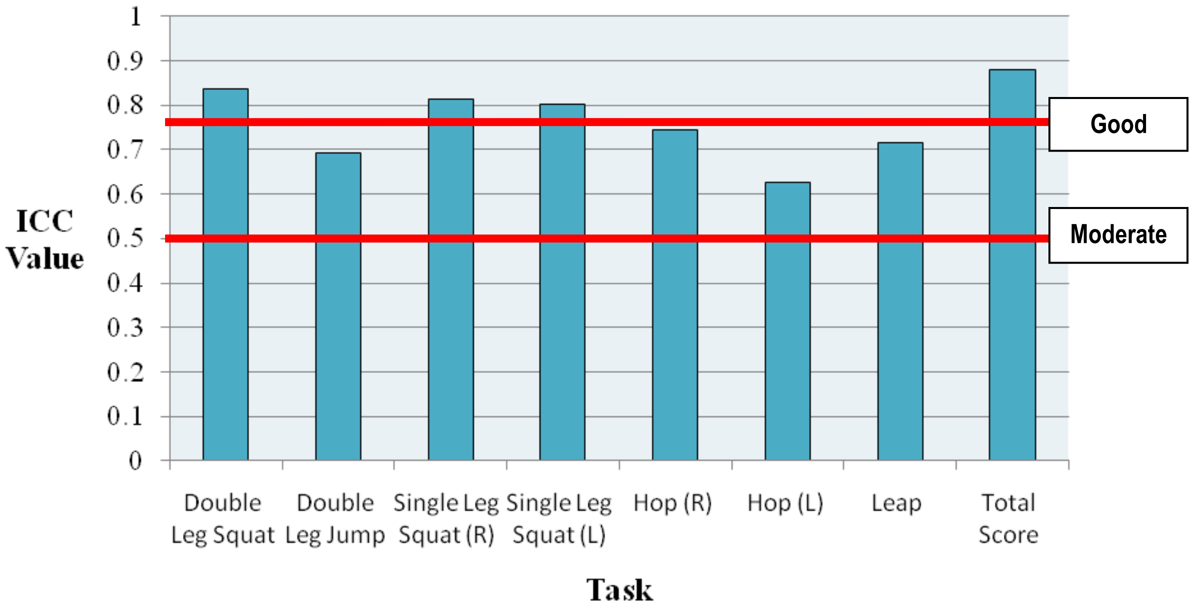
Interclass correlation coefficient (ICC) values were calculated based on ANOVA results for each task and the total score. Table 2 displays the interrater reliability among five raters for each task as well as the total scores. Graph 1 provides a visual analysis of the interrater reliability for each task as well as the total score. Among five raters the bars reaching 0.5 represent moderate correlations while the bars reaching 0.75 represent good correlation. ICC values ranged from 0.627 to 0.878 (double-leg squat ICC=0.835; double-leg jump ICC=0.691; right single-leg squat ICC=0.812; left single-leg squat ICC=0.802; right single-leg hop ICC=0.745; left single-leg hop ICC=0.627; leap ICC=0.716; total score ICC=0.878).

Table 2. Interrater Reliability for Lower Extremity Functional Screen

TASK	ICC
Double Leg Squat	0.835 ¥
Double Leg Jump	0.691 *
Single Leg Squat (R)	0.812 ¥
Single Leg Squat (L)	0.802 ¥
Hop (R)	0.745 ¥
Hop (L)	0.627 *
Leap	0.716 *
Total Score	0.878 ¥

¥ Indicates good correlation with a value ≥ 0.75
***** Indicates moderate correlation with a value 0.50- 0.74

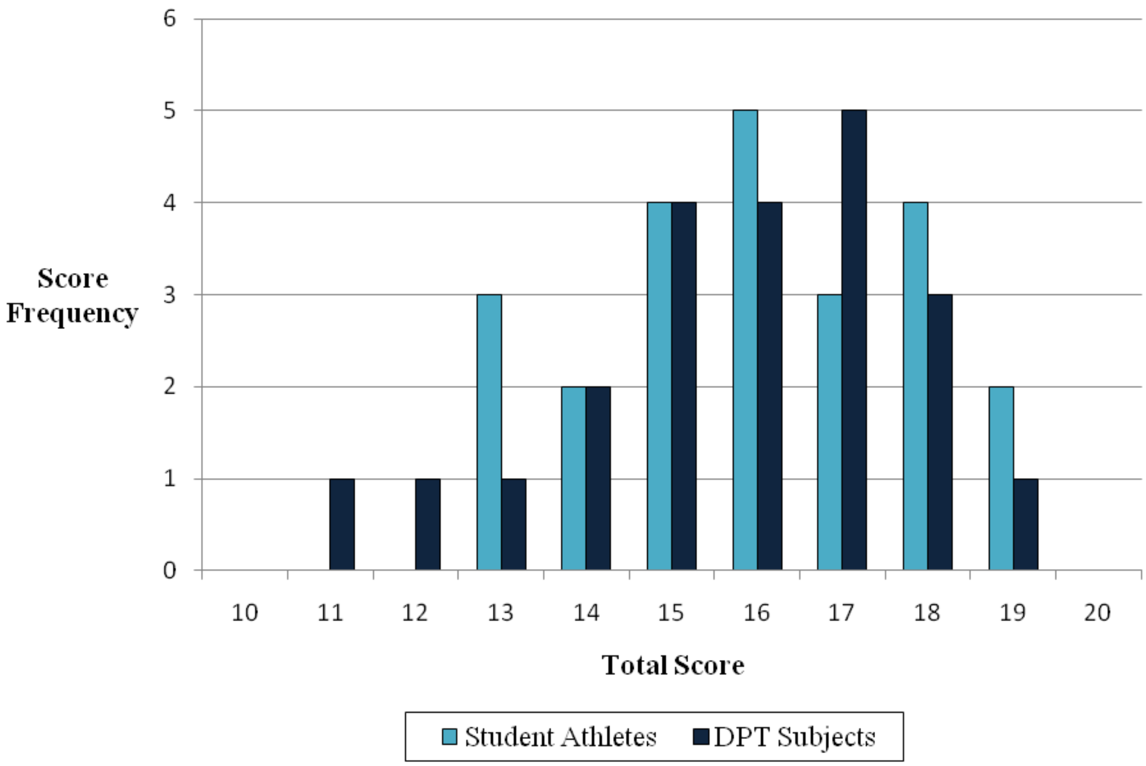
Graph 1. Interclass Correlation Coefficients for Lower Extremity Functional Screen



Total Score Frequency

Graph 2 represents the total score frequency distribution for both the DPT students and student athletes. A median score was utilized for the five raters for the DPT students. All total scores ranged between 11-19 points for the DPT students and between 13-19 points for the student athletes.

Graph 2. Total Score Frequency



Hip Strength

Spearman correlation coefficients were calculated to determine relationships between each task score and hip strength. The relationship between single-leg squat and hip strength is shown in Tables 3a and 3b. The correlation between the single-leg squat and right hip external rotation was found to be significant with a p-value of less than 0.05. The correlations between single-leg squat and right hip abduction, left hip external rotation, and left hip abduction were found to be trending towards significance with p-values of less than 0.10.

Table 3a. Hip Strength Correlations

Left Lower Extremity	Average Left Hip Abduction	Average Left Hip External Rotation
Average Single Leg Squat Score	0.416 (p=0.543)	0.377 (p=0.838)

Table 3b. Hip Strength Correlations

Right Lower Extremity	Average Right Hip Abduction	Average Right Hip External Rotation
Average Single Leg Squat Score	0.372 (p=0.884)	0.506 (p=0.0163)*

* Indicates significance ($p \leq 0.05$)

Non-Significant Results

Balance

Spearman correlation coefficients were calculated to determine relationships between each task score and balance. An inverse relationship was identified between the left single-leg squat and all balance scores (p=-0.292 to -0.197), while a direct relationship was found between right single-leg squat and all balance scores (p=0.079 to 0.065) (Table 4). No significant correlations were found between the double-leg squat and balance scores (p=0.910 to 0.646) (Table 5).

Table 4. Balance vs. Single-Leg Squat

	Reaching Right	Reaching Left
Left Lower Extremity	-0.292 (p=0.187)	-0.197 (p=0.379)
Right Lower Extremity	0.079 (p=0.727)	0.065 (p=0.775)

Table 5. Balance vs. Double-Leg Squat

	Reaching Right	Reaching Left
Left Lower Extremity	0.905	0.646
Right Lower Extremity	0.862	0.910

Hip Strength

Spearman correlation coefficients between each task score and hip strength are provided below. No significance was found for the correlations provided in the tables (Tables 6-10).

Table 6. Double-Leg Squat vs. Hip Strength Correlation

	Average Hip Strength
Hip Abduction	0.680
Hip External Rotation	0.545
Hip Extension	0.998

Table 7. Double- Leg Jump vs. Hip Strength Correlation

	Average Hip Strength
Hip Abduction	0.180
Hip External Rotation	0.307
Hip Extension	0.204

Table 8. Single-Leg Hop vs. Hip Strength Correlation

	Right	**Left**
Hip Abduction	0.156	0.001
Hip External Rotation	0.233	0.264
Hip Extension	-0.210	-0.035

Table 9. Leap vs. Hip Strength Correlation

	Average Hip Strength
Hip Abduction	0.470
Hip External Rotation	0.799
Hip Extension	0.817

Table 10. Lower Extremity Functional Screen Total Score vs. Previous Injury Occurrence

	Frequency	**Mean**
DPT No Previous LE Injury	16	15.688 ± 1.964
DPT Previous LE Injury	6	15.500 ± 1.862

p = 0.842 Accept Null Hypothesis

CHAPTER V:

DISCUSSION

Significant Findings

This study identified the Lower Extremity Functional Screen to have moderate to good interrater reliability in 22 healthy female subjects (ICC=0.627-0.878). These reliability findings are consistent when compared to two functional screens in the literature. The Functional Movement Screen (FMS™) established excellent or substantial agreement.[10,12] The FMS™ involves testing seven movements in which weakness or imbalance might be noticeable if deficits exist. However, this test was done only in the clinic, requires the use of equipment, and the testing procedures took greater than 10 minutes to complete. The Lower Extremity Functional Test (LEFT) established excellent agreement (ICC=0.95-0.97).[14] The LEFT is a comprehensive test of eight multi-directional skills performed in a standardized 16-step sequence between targets. Although excellent reliability was established, this test requires a large space to complete the tasks, cones to mark the targets, and more time due to increased practice trials for these complex motor movements.

The Lower Extremity Functional Screen can be used as a reliable functional assessment for athletic screening. The screen requires no equipment and can be performed in various environments as testing was done on a tile floor, a carpeted hallway, and on an outdoor soccer field. Each testing sequence took less than five minutes for subjects to complete. Finally, the established testing sequence allowed one practice trial prior to the graded trial. All subjects demonstrated comprehension through their ability to replicate the task following the practice trial

Frequency of total scores for the DPT students ranged from 11-19 points using a median score from the five raters. Total scores for the student athletes ranged from 13-19 points. These results showed no ceiling or floor effect in either population as no subjects scored zero points or the maximum 21 points. This indicates that the Lower Extremity Functional Screen contains appropriate tasks that are not too easy or too difficult. The testing sequence begins with easier double-leg tasks and progresses to more challenging single-leg tasks. The Lower Extremity Functional Screen was challenging for both populations tested in this study.

An initial hypothesis when comparing frequency of total scores between the DPT students and the student athletes was that the student athletes would score on average higher than the DPT students. However, similar distributions of total scores were found in both populations. The DPT students may have scored higher as their activity level may be more similar to an athletic population than initially expected. On average DPT students self-reported regular activity participation of three to four days per week for 30-60 minutes per day. In comparison, the student athletes self-reported their average regular sports participation as greater than five days per week for 60 or more minutes per day. High activity levels in both populations may have been a contributing factor in the similar distribution of scores.

Correlations were found between the Lower Extremity Functional Screen and hip strength. A significant correlation was found between the right single-leg squat and right hip external rotation strength ($r=0.506$, $p<0.05$). Correlations trending towards significance were found between the right single-leg squat and right hip abduction strength ($r=0.0884$), left single-leg squat and left hip external rotation strength ($r=0.0838$), and the left single-leg squat and left hip abduction strength ($r=0.0542$). These correlations between the single-leg squat and hip strength are consistent with results from the literature that identified hip muscle weakness as a significant predictor of frontal knee plane motion.[19] Results trending towards significance may have shown stronger correlations had more subjects been tested.

Non-Significant Findings

No significant correlations were found between the Lower Extremity Functional Screen and the mSEBT. Correlations between the left single-leg squat and mSEBT showed an inverse relationship (reaching right $r=-0.292$, $p=0.187$; reaching left $r=-0.197$, $p=0.379$). Correlations between the right single-leg squat and mSEBT showed a direct relationship (reaching right $r=0.079$, $p=0.727$; reaching left $r=0.065$, $p=0.775$). No significant correlations were found between the double-leg squat and mSEBT. Additionally, no significant correlations were found between the Lower Extremity Functional Screen and hip strength. These results may indicate that other factors beyond balance or strength alone play a role in tasks of the Lower Extremity Functional Screen. Additional factors that may contribute to the tasks include lower extremity coordination, lower extremity flexibility, neuromuscular control, proprioception, and fatigue level of the subject. Results may have shown stronger correlations had more subjects been tested.

Limitations

This study contains limitations that should be considered when reviewing the findings. First, a small number of subjects (n=22) for reliability testing and (n= 23) for pilot testing were analyzed. Correlations between tasks from the Lower Extremity Functional Screen and hip strength were trending towards significance. However, these findings may have had greater significance if there was a larger sample size. Second, this study only tested healthy female subjects. These findings cannot be generalized to healthy male athletes or injured athletes. Third, testing took place in variable environments. The different testing surfaces included a tile floor, a carpeted hallway, and on an outdoor grass soccer field. Although this could be a limitation, all subjects were able to perform the Lower Extremity Functional Screen safely and without incurring any injuries in these variable environments which may be beneficial in the application of this screen in any athletic venue. Fourth, researchers were limited to only a frontal plane view of subjects during video analysis. Good to moderate reliability was established despite this limited viewing angle. However, the tasks included in the screen do occur in three planes of motions so additional viewing angles may be beneficial

Future Research

Future research should include a larger healthy female athletic population to further analyze correlations between the Lower Extremity Functional Screen and hip strength / balance. Reliability testing on a large healthy athletic population of both males and females should be studied in order to establish greater generalization of the Lower Extremity Functional Screen to an overall athletic population. After establishing psychometric properties, the Lower Extremity Functional Screen should be used on injured subjects to determine correlations between the screen and hip strength / balance. These findings could then be compared to a healthy population. Injury rates should also be monitored during the sports season after testing athletes with the Lower Extremity Functional Screen in order to establish a cut-off score for potential injury. The psychometric properties should also be determined between the Lower Extremity Functional Screen and other functional screens currently being used.

CHAPTER VI:

CONCLUSION

The Lower Extremity Functional Screen is a reliable screening tool for identifying biomechanical faults in a female athletic population. Moderate to good interrater reliability was established (ICC=0.627-0.878) which is similar to results of other functional screens identified in the literature. The advantage to this newly developed screening tool is that it can be performed quickly, used in a variety of settings, and requires no additional equipment or set-up. Further research should be done in order to expand the generalizability of this screen to a broader athletic population.

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APPENDIX A

Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes
DPT 2011 Information and Consent Form

Introduction:

You are invited to be a subject in a study on a functional screening for female athletes by Doctor of Physical Therapy graduate students from St. Catherine University, under the supervision of Paul Niemuth, PT, DSc, OSC, SCS, ATC, Doctor of Physical Therapy program faculty member. You were selected as a possible participant in this research because you are a female St. Catherine University DPT student being used for the early part for the study. Please read this form and ask questions before you agree to be in the study.

Background:

The purpose of this study is to determine a way to measure normal or faulty leg mechanics in female athletes and to examine a possible relationship between a score obtained on a functional screening tool and the subsequent occurrence of lower extremity injury.

Procedure:

If you decide to participate, you will be asked to first fill out a brief questionnaire about history of leg injuries as well as you current activity levels. You will then perform a series of 5 leg squatting, jumping or hopping activities. You may also perform a balance test and have your leg muscle strength tested. The process will take between 5-10 minutes.

Risks and Benefits:

There are no benefits for participating in this study. The risks are minimal due to the physical requirements of data collection. In the event that this research activity results in an injury, we will assist you. For example, if you suffer a fall while performing a hopping activity we will assess the injury, apply ice, and refer you for the proper medical care. Any medical care for research-related injuries should be paid by you or your insurance company. If you think you have suffered a research-related injury, please let us know right away.

Confidentiality:

Any information obtained in connection with this research study that could identify you will not be disclosed. Participants will be assigned a research number. The number will be used for identification. Study information will be kept in a locked file I the office of the primary research advisor at St. Catherine University and will only be assessable by the researchers. Upon completion of the project in May of 2011, we will destroy all personal information, records, and videotapes

Voluntary Nature:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your future relations with the DPT Program or St. Catherine or Hamline University. If you decide to participate you are free to discontinue participation at any time without affecting these relationships.

Contacts and Questions:
You are encouraged to ask the researchers any questions about this study at any time. You may also contact Paul Niemuth, DPT program faculty if you have any questions at any time (see contact information below). If you have other questions or concerns regarding the study and would like to talk to someone other than the researcher(s), you may also contact John Schmitt, PhD, Chair of the St. Catherine University Institutional Review Board, at (651) 690-7739.
You may keep a copy of this consent form for your records.

Statement of Consent:
You are making a decision whether or not to participate in this study. Your signature indicates that you have read this information and your questions have been answered. Even after signing this form please know that you may discontinue your participation at any time.

I agree to participate in this study
Yes_______ No_______

____
Signature of subject Date

____
Signature of researcher Date

Supervising faculty member
Paul Neimuth, PT, DSc, OSC, SCS, ATC
Doctor of Physical Therapy Program
St. Catherine University
601 25th Avenue South
Minneapolis, MN 55454
Phone: 651-690-7981

APPENDIX B

Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes
Female Athletes Information and Consent Form

Introduction:
You are invited to be a subject in a study on a functional screening for female athletes by Doctor of Physical Therapy graduate students from St. Catherine University, under the supervision of Paul Niemuth, PT, DSc, OSC, SCS, ATC, Doctor of Physical Therapy program faculty member. You were selected as a possible participant in this research because you are a member of a women's collegiate soccer team. Please read this form and ask questions before you agree to be in the study.

Background:
The purpose of this study is to determine a way to measure normal or faulty leg mechanics in female athletes and to examine a possible relationship between a score obtained on a functional screening tool and the subsequent occurrence of lower extremity injury.

Procedure:
If you decide to participate, you will be asked to first fill out a brief questionnaire about history of leg injuries as well as you current activity levels. You will then perform a series of 5 leg squatting, jumping or hopping activities. You may also perform a balance test and have your leg muscle strength tested. The process will take between 5-10 minutes.

Risks and Benefits:
There are no benefits for participating in this study. The risks are minimal due to the physical requirements of data collection.

Confidentiality:
Any information obtained in connection with this research study that could identify you will not be disclosed. Participants will be assigned a research number. The number will be used for identification. Study information will be kept in a locked file I the office of the primary research advisor at St. Catherine University and will only be assessable by the researchers. Upon completion of the project in May of 2011, we will destroy all personal information, records, and videotapes

Voluntary Nature:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your future relations with the DPT Program or St. Catherine or Hamline

University. If you decide to participate you are free to discontinue participation at any time without affecting these relationships.

Contacts and Questions:
You are encouraged to ask the researchers any questions about this study at any time. You may also contact Paul Niemuth, DPT program faculty if you have any questions at any time (see contact information below). If you have other questions or concerns regarding the study and would like to talk to someone other than the researcher(s), you may also contact John Schmitt, PhD, Chair of the St. Catherine University Institutional Review Board, at (651) 690-7739.
You may keep a copy of this consent form for your records.

Statement of Consent:
You are making a decision whether or not to participate in this study. Your signature indicates that you have read this information and your questions have been answered. Even after signing this form please know that you may discontinue your participation at any time.

I agree to participate in this study
Yes_______ No_______

Signature of subject Date

Signature of researcher
Date

Supervising faculty member
Paul Niemuth, PT, DSc, OSC, SCS, ATC
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APPENDIX C

**Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes
Letter to Athletic Coaches**

Paul Neimuth, PT, DSc, OSC, SCS, ATC
Doctor of Physical Therapy Program
St. Catherine University
601 25th Avenue South
Minneapolis, MN 55454
Phone: 651-690-7981

Dear Coach___________,

Your team has been invited to participate in a study by Doctor of Physical Therapy graduate students from St. Catherine University, under the supervision of Paul Niemuth, PT, DSc, OSC, SCS, ATC, Doctor of Physical Therapy program faculty member. The purpose of this study is to determine a relationship between a score obtained on a functional screening tool and the subsequent occurrence of lower extremity injury. We have selected your team because the focus of our study is female collegiate athletes.

Prior to testing, participants will be given the St. Catherine University LE Functional Screening Tool Study Questionnaire to determine prevalence of previous lower extremity injury. The testing sequence includes a one to two minute jog to warm-up, watching a demonstration of the task, practicing the task two times, and then performing each task before moving on to the next. The total testing sequence is expected to take five to ten minutes per player. Participants will be allowed two practice trials of each component of the functional screening tool. The third trial will be graded on a 0 to 4 scale by two testers as follows: 0=cannot complete movement or loss of balance, 1=complete with two or more faults, 2=complete with one fault, 3= perfect technique.

The five tasks include: Squat, jump, single leg squat, hop, and leap. Participants will complete all five tasks in sequence regardless of success. Component scores will be added to obtain a total possible score of 20 points with a higher score hypothesizing a lower risk of injury. Follow up will occur post soccer season using the St. Catherine University LE Functional Screening Tool Study Questionnaire to determine injury rate for that season.

Participation in this study is voluntary. Your decision whether or not to allow your athletes to participate in this study will not affect your future relations with St.

Catherine University. If you decide to participate your players are free to discontinue participation at any time without affecting these relationships.

Any information obtained in connection with this research study that could identify you will not be disclosed. Participants will be given a number. The number will be used for identification. Personal information will be kept in a locked file only assessable by the researchers. There are no benefits for participating in this study. The risks are minimal due to the physical requirements of data collection.

You are encouraged to ask the researchers any questions about this study at any time. You may also contact Paul Niemuth, DPT program faculty if you have any questions at any time (see contact information below). You may keep a copy of this consent form for your records.

Thank you for your consideration.

Sincerely,

Paul Niemuth, Jackie Carpenter, Ann Donner, Kristi Hoff, and Naomi Johnson

APPENDIX D

Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes Questionnaire

Subject # ___________ Date ____________

1. What is your Gender? Please circle one.
   Male **Female**

2. What is your age? _________

3. Have you had a previous lower extremity injury within the past 5 years? Please circle one.
   Yes **No**

4. If yes, describe your incident including when it happened, type of injury, location, how it was injured (sports, exercising, work, etc.), and list any treatment you received (physical therapy, chiropractor, none, etc.)

Approximate date:	Type of injury:	Location on body:	How it was injured?	Type of treatment:

5. Does your previous injury currently affect your activity participation? Please circle one.
   Yes **No**

   If Yes, please explain:

6. Are you acutely injured? Please circle one
   Yes **No**

7. Have you participated in sports on a regular basis in the last 5 years? Please circle one.
   Yes **No**
   If no, skip to question 9.

8. If yes, please list which sports and the highest level you participated in the last 5 years.

Sport: **Highest level:** **Dates:**

9. How many **days** during a typical week do you engage in physical activity or exercise? Please circle one.

0 **1-2** **3-4** **5+**

10. How many **minutes** do you typically spend on the days you engage in physical activity or exercise? Please circle one.

Less than 15 min **15-29 min** **30-44min** **45-59 min** **60+**

11. How much effort do you spend when engaging in physical activity or exercise? Please circle one.

0 1 2 3 4 5 6 7 8 9 10

Light Effort **Moderate effort** **Heavy Effort**

12. Is your physical activity level now similar to what it was six months ago? Please circle one.

Yes **No**

APPENDIX E

Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes
Strength and Balance Testing Form

Participant Number:______ Date:____________

Leg Dominance: R / L / Neither Weight:________lbs Height:____ft_____in

Strength Testing

Hip Abduction

Right Leg
Trial 1:______
Trial 2:______

Left Leg
Trial 1:______
Trial 2:______

Hip Extension

Right Leg
Trial 1:______
Trial 2:______

Left Leg
Trial 1:______
Trial 2:______

Hip External Rotation

Right Leg
Trial 1:______
Trial 2:______

Left Leg
Trial 1:______
Trial 2:______

Balance Testing

Right Leg/Left Arm Reaching Left
Trial 1:______
Trial 2:______

Left Leg/Right Arm Reaching Right
Trial 1:______
Trial 2:______

Right Leg/Left Arm Reaching Right
Trial 1:______
Trial 2:______

Left Leg/Right Arm Reaching Left
Trial 1:______
Trial 2:______

APPENDIX F

Lower Extremity Functional Screen for Biomechanical Faults in Female Athletes Screening Tool

Participant # ____________ Date _________________________

Description introduction: "*I will first read you a description of the task. Next, I will demonstrate the task and you will be able to perform a practice trial. I will ask if you have any questions. Then you will perform the task for a graded trial. You will do each task 3 times in a row.*"

Task	Description	Criterion	Score
Double-Leg Squat	*You will be performing a double- leg squat. Stand with your feet shoulder width apart and your arms raised in front of you to 90°. Squat down until your thighs are parallel with the ground.*	✓ Equal weight bearing ✓ Maintain knee control in all 3 planes ✓ Must squat with thighs parallel to the floor or knee flexion to 90-degrees	3 2 1 0
Double-Leg Jump	*You will be performing a double- leg jump. Stand with your feet shoulder width apart and your arms extended behind you. Jump raising your arms overhead landing in a double-leg squat position each time. Try to land in the same place each time.*	✓ Equal weight bearing at take-off and landing ✓ Maintain knee control in all 3 planes at take-off and landing ✓ Upon landing, must squat with knee flexion from 45-degrees to 90-degrees	3 2 1 0
Single-Leg Squat	*You will be performing a single-leg squat. Stand on your R (L) leg with your opposite knee bent. Have your R (L) arm forward. Squat down until your bent knee drops below mid-shin of your stance leg using a reciprocating arm swing.*	✓ Maintain hip control and balance (no visible hip hike, drop, or rotation) ✓ Maintain knee control in all 3 planes ✓ Must squat so the L (R) knee drops below half the height of the R (L) leg shin length	R 3 2 1 0 L 3 2 1 0

Single-Leg Hop	*You will be performing a single-leg hop. Stand on your R (L) leg with your opposite knee bent and your arms extended behind you. Jump raising your arms overhead landing in a single-leg squat position each time. Try to land in the same place each time.*	✓ Maintain hip control and balance (no significant hip hike, drop, or rotation) at take-off and landing ✓ Maintain knee control in all 3 planes at take-off and landing ✓ Upon landing, must squat so the L (R) knee drops below half the height of the R (L) leg shin length	R 3 2 1 0 L 3 2 1 0
Leap	*You will be performing 6 alternating leaps. Stand on your R leg with your opposite knee bent. Have your L arm forward. As you leap onto your L leg at a 45° angle use a reciprocating arm swing. Continue through 6 leaps*	✓ Maintain hip control and balance (no visible hip hike, drop, or rotation) with no toe touch ✓ Maintain knee control in all 3 planes ✓ Upon landing, maintain foot position	3 2 1 0

Total ____________/21