**Statement of Need**

 Osteoarthritis (OA) is the most common joint disorder in the US 1,2,6. According to the Centers for Disease Control (CDC), an estimated 27 million people in the US had OA2. Of these adults, 3.75 million (14%) were age 25 years and older and 12.4 million (33.6%) were 65 and older2.The Johnston County Osteoarthritis Project in NC found 27.8% of adults aged 45 and older suffered from knee OA. Osteoarthritis has a huge financial impact on both patients and the healthcare field as whole. In 2006, OA accounted for 70% of all arthritis-related hospitalizations, with the average direct cost of OA per patient of $2,600 per year in 20092.Because knee OA is a disease involving cartilage, joint lining, ligaments and bone, knee replacement surgeries are often needed in later stages of the disease. In the US, the rate of total knee replacements from 1991 to 2007 increased 187%, with an estimated cost due to hospital expenditures of $28.5 billion in 20092.

 The CDC states that “The central aim of state arthritis programs is to improve the quality of life among persons affected by arthritis10.” Currently, the CDC Arthritis Program publishes resources and interventions aimed mostly at the management of knee OA symptoms, including walking, swimming, and other fitness programs. The CDC offers little information in terms of the prevention of knee OA. In order to help reduce the incidence of knee OA and its impact on the healthcare system, individuals need to be targeted earlier in life. Not engaging in preventative care and waiting until the onset of OA contributes to the billions of dollars spent by the healthcare industry on these individuals.

Numerous studies have proven that knee injury, particularly an anterior cruciate ligament (ACL) injury, and/or chronic knee instability are two of the strongest risk factors for developing knee OA1,2,3,4. In addition, it has been shown that having an ACL reconstruction can also lead to the development of OA7,11,12.One study found that having an ACL injury makes an individual 10 times more likely to develop knee OA13. These risk factors are modifiable, meaning that their contributions to developing knee OA can be altered and ideally decreased. Targeting the population most at risk for developing ACL injuries and chronic knee instability is one method to modify the prevalence of knee OA in the future.

The number of young athletes sustaining ACL injuries has increased over the past 20 years, mainly due to increased awareness and detection of these injuries, as well as the growing number of children involved in sports at an early age14,15,16. ACL injury rates begin to increase in females at 12-13 years of age and in males at 14-15 years of age7. ACL injuries are most prevalent in individuals aged 15-45,with the risk rising to 1 in 175027. According to the High School Sports-Related Injury Surveillance Study28, ACL injuries accounted for 25.6% of all knee-related injuries in the United States28. ACL injuries put these athletes at risk for limited future sport participation; maintaining sport participation has been shown to improve bone health, enhance self-esteem and academic performance, in addition to lowering rates of depression, teen pregnancy and obesity17,18,19,20,21.Injuries to the ACL are predominately non-contact in nature and commonly occur in sports that require bearing weight while twisting the body, quickly changing direction, or suddenly decelerating in speed7.

Soccer is one sport where many ACL injuries have been documented. Girls’ soccer has the highest ACL injury rate of all sports, while soccer has the second highest ACL injury rate for boys29. It was estimated in 2008 that that the occurrence of ACL injuries on a soccer team (as a percentage of total injures on the team) is 1.3% for males and 3.7% for females36. While females are more at risk for ACL injuries, more males sustain ACL injuries per year; therefore, all adolescents participating in soccer are at an increased risk for ACL injuries and future development of OA7.Athletes younger than 13 to 14 usually sustain growth plate injuries rather than ACL injuries, due to the relative weakness of cartilage at the ends of bones compared with the ACL30. Because of this, adolescent soccer players aged 14 and older can be targeted for ACL injury prevention in order to help prevent development of OA.

 Over the past 15 years, soccer has gradually increased in popularity in the US and in North Carolina as well. Wake County, NC is home to the Capital Area Soccer League (CASL), which is a well known, non-profit soccer club with over 9,000 youth soccer players from ages 4-1822. CASL contains around 75 teams (both boys and girls leagues) consisting of roughly 1,100 athletes aged 14-1822. This program will target athletes from this specific population to help prevent ACL injuries and future development of knee OA.

 In order to have the largest impact, this health and wellness program will utilize a social-ecological model (SEM) of health behavior. The reason for utilizing this type of model is because it considers multiple levels of influence, including intrapersonal, interpersonal, institutional/organizational, community and policy levels23,24. Behavior changes are most likely to happen when individuals are educated and motivated to make the change, social environments are optimized for healthy behaviors, and communities support the individuals with their healthy choices24.This program is designed to influence behaviors and utilize interventions specifically tailored to the intrapersonal, interpersonal, and organizational levels of the SEM. Educational sessions will be offered to athletes and their teams, in additional to evidence-based physical training interventions.

 As previously mentioned, positive health behavior changes are more likely to occur when they target specific mechanisms of change at different levels of influence. Physical therapists have been given the knowledge and skills to help target those specific mechanisms of change. In addition, ACL injuries and rehabilitation are not uncommon to physical therapists. The American Physical Therapy Association (APTA) has already published evidence to support the use of strengthening/exercise programs to decrease ACL injuries in female athletes8,25. The Guide to PT Practice, the official description of physical therapist practice for use by physical therapists, discusses a physical therapist’s role in recognizing, treating, and helping prevent joint dysfunctions, including ACL injuries26. This program is designed to provide education to athletes and their social networks, implement exercise and neuromuscular training interventions, and utilize strategies to influence the local CASL organization. All of these efforts are aimed at helping prevent ACL injuries in adolescents and future development of knee OA.

**Background**

 As discussed previously, two of the most influential risk factors for developing knee OA are sustaining an injury to the ACL and having ACL reconstructive surgery1,2,3,4,7. A community-based program aimed at reducing these risk factors can have a significant impact on the prevalence of knee OA and its associated healthcare costs. This program targets multiple levels of the social-ecological model (SEM), and is tailored to have positive impacts on the intrapersonal, interpersonal, and organizational levels. Healthy behaviors are most likely to take root in individuals when they are influenced by numerous levels of social influence24.

 The first step of this program involves reaching out to the CASL board of directors and soccer coaches to present this community-based health initiative. Educating organization leaders on the existing evidence and importance of ACL injury prevention measures and gaining their support for implementation of the program will influence individual athletes at the organizational level of the SEM. This is a crucial step, as CASL’s implementation of this program at practices and games is vital to the success of the program. A 2013 study identified factors that influence coaches’ implementation of ACL injury prevention programs (IPPs) in female soccer players31. Factors associated with successful implementation included length of time coaching experience and presence of additional support staff31. An additional finding was that successful coaches agreed that education on ACL injury prevention should be required for coaches and athletes and that dissemination and implementation will require soccer associations to enact policies that require IPPs31. To increase successful implementation of this proposed program, local physical therapists and physical therapy students will be trained in specific injury prevention education/interventions and will be available to support coaches. They will be available to provide coaches with more support at the beginning of the season, with opportunities to taper the amount of assistance needed.

 Education strongly influences individuals at the intrapersonal level of the SEM and can become an internal motivator to maintain compliance in this ACL injury prevention program24. McLeroy’s ecological perspective on using interpersonal strategies states that they “have typically focused on changing individuals through social influences, rather than on changing the social groups to which individuals belong to23.” With this in mind, interactive and educational sessions involving the athletes’ teammates, coaches, and family will be included in the program. Holly Silvers, the spokesperson for the APTA’s taskforce on ACL prevention, has conducted research demonstrating how educational interventions aimed at reducing internal and external risk factors for ACL injury are most successful25. Factors include dangerous leg positions, awareness of lower extremity joint position, muscle strength imbalances, proper hydration, playing surfaces, and family involvement at home25. These risk factors will be the subject of the educational sessions targeting athletes on the intrapersonal and interpersonal level, influencing their own thoughts, as well as social support systems of teammates, family, and coaches23.

 The key component of this program involves introducing the athletes and coaches to soccer-specific neuromuscular, strengthening, flexibility and movement trainings to help prevent ACL injuries. A 2009 systematic review of prevention programs aimed at reducing ACL injury rates found that multi-faceted programs produce better results than single component programs (i.e. strengthening or neuromuscular components only)32. To reduce non-contact ACL injuries, the review found that lower extremity plyometrics, neuromuscular and proprioceptive training, dynamic balance and strength, stretching, body awareness, and targeted core and trunk control are the most successful training components32. The majority of the included studies looked at female athletes, but the authors concluded that both genders gain improvements in force absorption, active joint stabilization, muscle balance and functional biomechanics32. There is a lack of evidence to support ACL injury prevention programs in male soccer athletes and this program is one effort to help fill this “gap.” A 2012 systematic review found evidence to support the use of stretching, proprioception-balance, strength, plyometric and agility exercises with verbal feedback on proper landing techniques34. One randomized control trial assigned adolescent female sports teams to either a neuromuscular warm-up intervention or a control group with their usual playing practices35. The intervention group progressed through different levels of 6 exercises with coach supervision after instruction from physical therapists. After 6 months, a reduced rate of ACL injuries was found in the neuromuscular exercise group35.

 Many multi-faceted neuromuscular training programs have identified a position of “knee valgus collapse” (when the medial knee points inward with the hip and foot more lateral) as being the most detrimental for ACL injury39. Specific interventions are targeted to increase the neuromuscular control of the trunk and lower extremities to avoid this valgus collapse position. Squats, lunges, calf-raises and side plank exercises strengthen the quadriceps, gluteus muscles, hamstrings, gastroc/soleus and hip external rotators to prevent muscle imbalances that subject athletes to a dynamic knee valgus position and valgus collapse7,39. Plyometric drills (repetitive jumping) aim to increase muscle power and maximum force by pairing different types of muscle contractions that gradually progress in difficulty7. Plyometrics have been shown to help athletes correctly position the thigh in anticipation of ground forces to avoid knee valgus collapse32,39. Paramount to plyometric training is progression from double leg jumping to single leg maneuvers to simulate game demands, as well as incorporating close monitoring and continuous verbal feedback by coaches during and after jump landing tasks39. Emphasis on landing with increased hip and knee flexion and keeping “knees pointed over the toes” helps avoid landing with increased knee valgus angles8,39. Dynamic balance/proprioceptive exercises, specifically involving perturbation training, have been shown to reduce ACL injury risk39. Beneficial alteration of movement patterns leads to improved activation timing of gastrocnemius and hamstring muscles, as well as improvements in biomechanics and muscular stability32,39. In addition, training of the calf musculature to decrease ankle plantarflexion fatigue leads to better overall leg stability39. Adequate core strength is needed in order to keep ground reaction forces medially and decrease the potential for knee valgus loading. Prone trunk extensions coupled with side-plank exercises have shown increases in trunk muscle strength to help stabilize in multiple planes32,39. With regards to stretching, Bien’s review of the literature found that limited ankle dorsiflexion range of motion leads to increased hip internal rotation and foot pronation, which are components of knee valgus collapse39. Adequate flexibility of the quadriceps and hamstrings is also desired to allow for safe landings with knee and hip flexion39. Dynamic warm-up activities, as opposed to static stretching, have demonstrated greater effects on agility and power tests and should be incorporated first in warm-up activities8,39. There is a clear indication that high-level evidence of ACL injury prevention programs involves a comprehensive and dynamic neuromuscular program, which has been integrated into this current program.

 An initial pre-season educational/training session, paired with an in-season maintenance schedule, has been found to most successfully prevent ACL injury32. Mandelbaum et al demonstrated an 88% reduction in ACL injury with a comprehensive program comprised of the neuromuscular and strength/flexibility components mentioned previously32. In the study, coaches and soccer players were given educational videos/diagrams explaining how to perform the interventions. In addition, coaches attended a mandatory meeting where the program was introduced and the specific parameters described32. Literature packets contained sample field set-ups and detailed information regarding each specific exercise. Sessions were designed to last around 20 minutes and performed 2-3 times per week. Three dynamic warm-up activities were performed, followed by 5 stretching techniques for the lower extremities and trunk, followed by 3 strengthening exercises, 5 plyometric activities, and 3 soccer specific agility drills32. All of these were performed before athletic activity throughout the season. A review by Bien found that most ACL injury prevention programs are at least 6-8 weeks in length, as this amount of time is required to effect neuromuscular changes and performance training effects39. The results from this study will be used as the basis for the current program’s in-season protocol. Progressions of exercises will be available, as players have been shown to adapt to repeated interventions over time and require new stimuli for continued improvement32. A commonly used outcome assessment to analyze lower extremity movement patterns during a jump-landing task is the Landing Error Scoring System (LESS)41. This measure asks individuals to jump off a box, land with two feet on the floor, and jump straight up in the air. The LESS has been shown to be an excellent tool to identify positions of valgus knee collapse and allow for the tracking of progress of neuromuscular training programs41.

 Two additional, important aspects of the proposed program to consider are the ease of incorporation into regular training soccer programs and its very low cost of implementation. Both of these will serve to increase implementation and adherence by coaches and athletes32,33. This program is designed to be fun for the athletes, which influences their thoughts and behaviors on the intrapersonal level of the SEM24. Adolescents are more likely to follow through with physical activity such as an ACL injury prevention and wellness program if it is perceived as fun for them40. Individual athletes are influenced on the interpersonal level by their teammates and friends24,40. Friends can be powerful motivators of behavioral changes, as adolescents at this age are highly susceptible to pressures from their peers40. Participation in physical activity is also positively influenced by the involvement of friends and support of families40. Having educational and training sessions in a team-based format will place athletes in an environment surrounded by their peers, coaches, and family for most of this prevention program.

 Evidence has shown that surgical reconstruction of ACL injuries does not reduce the increased risk for developing knee OA later in life37,38. The prevention of ACL injuries is one significant strategy of preventing knee OA and its immense financial burden on the healthcare system. The evidence discussed has led to the development of a multi-faceted ACL injury prevention program, aimed at influencing local adolescent soccer players on multiple social-ecological levels. By incorporating proven educational and neuromuscular training concepts, along with strategies to support implementation and adherence, this community-based program aims to produce a model capable of creating healthy and lasting impacts on its participants.

**Program Description**

**Program Objectives**

Following successful completion of the CASL ACL Injury Prevention Program (CAIPP): (program length corresponds to CASL Spring season of 3 months)

* At least 80% of included athletes will be able to verbalize and demonstrate dynamic body positions that increase their risk for non-contact ACL injury, with associated corrected positions.
* Athletes will achieve a lower score on a modified Landing Error Scoring System (LESS) compared to pre-season scores. (Norms for this assessment do not currently exist. Instead, serial testing will help determine improvement in an individual’s movement quality).
* Total number of ACL injuries from participating soccer players will be lower than the previous year (data obtained from the CASL Board of Directors).
* At least 85% of players, coaches, and CASL board members will be “highly satisfied” with the program’s outcomes (as measured on a post-season satisfaction survey) and will commit to another season of program participation.

**Methods**

**Target Population**

 The target population for this program is soccer players from the CASL who are between the ages of 14 to 18.

**Pre-Season Program Introduction**

 One week prior to the start of the Spring CASL soccer season (February 17, 2015), the CASL Board of Directors and coaches from each participating and qualified team will meet at the CASL home soccer complex for an introduction to and training of the program components. Objectives and program parameters will be covered, as well as education on the research behind each specific intervention. Knee OA prevalence, as well as ACL injury statistics, will be presented in an effort to target CASL’s core initiative of injury prevention. Demonstrations of each exercise/activity will be provided, as well as literature packets detailing specific instructions for each exercise and sample field set-ups. Because research has demonstrated that poor adherence is a major barrier for the success of existing ACL-injury prevention programs, the packets are designed to increase adherence by improving the time efficiency of implementation and being easy and transparent for coaches to understand. Videos demonstrating proper and improper training techniques will be available for coaches to take and use as educational materials for players during the season. Emphasis will be placed on providing verbal feedback on landings while athletes complete the exercises. Key phrases to use include “Land with your knees over your toes,” “Land with your knees bent,” and “Have soft landings.” These phrases are designed to decrease the valgus knee collapse position, which research has shown contributes to ACL injuries39. Volunteer physical therapists from the capital area, as well as physical therapy students from UNC-CH and Duke, will be trained in the program’s exercises as well as in being able to recognize improper techniques. They will be attending this pre-season meeting as well and will be assigned to CASL coaches for the duration of the program.

 Data collection will be explained at this meeting, including the LESS outcome measure. Below is an example of a modified LESS that will be utilized for outcome assessment of athletes42. In addition, weekly injury forms and questionnaires will be distributed at this time. Each week, coaches will fill out a form that asks about anatomical locations of injuries, cause, type, severity, and whether the injured player sought subsequent medical follow-up. If a knee injury occurs, a knee injury questionnaire will be given to the player that asks information regarding type of tissue injured, history of knee injury, duration of injury, and diagnosis of injury.



**Program Kickoff/Initial Training Day**

The weekend before the start of the CASL soccer season will serve as the CASL ACL Injury Prevention Program kickoff. Teams will be assigned to either Saturday or Sunday as their initial training day at the CASL home soccer complex. Since roughly half of CASL is composed of Recreation level players, they will attend Saturday’s training, while the other half of the players (Challenge and Classic level) will attend on Sunday. This will allow for smaller groups and more individualized instruction. Players and coaches will be welcomed and ushered into the field house, where an initial program overview and description will be given. Similar to the coaches initial meeting, ACL injury statistics and their impact on soccer players’ future sport participation will be presented in an effort to target this specific population. A short video will be shown explaining how non-contact ACL injuries commonly occur and how the components of this program are designed to modify athletes’ risk factors for ACL injuries. Players from the Carolina RailHawks professional soccer team will demonstrate all exercises and training components in front of the teams before teams break out into groups to practice them on the surrounding soccer fields. Initial data collection via the LESS outcome measure will be conducted on each participant during a lunch session, before groups break out for program exercise training. The trained PTs and students will be helping will data collection in order to streamline this process.

 Each breakout group will have 2 RailHawk players and 1 trained volunteer PT or PT student with them during training of the program exercises. Using the RailHawks as demonstrators further culturally targets these athletes and aims to get them more invested. They will also allow for adequate verbal and visual feedback, which research has shown to improve performance8,32,33,34. Research supports the use of a multi-faceted approach, including strengthening, stretching, plyometrics, proprioceptive and balance activities8,32.Table 1 contains the specific exercise interventions adapted from Mandelbaum et al8 that will be included in this ACL injury prevention program, along with specific distances and repetitions for each. While this initial training will require more time to teach, the program is designed to take around 20 minutes as a warm-up before practices and games during the season. Ways to increase the difficulty for each strengthening, plyometric, and agility exercise will be taught in order to allow for progression of training as individuals demonstrate mastery of each exercise.

**Table 1**: Program Exercises

|  |  |  |
| --- | --- | --- |
| **Exercise** | **Distance** | **Repetitions** |
| **1. Warm-up** |  |  |
| Jog line to line | 50 yd | 1 |
| Shuttle Run | 50 yd | 1 |
| Backward running | 50 yd | 1 |
| **2. Stretching** |  |  |
| Calf stretch | NA | 2 x 30 sec |
| Quadriceps stretch | NA | 2 x 30 sec |
| Hamstring stretch | NA | 2 x 30 sec |
| Inner thigh stretch | NA | 2 x 30 sec |
| Hip flexor stretch | NA | 2 x 30 sec |
| **3. Strengthening** |  |  |
| Walking lunges | 20 yd | 2 passes |
| Russian hamstrings | NA | 30 |
| Single-toe raises | NA | 30 each leg |
| Prone plank | NA | 30 sec x 2 |
| Bicycle kicks | NA | 30 sec x 2 |
| Side-lying clamshells | NA | 3x10 each side |
| **4. Plyometrics** |  |  |
| Lateral hops | 2- to 6-in cone | 20 |
| Forward hops | 2- to 6-in cone | 20 |
| Single-leg hops | 2- to 6-in cone | 20 |
| Vertical jumps | NA | 20 |
| Scissors jumps | NA | 20 |
| **5. Agilities** |  |  |
| Shuttle run | 40 yd | 1 |
| Diagonal run | 40 yd | 1 |
| Bounding run | 50 yd | 1 |

To help keep the environment fun, prizes will be awarded at the completion of the training to athletes who correctly answer questions regarding material presented.

**In-Season Program Protocol**

 As stated, the protocol will be performed at the start of each practice and game as a warm-up. At the beginning of the season, each team will have their assigned physical therapist or physical therapy student attend 1 practice/week in order to answer any questions, provide feedback, and correct any improper techniques. If coaches require additional assistance beyond their once/week visit, they can request additional assistance by contacting the program administrators. Each week, coaches will email or fax their weekly injury reports to the CAIPP administrators.

 Educational sessions will be offered throughout the season at the CASL home soccer complex and topics will include: avoiding dangerous leg positions, how neuromuscular, proprioceptive, and strength training can help prevent ACL injuries; proper hydration and its influence on athletic performance; and parent/coach sessions on how to help your athlete at home/practice. As Silver’s research concluded, these are some of the internal and external risk factors that can be targeted for decreasing ACL injuries25. Incentives for participating in these sessions will be awarded to teams with the highest attendance (RailHawk soccer tickets and a pizza party).

 As previously mentioned, coaches will mail in their weekly injury forms and any athlete injury questionnaires. These will serve as valuable data to be included in our program evaluation.

**Post-Season Program Wrap-Up**

At the end of the 3-month season, the program will be complete. CAIPP administrators, along with the volunteer physical therapists and students, will attend the end of the season program that CASL holds each year. Here, final LESS ratings will be taken, as well as collecting any additional injury reports from coaches. Satisfaction surveys will be administered to coaches, players, and the CASL Board of Directors. Surveys will contain questions rated on a 5-point Likert scale from “Highly Dissatisfied” to “Highly Satisfied” regarding levels of overall satisfaction with the program, included exercise components, whether the program was fun, and whether participants wanted to participate in future seasons.

**Program Evaluation**

It is our hope to conduct a program evaluation that will serve 4 main purposes, as outlined by the CDC’s publication on program evaluation framework43. These purposes are to gain insight, change practice, assess effects, and to affect participants through evaluation inquiry.

The modified LESS will serve as one of the primary means of assessing the level of program effectiveness. While no norms currently exist for the modified LESS, comparison of pre- and post-intervention scores will give us an idea of improved body mechanics. Another means of assessing program effectiveness will be through analysis of the weekly injury forms submitted from each team. Data will be compared to previous years’ data to see if our program made a clinically significant change in the number of ACL injuries sustained during the soccer season. This data is also important in being able to accurately classify the types of knee injuries sustained by the athletes and ensure exclusion of those injuries not related to ACL ruptures. Program adherence will be assessed via participation in the educational components, as well as through weekly check-ins with coaches on exercise/training components. A very important component of this program is raising awareness of dynamic body positions that increase athletes’ risk for non-contact ACL injury. After each athlete’s post-season LESS score is obtained, they also will be asked a few questions regarding at-risk body positions as well as other risk factors for creating an ACL injury. Their responses will be taken in order for us to assess whether our program components have increased their awareness about these important risk factors. Program satisfaction will be assessed via coach, athlete and CASL Board of Directors satisfaction surveys. Using a 5-point Likert scale from “Highly Dissatisfied to “Highly Satisfied,” all participants will answer questions related to overall satisfaction of the program, included exercises and training materials, if participation was fun, likelihood of participating in the program next season, and an open-ended section for recommendations for CAIPP development. The results from these surveys will allow the program to be tailored more specifically to this population’s needs, as well as designing it in such a way that enhances future participation.

 There are a few limitations of this program that are important to consider. One limitation is program adherence. While we cannot adequately assess whether or not teams are completing training components before each practice and game, we are attempting to analyze this through weekly check-ins and educational class attendance. Another limitation is the short nature of the program (3 months). A longer duration and inclusion of future athletes would allow for increased power and significance of our findings. The findings from this program only apply to soccer athletes; however, non-contact ACL injuries occur in other sports and we believe that this program has relevance to sports such as basketball and football.

 The potential for the CAIPP to create a significant and lasting effect on this population can be enhanced if it becomes longitudinal in nature. Data from multiple seasons would allow for continual program development and further analysis of its effect on the rate of ACL injuries in a younger, active population. CAIPP’s mission is to decrease the number of younger individuals sustaining ACL injuries, in the hopes of affecting the overall number of individuals developing knee osteoarthritis later in life.

Resources

1. Zhang Y, Jordan JM. Epidemiology of osteoarthritis. Clin Geriatr Med. 2010 Aug;26(3):355-69. PubMed PMID: 20699159; PubMed Central PMCID: PMC2920533.

2. Centers for Disease Control and Prevention. Osteoarthritis. 2014. Assessed September 11, 2014, from http://www.cdc.gov/arthritis/basics/osteoarthritis.htm.

3. PubMed Health. Osteoarthritis. 2013. Retrieved from http://www.ncbi.nlm.nih.gov/ pubmedhealth/PMH0001460/.

4. Lohmander LS, Englund PM, Dahl LL, Roos EM. The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis. Am J Sports Med. 2007 Oct;35(10):1756-69. PubMed PMID: 17761605.

5. Centers for Disease Control and Prevention. Arthritis Related Statistics. 2014. Retrieved 11 September 2014, from http://www.cdc.gov/arthritis/data\_statistics/arthritis\_ related\_stats.htm.

6. Nelson AE, Renner JB, Schwartz TA, Kraus VB, Helmick CG, Jordan JM. Differences in multijoint radiographic osteoarthritis phenotypes among African Americans and Caucasians: the Johnston County Osteoarthritis project. Arthritis Rheum. 2011 Dec;63(12):3843-52. PubMed PMID: 22020742; PubMed Central PMCID: PMC3227756.

7. Dharamsi, A., & LaBella, C. Prevention of ACL Injuries in Adolescent Female Athletes. Contemporary Pediatrics. 2014. Accessed September 11, 2014, from http://contemporarypediatrics.modernmedicine.com/contemporary-pediatrics/news/prevention-acl-injuries-adolescent-female-athletes.

8. Mandelbaum BR, Silvers HJ, Watanabe DS. et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. Am J Sports Med*.* 2005;33(7):1003–1010.

9. Lawrence RC, Felson DT, Helmick CG, Arnold LM, Choi H, Deyo RA, Gabriel S, Hirsch R, Hochberg MC, Hunder GG, Jordan JM, Katz JN, Kremers HM, Wolfe F, National Arthritis Data Workgroup. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States Part II. Arthritis Rheum. 2008 Jan;58(1):26-35. PubMed PMID: 18163497; PubMed Central PMCID: PMC3266664.

10. Centers for Disease Control and Prevention. CDC - Arthritis - State Programs. 2014. Retrieved 11 September 2014, from http://www.cdc.gov/arthritis/state\_programs. htm.

11. Claes S, Hermie L, Verdonk R, Bellemans J, Verdonk P. Is osteoarthritis an inevitable consequence of anterior cruciate ligament reconstruction? A meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2013 Sep;21(9):1967-76. PubMed PMID: 23100047.

12. Struewer J, Frangen TM, Ishaque B, Bliemel C, Efe T, Ruchholtz S, Ziring E. Knee function and prevalence of osteoarthritis after isolated anterior cruciate ligament reconstruction using bone-patellar tendon-bone graft: long-term follow-up. Int Orthop. 2012 Jan;36(1):171-7. PubMed PMID: 21898038; PubMed Central PMCID: PMC3251675.

13. Labella CR, Hennrikus W, Hewett TE, COUNCIL ON SPORTS MEDICINE AND FITNESS, and SECTION ON ORTHOPAEDICS. Anterior Cruciate Ligament Injuries: Diagnosis, Treatment, and Prevention. Pediatrics. 2014 Apr 28;PubMed PMID: 24777218.

14. Micheli LJ, Metzl JD, Di Canzio J, Zurakowski D. Anterior cruciate ligament reconstructive surgery in adolescent soccer and basketball players. Clin J Sport Med. 1999;9(3):138-141.

15. Caine D, Caine C, Maffulli N. Incidence and distribution of pediatric sport-related injuries. Clin J Sport Med. 2006;16(6):500-513.

16. Comstock RD, Collins CL, Corlette JD, Fletcher EN; Center for Injury Research and Policy of The Research Institute at Nationwide Children’s Hospital. National high-school sports-related injury surveillance study, United States, 2007-2008 school year; 2011-2012 school year. http://www.nationwidechildrens.org/cirp-rio-study-reports. Accessed September 11, 2014.

17. Miller KE, Sabo DF, Farrell MP, Barnes GM, Melnick MJ. Sports, sexual behavior, contraceptive use, and pregnancy among female and male high school students: testing cultural resource theory. Sociol Sport J. 1999;16(4):366-387.

18. King AC, Tribble DL. The role of exercise in weight regulation in nonathletes. Sports Med*.* 1991;11(5):331-349.

19. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic achievement: project SPARK. Res Q Exerc Sport*.* 1999;70(2):127-134.

20. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR; American College of Sports Medicine. American College of Sports Medicine position stand: physical activity and bone health. Med Sci Sports Exerc*.* 2004;36(11):1985-1996.

21. Dishman RK, Hales DP, Pfeiffer KA, et al. Physical self-concept and self-esteem mediate cross-sectional relations of physical activity and sport participation with depression symptoms among adolescent girls. Health Psychol*.* 2006;25(3):396-407.

22. CASL. 40th Anniversary. 2014. Accessed September 11, 2014, from http://www.caslnc.com/About/40th-Anniversary.

23. McLeroy KR, Bibeau D, Stecker A, Glanz K. An Ecological Perspective on Health Promotion Programs. *Health Education Quarterly* 1988;15(4): 351-377.

24. Sallis JF, Owen N, Fisher EB. (2008). Ecological Models of Health Behavior. In Glanz, Rimer, Viswanath (Eds.), Health Behavior and Health Education: Theory, Research, and Practice (pp. 465-485). Indianapolis: Jossey-Bass.

25. APTA. (2014). PTs: Appropriate Exercise Can Help Prevent ACL Injuries in Females. Assessed September 11, 2014, from http://www.apta.org/Media/ Releases/Consumer/2008/9/25/.

26. Guide to Physical Therapy Practice. Joint Intergrity and Mobility. 2014. Retrieved 11 September 2014, from http://guidetoptpractice.apta.org/content/1/SEC16.body.

27. [Anterior Cruciate Ligament Injury (ACL). *Department of Orthopaedic Surgery*. Retrieved October 16, 2014, from http://orthosurg.ucsf.edu/patient-care/divisions/sports-medicine/conditions/knee/anterior-cruciate-ligament-injury-acl/](Anterior%20Cruciate%20Ligament%20Injury%20%28ACL%29.%20Department%20of%20Orthopaedic%20Surgery.%20Retrieved%20October%2016%2C%202014%2C%20from%20http%3A//orthosurg.ucsf.edu/patient-care/divisions/sports-medicine/conditions/knee/anterior-cruciate-ligament-injury-acl/).

28. Comstock RD, Collins CL, Currie DW. National High School Sports-Related Injury Surveillance Study: 2012-2013 School Year. High School RIO. 2013. Retrieved October 18, 2014 from http://www.ucdenver.edu/academics/colleges/PublicHealth/ research/ResearchProjects /piper/projects/RIO/Pages/Study-Reports.aspx.

29. Shea KG, Grimm NL, Ewing CK, Aoki SK. Youth sports anterior cruciate ligament and knee injury epidemiology: who is getting injured? In what sports? When?. Clin Sports Med. 2011 Oct;30(4):691-706. PubMed PMID: 22018311.

30. Cimino F, Volk BS, Setter D. Anterior cruciate ligament injury: diagnosis, management, and prevention. Am Fam Physician. 2010 Oct 15;82(8):917-22. PubMed PMID: 20949884.

31. Joy EA, Taylor JR, Novak MA, Chen M, Fink BP, Porucznik CA. Factors influencing the implementation of anterior cruciate ligament injury prevention strategies by girls soccer coaches. *J Strength Cond Res*. 2013;27(8):2263-2269. doi: 10.1519/JSC.0b013e31827ef12e.

32. Alentorn-Geli E, Myer GD, Silvers HJ, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. part 2: A review of prevention programs aimed to modify risk factors and to reduce injury rates. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(8):859-879. doi: 10.1007/s00167-009-0823-z [doi].

33. Paszkewicz J, Webb T, Waters B, Welch McCarty C, Van Lunen B. The effectiveness of injury-prevention programs in reducing the incidence of anterior cruciate ligament sprains in adolescent athletes. *J Sport Rehabil*. 2012;21(4):371-377. doi: 2011-0046 [pii].

34. Stojanovic MD, Ostojic SM. Preventing ACL injuries in team-sport athletes: A systematic review of training interventions. *Res Sports Med*. 2012;20(3-4):223-238. doi: 10.1080/15438627.2012.680988 [doi].

35. Wingfield K. Neuromuscular training to prevent knee injuries in adolescent female soccer players. *Clin J Sport Med*. 2013;23(5):407-408. doi: 10.1097/01.jsm. 0000433153.51313.6b [doi].

36. Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W, Georgoulis T, Hewett TE, Johnson R, Krosshaug T, Mandelbaum B, Micheli L, Myklebust G, Roos E, Roos H, Schamasch P, Shultz S, Werner S, Wojtys E, Engebretsen L (2008) Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. Br J Sports Med 42:394–412.

37. Meunier A, Odensten M, Good L. Long-term results after primary repair or non-surgical treatment of anterior cruciate ligament rupture: a randomized study with a 15-year follow-up. Scand J Med Sci Sports. 2007;17:230–237.

38. Myklebust G, Bahr R. Return to play guidelines after anterior cruciate ligament surgery. Br J Sports Med. 2005;39:127–131.

39. Bien DP. Rationale and implementation of anterior cruciate ligament injury prevention warm-up programs in female athletes. *J Strength Cond Res*. 2011;25(1):271-285. doi: 10.1519/JSC.0b013e3181fb4a5a.

40. Casey MM, Eime RM, Payne WR, Harvey JT. Using a Socioecological Approach to Examine Participation in Sport and Physical Activity Among Rural Adolescent Girls. *Qualitative Health Research.* 2009; 19(7): 881-893.

41. Markbreiter JG, Sagon BK, Valovich McLeod TC, Welch CE. Clinician Scoring of the Landing Error Scoring System is Reliable to Assess Jump-Landing Movement Patterns. J Sport Rehabil. 2014 Sep 8;PubMed PMID: 25203628.

42. Sutton B. Modified Landing Error Scoring System and Noncontact ACL Injury. 2014. http://blog.nasm.org/sports-performance/modified-landing-error-scoring-system-less-acl-injury/#more-1909.

43. CDC. (1999). Framework for program evaluation in public health. *MMWR*. 48:1-40.