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| **CRITICALLY APPRAISED TOPIC** |

**FOCUSED CLINICAL QUESTION**

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| For high school and/or collegiate female soccer players does an ACL prevention program reduce the incidence of ACL tears compared to not participating in an ACL prevention program? |

**AUTHOR**

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**CLINICAL SCENARIO**

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| In my first outpatient ortho clinical rotation we had a high school female soccer player rehabbing s/p ACL reconstruction. She, nor was her school, involved with any sort of ACL prevention program or warm-up routine. I am aware of these ACL prevention programs and was going to assist in leading one but it was cancelled. I know that some of the major soccer clubs and international teams in Europe participate in similar warm-ups and I was interested at how effective they are at preventing ACL tears. If programs such as these are beneficial at preventing injury in practice and games then sufficient evidence should be presented to high schools and college teams to implement prevention programs in their practice and game day warm-up routine. |

**SUMMARY OF SEARCH**

[Best evidence appraised and key findings]

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| * ACL prevention programs can significantly reduce the incidence and injury rate of ACL injuries among the female high school and collegiate soccer players.
* The best ACL prevention programs are multicomponent and focus on plyometrics, strengthening, dynamic stabilization, sport-specific agility drills, and education feedback on technique.
* It is recommended to begin a prevention program during the preseason, preferably 6 weeks before the season, and continue the program throughout the season 1 -2 times a week.
* Key points for future research include more high-quality randomized control trials with consistent component design.
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**CLINICAL BOTTOM LINE**

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| Current literature supports favourable evidence that an ACL prevention program implemented in the pre-season and season focused on neuromuscular components (plyometrics, strength, soccer-spefici agility drills, and dynamic stabilization) can reduce the incidence and injury rate of ACL injuries in female high school and collegiate soccer athletes.  |

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| ***This critically appraised topic has been individually prepared as part of a course requirement and has been peer-reviewed by one other independent course instructor*** |

**SEARCH STRATEGY**

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| **Terms used to guide the search strategy** |
| **P**atient/Client Group | **I**ntervention (or Assessment) | **C**omparison | **O**utcome(s) |
| Soccer playerFemaleAthleteCollege High schoolAdolescent Young adultSports | ACLPrevention ProgramWarm-upWarm upTrain\*Exercise |  | ACLInjuryRupture Tear |

**Final search strategy:**

PubMed:

1. (soccer OR football) AND athlete
2. high school OR collegiate OR varsity AND sport\*
3. ACL OR anterior cruciate ligament OR Injury OR tear OR rupture
4. prevention OR program OR warm-up OR warm up OR train\* OR exercise OR neuromuscular
5. #1 AND #2 AND #3 AND #4 - - 824 results
6. #5 applied Filters: Publication dates: 2000 – 2015; Humans; English; female; young adult (19-24 years) AND child (birth – 18 years) - - 175 results

#6 applied NOT (concussion OR head OR middle) 107 results

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| **Databases and Sites Searched** | **Number of results** | **Limits applied, revised number of results (if applicable)** |
| **PubMed****CINAHL** **PEDro****Cochrane Library** | **107****41****3****1** | **Filtered: publication date 2000-2015, female, English, age (child and young adult - - 15 results** |

## INCLUSION and EXCLUSION CRITERIA

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| **Inclusion Criteria** |
| * Randomized Control Trials, Controlled Trials, uncontrolled trials
* Published up to September 2015
* A protocol that included an ACL prevention program
* Studied a population of high school of collegiate soccer players
* Measured incidence rate after intervention
* Published in English
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| **Exclusion Criteria** |
| * Abstracts
* Letters to editors
* Dissertations
* Narrative review articles
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**RESULTS OF SEARCH**

**Summary of articles retrieved that met inclusion and exclusion criteria**

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| **Author (Year)** | **Study quality score** | **Level of Evidence** | **Study design** |
| **Gilchrist 20081** | **PEDro score: 4/10** | **1b** | **Cluster Randomized Control Trial** |
| **Heidt 20002** | **PEDro score: 4/10** | **1b** | **Cluster Randomized Control Trial**  |
| **Kiani 20103** | **Downs and Black Checklist: 19/29** | **2b** | **Cluster, cohort, prospective, Non-randomized** |
| **LaBella 20114** | **PEDro score: 7/11** | **1b** | **Cluster Randomized Control Trial** |
| **Mandelbaum 20055** | **Downs and Black Checklist: 18/29**  | **2b** | **Prospective Non-randomized Cohort** |
| **Michaelidis and Koumantakis 20146** | **AMSTAR score: 8/11** | **1b** | **Systematic Review** |
| **Söderman 20007** | **PEDro score: 4/10** | **1b** | **Prospective Cluster Randomized Control Trial** |
| **Steffen 20088** | **PEDro score: 7/10** | **1b** | **Cluster randomized Control Trial** |
| **Waldén 20129** | **PEDro score: 7/10** | **1b** | **Cluster Randomized Control Trial** |
| **Yoo 201010** | **AMSTAR score: 9/11** | **1b** | **Meta-Analysis** |

**BEST EVIDENCE**

The following 3 studies were identified as the ‘best’ evidence and selected for critical appraisal. Reasons for selecting these studies were:

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| * **Michaelidis and Koumantakis** **2014:**  This systematic review was chosen because of its high quality and inclusion of female only prevention program programs. There is a separate section in this review that focuses on soccer prevention programs for my targeted female population. Most of the articles included in this section are RCT’s that I found on my own search.
* **Yoo 2010:** I chose Yoo 2010 because it was a high quality Meta-analysis of neuromuscular training to prevent ACL injuries in female athletes for a variety of sports. Although it includes female athletes from other sports, soccer is the sport included in the majority of the articles.
* **Gilchrist 2008:** I chose this RCT because it is exactly what my PICO question is looking to answer. It is a RCT (high level of evidence) to prevent Noncontact ACL injury in female collegiate soccer players. The study investigates the efficacy of a prevention program performed 3 times a week on 61 NCAA Division 1 female soccer teams.
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**SUMMARY OF BEST EVIDENCE**

**(1) Description and appraisal of “Effects of knee injury primary prevention programs on anterior cruciate ligament injury rates in female athletes in different sports: A systematic review” by Michaelidis and Koumantakis 2014.**

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| **Aim/Objective of the Study/Systematic Review:** |
| The objective of this study was to use a systematic review approach to assess the effectiveness and success of ACL injury prevention programs on injury rates in female athletes between different sports. The study also aimed to analyse the content and method of delivery of successful programs.  |
| **Study Design** |
| The study is a systematic review of 13 randomized and non-randomized controlled studies.**Search Strategy:** This systematic review was conducted in September 2012 using the following electronic databases: Pubmed Central, Science Direct, CINAHL, PEDro, Cochrane Library, SCOPUS, and SPORTDiscus. The search was filtered for studies in the English language, from the earliest records available, and for human subjects. Key words were: anterior cruciate ligament, ACL, knee joint, knee injuries, female, athletes, neuromuscular, training, and prevention. In addition, sport injury textbooks were hand searched. **Selection Criteria:** Articles had to meet three inclusion criteria: (1) ACL injury prevention training program for female athletes; (2) Athlete-exposure data, expressed in hours; and (3) effect of training on incidence rates for female athletes. Studies were excluded if the prevention programs were tested on males only, only used video awareness or cognitive training techniques, or focused on neuromuscular training following ACL reconstruction. **Methodological Quality Evaluation:** Two reviewers independently evaluated the randomized control trial studies included in this systematic review with the PEDro scale. Studies rated 8/10 or higher were considered excellent quality, 5-7/10 were considered good quality, and studies rated 4/10 or below were considered poor quality. Seven of the 13 studies were rated on the PEDro scale resulting in 1 study of excellent quality, 4 studies of good quality, and 2 studies of poor quality. **Data Extraction**: Data from the chosen articles were:1. Sport, age, level and number of athletes tested
2. Number of ACL injuries; categorized as non-contact or contact
3. The program training components (plyometrics, strength, balance, etc…) and duration
4. ACL injury incidence rates in terms of athlete exposures
5. Compliance level

**Meta-analysis:** ACL injuries per 1000 hours of exposure were calculated for each study. The authors calculated the between-group injury rate significance in the studies that had multiple sport populations. The Chi-square test was utilized through the IBM SPSS Statistics program (version 19) to obtain the number of non-contact ACL injuries and the athlete-exposure for each sport separately.  |
| **Setting** |
| * Female sport programs in a variety of different cities
* Sport settings included: soccer, floorball, basketball, handball, and volleyball
* Level of sport included competitive organized high school, collegiate and other levels.
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| **Participants** |
| This meta-analysis of 13 studies yielded a total sample size of 22,052 female athletes, with 9,9897 in the trained group (received an ACL prevention program) and 12,155 in the untrained group (did not participate in a prevention program). The sports (number of articles) included in this analysis were soccer (9), floorball (1), basketball (2), handball (3), and volleyball (2). A couple of the studies used a mixed population. For these studies sport specific data was separated. Overall, female soccer players represented the majority of athletes involved in this study, with 9 out of the 13 articles focused on soccer players. The majority of athletes’ age ranged from 14 – 26 years of old and athletes were described as elite or non-elite.  |
| **Intervention Investigated** |
| *Control* |
| Female athletes who did not participate in an ACL prevention program at any point during the pre-season or season.  |
| *Experimental* |
| Female athletes who performed an ACL-prevention program during the pre-season, in-season, or combination of both. Prevention program components varied between studies and included training in plyometrics, strengthening, agility, and/or balance.  |
| **Outcome Measures** (Primary and Secondary) |
| **Primary Outcome Measure:*** **Injury** **Rate**: The main outcome measure in this study was the ACL injury rate described as “ACL knee Injuries per 1000 hours of exposure”. One athlete-exposure was equivalent to 1 practice or game. Injury rates from the control groups and experimental groups were compared and a “between-group significance” was calculated.

**Secondary Outcome Measure:*** **Program Components:** Successful Prevention Programs were further analysed to identify training components, volume, sport-specific drills, training environment, and feedback on performance.
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| **Main Findings** |
| * This systematic review provided the following sport specific results on ACL Prevention Programs
* Statistical significance between injury rates of experimental and control groups was defined as a p-value < 0.05

*Soccer*: * 3 successful programs with statistically significant less ACL injuries between groups:

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| Authors | Injury Rate: Experimental | Injury Rate Control | P-value |
| Mandelbaum et al. 2005 | 0.04 | 0.67 | P < 0.0001 |
| Kiani et al. 2010 | 0.0 | 0.08 | P = 0.025 |
| Waldén et al. 2012 | 0.05 | 0.11 | P = 0.02 |

* 6 studies did not produce statistically significant less ACL injuries between groups:

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| Authors | Injury Rate: Experimental | Injury Rate Control | P-value |
| Steffen et al. 2008 | 0.06 | 0.08 | P = 0.73 |
| Pfeiffer et al. 2006 | 0.0 | 0.05 | P = 0.43 |
| Heidt et al. 2000 | 0.13 | 0.16 | P > 0.05 |
| Söderman et al. 2000 | 0.49 | 0.11 | P > 0.05 |
| Gilchrist et al. 2008 | 0.20 | 0.34 | P = 0.198 |
| Hewett et al. 1999 | 0.0 | 0.11 | P = 0.32 |

*Handball*:* Only one study, Myklebust et al. 2003, of three studies on handball athletes provided statistically significant results.
* Specifically, only for compliant athletes from an elite division.

*Floorball*:* The only study that focused on floorball did not produce significant results and was not effective in reducing the injury rate of ACL injuries.

*Basketball*:* Both programs that focused on basketball athletes were unsuccessful in significantly reducing ACL injuries

*Volleyball*:* There were no reported ACL injuries in the two prevention studies on volleyball athletes in either the experimental or control group.

**Program components:*** The Prevent Injury and Enhance Performance (PEP), the Harmoknee Preventive Training program (HPT) and the WALDEN training program were found to be successful in soccer athletes.
* All three programs were multicomponent oriented to include: strengthening, stretching, plyometrics, agility training, dynamic stabilization, education, and sport-specific drill in a field environment.
* The HPT and the WALDEN incorporated core stability and balance training as well.
* Strength training utilized body weight exercises focused on trunk, upper, and lower body muscles.
* Education included feedback on correct technique
* All three successful programs were 20-25 minutes long per session
* It is recommended to begin an ACL prevention program in the pre-season (at east 6 weeks) and continue throughout the season (1-2 times per week).
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| **Original Authors’ Conclusions** |
| This systematic review concluded that in order for an ACL injury prevention program to be successful it should start in the preseason (about 6 weeks before the season) and continue in-season with a frequency of about 1 – 2 days a week. Training components should focus on strengthening, plyometrics, balance, proprioception, and the athletes should be provided with feedback on correct technique. Soccer and handball athletes should emphasize sport-specific agility drills. It is recommended that jumping sports, such as basketball, should include high intensity plyometrics with appropriate feedback for sport-specific biomechanics.  |
| **Critical Appraisal** |
| **Validity** |
| I calculated an AMSTAR score of 8/11 for this systematic review, which indicates good methodological strength and quality. A strength of this review was that more than half (7/13) were randomized control trials (RCT). Each RCT was scored for methodological quality with the PEDro scale (a valid and reliable scale) yielding 1 study of excellent quality, 4 studies of good quality, and 2 studies of poor quality. Rating the RCTs and providing the score of the eligible studies is a strength to this review however, there was only one good quality RCT that was found to be effective while the other successful studies were non-RCT’s. Having two different authors independently and separately review, rate, and perform necessary calculations is a strength, as opposed to a single reviewer. Another strength of this study was that the authors performed a thorough systematic literature search of electronic databases including: Pubmed Central, Science Direct, CINAHL, PEDro, Cochrane Library, SCOPUS, and SPORTSDiscus.An additional source of sport injury textbooks was also performed. The search strategy was conducted and reported in a manner to allow the reader to replicate the review. Specific articles that were excluded from the review were noted and explained as to why they were excluded from this study. The authors provided good discussion with identifying bias among the included studies. For example, the authors mention possible biased results in the successful Mandelbaum et al 2005 study because the subjects were not randomized (selection bias) and that the participants voluntarily enrolled into the intervention program (motivation bias). The authors also discuss every article in detail with relevant findings for its respected sport of interest. A limitation of this review is the exclusion of articles based on the outcome measure (ACL injuries per 1000 hours of exposures) used to assess the effects of the training program. The authors identified low compliance rates that negatively influence the results among the selected studies. It is recommended that higher methodological quality randomized control trials be conducted on a variety of female sporting populations to further validate the effectiveness of an ACL prevention program.  |
| **Interpretation of Results** |
| This systematic review identified scientific support of successful ACL prevention programs for female soccer athletes. It also broke down the components of training to guide the development of future prevention programs. Although not all of the studies that focused on soccer athletes provided statistically significant differences between injury rates, most studies did see a reduction in ACL injuries in those who completed a prevention program. When designing an ACL prevention program for female soccer players it is important to focus on core, upper and lower extremity strengthening, plyometric exercises, dynamic stabilization, and soccer-specific drills. There should also be adequate feedback provided for proper technique. Prevention programs should begin early enough before the season to allow neuromuscular changes/improvement. For best results, it is suggested to begin 6 weeks before the season and to continue the program exercises 1-2 days a week during the season.  |

**(2) Description and appraisal of “A meta-analysis of the effect of neuromuscular training on the prevention of the anterior cruciate ligament injury in female athletes” by Jae Ho Yoo et al. 2010**

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| **Aim/Objective of the Study/Systematic Review:** |
| The objective of this study was to use a meta-analysis approach to evaluate the effectiveness of ACL prevention programs for female athletes. The study also aimed to identify the essential components of the different prevention training (plyometric, strength, agility, or balance). The data was further analysed according to age, sport, and period of training (preseason, in season, or combination). |
| **Study Design** |
| The study is a meta-analysis of 7 randomized controlled trials (RCT) or prospective cohort studies.**Search Strategy:** A Medline literature search was conducted of relevant articles before June 2007. Key words were: knee injury, ACL injury, gender difference, injury prevention, neuromuscular training, plyometrics, strengthening training, and balance training. The Cochrane Database, additional web-based searches, proceedings from the American Academy of Orthopaedic Surgeons and textbooks, and manual searches of Journals. Also, experts in ACL injury prevention training were contacted for any additional articles missed in the search.**Selection Criteria:** An evaluation committee of three orthopaedic surgeons and one biomechanical researcher, all with experience with ACL care, conducted the search and selected the eligible articles. Only RCTs and prospective cohort studies were included in the meta-analysis. **Data Collection**: Studies chosen were required to be intention to treat analysis. Data from the chosen articles were distinguished as one of two groups: female athletes trained in an ACL prevention program and female athletes who were untrained. Subgroups of age, sport, training time, and program components were formed and analysed from all the studies. Age was divided into two groups: females less than 18 years of age and females 18 years of age or older. Soccer and handball were the two sports included in the analysis. Training times were separated as pre-season, in-season, or a combination of both. Biomechanical components of the preventive program were plyometrics, strengthening, and balancing exercises. **Meta-analysis:** Odds ratios (OR) and 95% confidence intervals (CI) were calculated for each study and analysed by the Mantel-Haenszel common OR estimate. Subgroup analysis was also performed in the same manner using ORs and 95% CI. The authors used the chi-square test to determine heterogeneity between the studies. Lastly, publication bias was assessed with the Egger regression asymmetry test and the Begg and Mazumdar adjusted rank correlation test.  |
| **Setting** |
| * Female sport programs in a variety of different cities
* Level of sport included competitive organized high school and college athletics.
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| **Participants** |
| This meta-analysis of 7 studies yielded a total sample size of 10,618 female athletes, with 4,033 in the trained group (received an ACL prevention program) and 6,585 in the untrained group (did not participate in a prevention program). The sports included in this analysis were soccer, volleyball, basketball, and handball. Female soccer players represented the majority of athletes involved in this study, with 5 out of the 7 articles specific to soccer. The majority of athletes’ age ranged from 14 – 26 years of old. The two handball studies had age ranges of 16 – adult (~35).  |
| **Intervention Investigated** |
| *Control* |
| Female athletes described as “untrained”. These athletes did not participate in an ACL prevention program at any point during the pre-season or season.  |
| *Experimental* |
| Female athletes described as “trained”. These athletes performed an ACL-prevention program during the pre-season, in-season, or combination of both. Prevention program components varied between studies and included training in plyometrics, strengthening, agility, and/or balance.  |
| **Outcome Measures** (Primary and Secondary) |
| **Primary Outcome:** * **Odds Ratio (OR):** Describes the proportion of ACL injuries among trained athletes divided by the proportion of ACL injuries among untrained athletes. An OR less than one is indicative of favourable results for the trained athletes. In other words, trained athletes would have a lower risk of being injured. An OR closer to 1 means there is no effect of the prevention program. Odds Ratio greater than 1 would indicate the trained athletes are at higher risk for ACL injury.

**Secondary Outcome:*** **Number of Injured or Uninjured Athletes:** This measurement was analysed for both the trained and untrained groups, among the data in whole, and for the different subgroups.
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| **Main Findings** |
| * **Pooled Data:**
* This meta-analysis calculated an overall odds ratio of .40 and a 95% CI of [0.27, 0.60] in the fixed model indicating the effectiveness of an ACL preventing program.
* **Subgroup Analyses:**
* Subgroups favorable for decreasing the probability of suffering an ACL injury:
* Athletes age 18 or younger: OR = 0.27 [0.14, 0.49]
* Soccer athletes: OR = 0.32 [0.19, 0.56])
* Handball athletes: OR = 0.54 [0.30, 0.97]
* In-season training: OR = 0.32 [0.17, 0.59]
* Combination of pre-season and in-season: OR = 0.54 [0.30, 0.97]
* Plyometric exercise: OR = 0.37 [0.24, 0.55]
* Strengthening exercise: OR = 0.21 [0.11, 0.43]
* Subgroups that do not significantly decrease the probability of suffering an ACL injury:
	+ Adult population: OR = adult 0.78 [0.23, 2.64]
	+ Pre-season training: OR = 0.35 [0.1, 1.21]
	+ Balancing exercise: OR = 0.63 [0.37, 1.09]
* **Publication Bias:**
* The Egger test revealed a *P*-value of 0.64
* The Begg’s test scored a *P*-value of 0.37
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| **Original Authors’ Conclusions** |
| This meta-analysis concluded that ACL injuries could be reduced in female athletes through the adherence of a neuromuscular prevention program. In other words, neuromuscular ACL prevention programs are effective at preventing ACL injuries in female athletes. Specifically, the study found that athletes under the age of 18 years and those who play soccer will benefit most from an ACL prevention program. The authors also concluded that prevention programs that focus on plyometric and strengthening exercises are most beneficial, whereas balancing exercises are not.  |
| **Critical Appraisal** |
| **Validity** |
| I calculated a total score of 9/11 on the AMSTAR, which indicates strong validity and quality. A strength of this meta-analysis was that it limited the eligible studies to only include randomized control trials and prospective cohort studies. Another strength was to ensure that all studies included were using an intention to treat analysis as to provide more “real life” results. There were 4 different experts conducting the literature review and they used a comprehensive method of Medline search, Cochrane Database, journals, additional web searches and proceedings of the American Academy of Orthopaedic Surgeons. Although the selection committee graded each study’s quality, it was performed in a non-validated manner. This study also failed to represent the quality results of each study. Overall, based on the information provided, the search methods, selection, and appraisal of articles was performed in a manner that would be difficult to replicate. There was a complete detail representation of each article with appropriate outcome measures of odds ratios and number of injuries among trained/untrained athletes. The authors also provide the reader with information regarding publication bias to defend its findings. |
| **Interpretation of Results** |
| This meta-analysis supports and defends the efficacy of using an ACL prevention programs to prevent and reduce the incidence of ACL injuries among female athletes. This study also explores different subgroups and identifies which population will benefit most from participating in an ACL injury prevention program. It identifies that female athletes 18 years or younger have approximately a 75% lower risk of suffering an ACL injury if they adhere to a neuromuscular ACL prevention program. In particular, female soccer athletes were found to have the best prevention results. This analysis also investigated what type of training yields the best results. It found that a prevention program focused on plyometric and strength training was most effective, whereas balance training was ineffective at reducing the risk for an ACL injury. Overall, this meta-analysis provides healthcare providers with evidence that ACL prevention programs are effective at preventing ACL injuries among female athletes.  |

**(3) Description and appraisal of “A Randomized Controlled Trial to Prevent Noncontact Anterior Cruciate Ligament Injury in Female Collegiate Soccer Players“ by Gilchrist et al. 2008.**

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| **Aim/Objective of the Study/Systematic Review:** |
| The objective of this randomized control trial was to assess the efficacy of an alternative warm-up called the Prevent injury and Enhance Performance (PEP) at reducing ACL injuries, specifically noncontact injuries, among NCAA Division I female soccer athletes.  |
| **Study Design** |
| **Eligible Criteria**: Eligible teams for this study were 273 NCAA Division I women’s soccer teams. Fourteen teams were ineligible due to participation in a previous pilot study. Eligible teams were required to have a certified athletic training staff with appropriate time and equipment to supervise each training session and complete reporting needs of the study.**Allocation**: Teams whose coach, Athletic trainer (ATC), and athletic director agreed to participate in the study were randomized into either the intervention or control group. **Intervention Overview**: After randomization, each team’s ATC informed the athletes of an overview of the study and then collected consent forms and pre-participation questionnaires on demographic factors. Interventions teams received a manual instructions and a videotape of the PEP warm-up. Intervention teams were asked to complete the PEP warm-up 3 times per week during the regular season. Control teams performed their usual normal warm-up and received the intervention materials at the end of the season after all data was collected. **Data Collection**: The ATCs of each team reported weekly participation in games and practices (athletic exposures, AEs) and any knee injuries. Weekly compliance among the intervention teams was also reported by the ATCs. ACL injuries were counted only if confirmed by MRI, arthroscopy, or direct visualization at the time of repair. Intervention and control teams were paired by proximity and clustered geographically by region (Northeast, South, Midwest, and West). **Implementation Fidelity**: One pair from each region (13% of teams) was randomly selected to be observed for proper implementation and comparison of similar drills among the control groups. Drills or exercises performed by control groups were reported as the same drill or similar to components of the PEP Program. Staff from this study observed the quality of the exercises being performed by the athletes undergoing the PEP Program with a standardized observational instrument scale. **Statistical Methods and Data Analysis:** All extracted data was entered into an Access database and analysed using SAS version 8.2. An as treated analysis was conducted as opposed to an intent-to-treat analysis. This study was primarily concerned with the efficacy of the program rather than the effectiveness. Intervention teams were excluded from the analyses if they did not complete 12 or more sessions. Statistical tests utilized a *z* statistic for rate ratios using Kish’s formula for the variance of the ratio. A p-value of less than 0.05 was considered significant. The authors who developed and designed the PEP Program did not participate in data collection or analysis.  |
| **Setting** |
| The study was conducted among NCAA Division I women’s soccer teams in the United States of America. Teams were clustered into geographical regions of Northeast, South, Midwest and West. |
| **Participants** |
| A total of 273 NCAA teams were eligible for participation in this study. In the summer and fall before the season, the coaches and certified athletic trainers of all 273 eligible teams were invited to participate. A total of 61 Division I women soccer teams completed the study, with 35 control teams and 26 intervention teams. A total of 1435 female athletes participated in the study, with 852 control athletes and 583 experimental/intervention athletes. Eight intervention teams were excluded from data analysis due to low compliance with the PEP Program (performed less than 12 sessions). There were no significant differences of subject demographics (average years in college, age, height, weight, BMI, history of ACL injury) between the intervention teams and the control teams. The average age for both groups was 19.88 years old.  |
| **Intervention Investigated** |
| *Control* |
| * Control teams did not participate in the PEP warm-up ACL prevention program.
* Control teams carried out their normal and customary warm-up.
* Control teams were given all intervention materials (videotapes and manual instructions) at the end of the season and completion of all data collection.
 |
| *Experimental* |
| * Intervention teams participated in the alternative warm-up called Prevent Injury and Enhance Performance (PEP) Program.
* Teams were instructed to perform the warm-up 3 times a week throughout the regular season (12 weeks in total).
* The PEP program consists of 19 components and can be completed in 30 minutes. This multicomponent program includes the following basic exercises:
* Warm-up: jog line to line, shuttle run, backward running,
* Stretching: calf, quadriceps, figure 4 hamstring, inner thigh, hip flexor
* Strengthening: walking lunges, Russian hamstring, single toe raises
* Plyometrics: lateral hops, forward/backward, and single leg hops over cones; vertical jumps with headers, scissors jump
* Soccer-specific agility exercises: shuttle run, diagonal runs, bounding run
* Additionally, athletes were taught to avoid high-risk positions as demonstrated on a video.
* The program emphasizes correct technique and the coaches/ATCs provided feedback on technique to all the athletes.
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| **Outcome Measures** (Primary and Secondary) |
| **Primary Outcome Measure:*** **Injury** **Rate**: The main outcome measure in this study was the ACL injury rate described as ACL knee Injuries per 1000 hours of athletic exposures. One athlete-exposure was equivalent to 1 practice or game. Injury rates from the control groups and experimental groups were compared and a “between-group significance” was calculated. ACL injuries were defined by injuries confirmed by MRI, arthroscopy, or direct visualization at the time of repair.

**Secondary Outcome Measure:*** **All knee injuries:** Described as any injury to the knee that occurred during a game, practice, or conditioning activity that required medical care by ATC or physician and caused the athlete to miss at least on day of training.
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| **Main Findings** |
| * Intervention teams, on average, used the PEP Program 25.8 times during the season with a range of 12 to 37 uses,
* Medial Collateral Ligament (MCL) injuries were most common for both groups accounting for about 35% of all knee injuries.
* There was a 41% lower ACL injury rates for the intervention group compared to the control however, the results were not significantly different (p = 0.198)
	+ Intervention: 7 ACL injuries, 0.199 per 1000 AE
	+ Control: 18 ACL injuries, 0.340 per 1000 AE
* There was a 70% decrease in non-contact ACL injuries for the intervention group compared to the control however; the findings were not significant (p = 0.066).
	+ Intervention: 2 non-contact ACL injuries, 0.0057 per 1000 AE
	+ Control: 10 non-contact ACL injuries, 0.189 per 1000 AE
* There was a statistically significant reduction in non-contact ACL injury rate for athletes who reported a history of ACL injury (p = 0.046)
	+ Intervention: 0 injuries
	+ Control: 4 injuries, 0.076 per 1000 AE
* There was a statistically significant reduction in ACL injuries during the last 6 weeks of the season (p = 0.025)
	+ Intervention: 0 injuries
	+ Control: 5 injuries, 0.249 per 1000 AE
* Based off of the on-site observations and coach surveys, control teams did not use strengthening, plyometric training, or agility drills routinely in their on-field practices.
 |
| **Original Authors’ Conclusions** |
| An alternative warm-up program such as the PEP Program may reduce the risk of non-contact ACL injuries among collegiate female soccer players. Although non-significant results were obtained for overall ACL risk, there were significant reductions of ACL injuries in practice and the second half of the season. It was concluded that the PEP Program could be appropriate to incorporate into practice time of college soccer teams without the need of additional resources or special equipment. The PEP Program is appropriate to implement in a team setting and requires little training to deliver. Further research on the effectiveness of the PEP Program is recommended using an intent-to-treat analysis under less controlled circumstances.  |
| **Critical Appraisal** |
| **Validity** |
| This randomized control trial has a calculated PEDro score of 4/10, indicating poor methodological quality. A strength of the study was that the authors who were involved in the design and development of the intervention were not involved in the data collection or analysis. However, the participants and the article does not state whether or not the data collectors were blinded which creates bias in the study. Due to the nature of the intervention it would difficult to blind the subjects. Theoretically, any of the teams (controls) could have incorporated similar exercises and drills into their practices/warm-up, this indicates a lack of ability to control the control group. Observational surveys and end of the season questionnaires help ensure that the control teams did not routinely participate in exercises similar to the PEP Program. Another limitation is report bias. The authors depended on weekly reports from the ATCs as to how many times the team completed the PEP Program and the authors were unable to control the fidelity of the program. Observational surveys suggest that coaches corrected athletes in biomechanical technique however, these observations were only conducted on 13% of the teams and one cannot assume that other or all intervention teams followed suit and did the same. These findings cannot be generalized to collegiate athletes from other divisions or other age groups. There is a higher incidence rate of ACL injuries among female soccer athletes aged 14-18 years old, therefore, Division 1 collegiate soccer athletes may be biomechanically superior than the younger or age-matched population. A pre-study power calculation suggests that a sample of 100 different teams is required for more reliable results. Lastly, the data was analysed in an “as-treated” analysis (per protocol) rather than an intent-to-treat analysis. An intent-to-treat analysis would produce more “real world” results on the effectiveness of the prevention program. Instead, this study was primarily interested in studying the efficacy of the program, or whether the intervention produces a reduction in ACL injuries in ideal circumstances.  |
| **Interpretation of Results** |
| It was concluded that the PEP Program may reduce ACL injuries among a collegiate Division 1 women soccer players. The PEP Program is an alternative warm-up that requires little training and can be implemented into a collegiate team’s practice without expensive equipment or additional resources. Although it was not statistically significant, a 70% reduction in non-contact ACL injuries is a decent result. I found it interesting that the program was more effective in the latter half of the season, or after 6 weeks of implementation. This may have been a sufficient amount of time for the athletes to gain neuromuscular improvements. Also, it should be noted that these Division I athletes may be biomechanically and technically superior compared to a younger population (14-18 years of age) or a lower level of competitive collegiate division (D II or D III). These athletes may already be more appropriately prepared (biomechanically and neuromuscularly) to see significant improvements in neuromuscular adaptions/improvements. It is recommended that future studies should have an intent-to-treat analysis with a larger sample size.  |

**EVIDENCE SYNTHESIS AND IMPLICATIONS**

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| **Implications for clinical practice:**The existing literature suggests that a neuromuscular ACL Prevention Programs can be beneficial and could reduce the risk of suffering an ACL injury among female soccer athletes. Specific components have been identified as most successful. In order for an ACL prevention program to be successful it should include exercises in core and lower extremity strengthening, dynamic stabilization, balance, plyometrics, stretching, educational feedback on technique, and sport-specific agility drills. The literature suggests that programs should begin 6 weeks during preseason and continue throughout the season 1-2 times a week. Younger athletes (14-18) tend to benefit from these programs the most. This is probably due to the lack of initial neuromuscular control and strength. The prevention program will target these weaknesses and improve a younger athletes control more so than a more developed or older soccer player with superior biomechanical properties. There is evidence that a prevention program can be implemented at low cost with no additional resources or equipment. Successful programs are time efficient and only take 20 – 30 minutes to complete. These cheap and efficient characteristics coupled with favourable results promote the implementation of ACL prevention programs for female soccer teams, specifically high school aged teams (14-18 years of age). **Implications for future research:**Based on the evidence reviewed, future research should focus efforts to include higher quality randomized control trials (RCTs). In the systematic review by Michaelidis and Koumantakis 2014 found only 7 out 13 RCTs and of them only 5 were focused on female soccer athletes. Of the 5 RCTs two were rated of poor quality (less than equal to 4/10) on the PEDro scale and the other three were rated good quality (5-7/10). Conducting a high quality randomized control trial is difficult for this particular type of study and intervention due to the demands and challenges between coordination of coaches, athletes, and therapists. However, in order to bulk up the validity of ACL injury prevention programs high-quality RCTs are needed. ACL prevention programs should develop more consistent methodology to decrease the variability of program components. General components of prevention programs have been identified to include strengthening, plyometrics, dynamic stabilization, sport-specific agility drills, and feedback on proper technique. However, the studied articles provide a variety of different programs with inconsistent levels of intensity and duration. Future research should focus on the components of the successful programs to create a more homogeneous body of literature. Future research should also focus on an intent-to-treat analysis to obtain more “real world” circumstantial results of the effectiveness of ACL prevention programs. Although the available literature could benefit from higher quality RCTs and more homogenous methodology there is still favorable evidence to support the efficacy of an ACL prevention program for female soccer athletes. Specifically, younger female soccer players (14-18) would benefit more than a collegiate athlete.  |

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[List all references cited in the CAT]

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