CRITICALLY APPRAISED TOPIC

FOCUSED CLINICAL QUESTION

For a 17-year-old female athlete recovering from an ACL reconstruction, does participation in an ACL injury prevention program, compared to no participation, decrease the risk, rate, and/or incidence of suffering a future ACL injury to either knee?

AUTHOR

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CLINICAL SCENARIO

The patient is a 17-year-old female basketball player who suffered a complete ACL-tear in a game this past winter. She had an ACL reconstruction using a patellar tendon graft.

Nearly 44% of severe injuries to female high school athletes are to the knee.[1] It's been reported that female high school athletes suffer ACL injuries at a rate of 1 per 60-100 athletes, with most leading to surgery.[2,3] These injuries are costly not only to pocketbooks[4], but can adversely affect the athlete's psychology and their ability to return to previous levels of competition.[5–7]

After surgery, these athletes will likely see a physical therapist for a return-to-sport rehabilitation program. In females, the incidence of re-injury to either the contralateral or ipsilateral ACL after returning to athletics is alarmingly high. Paterno et al, reported that ACL re-injury rates for high school athletes following ACL reconstruction are 15 times higher compared to those who have not suffered an ACL injury. For females, this rate is 4 times higher than males.[2] It is clear that the current rehabilitation process is not sufficiently addressing the needs of female athletes who are recovering from ACL injury.

An ACL-injury prevention program that can decrease the rate, risk, and/or incidence of ACL injuries in female athletes would be beneficial in helping the patient return-to-sport.

SUMMARY OF SEARCH

[Best evidence appraised and key findings]

- There is currently no published research reporting the effects of an ACL prevention program on the prevention of subsequent ACL injury following an ACL reconstruction. Therefore, I searched the effects of ACL prevention programs on the rate, risk, or incidence of ACL injury in general. This strategy yielded 17 studies that met my inclusion/exclusion criteria, including nine systematic reviews and meta-analyses, four randomized controlled trials, and four quasi-experimental studies.
- ACL-prevention programs significantly decrease the incidence, risk and rate of ACL injuries in female high school athletes, including basketball players.
- The best ACL-prevention programs are comprehensive and intense, including components of plyometric, strength, agility, and balance exercise. The program appears to have the greatest effect when implemented during the season, or as part of the pre-season and season combined.
- Key points for future research include more randomized controlled trials, more homogenous ACL-prevention programs that reflect proper components, and greater focus on high school female basketball players.

CLINICAL BOTTOM LINE

While there is currently no evidence regarding the prevention of subsequent ACL injury following an ACL reconstructive surgery, the current evidence shows that an ACL prevention program implemented in the pre-season and season focusing on neuromuscular components (plyometric, strength, agility, and balance exercise) can reduce the risk, rate, and/or incidence of ACL injuries in female high school basketball players.

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

Terms used to guide the search strategy			
Patient/Client Group	**I**ntervention (or Assessment)	**C**omparison	**O**utcome(s)
female* adolescent "high school" high-school athlete basketball ACL anterior cruciate ligament reconstruction surgery injury	prevention rehabilitation physical therapy physiotherapy neuromuscular strength plyometric program exercise* training	*Not applicable*	second* repeat subsequent rate risk incidence

Final search strategy:

Show your final search strategy from one of the databases you searched. In the table below, show how many results you got from your search from each database you searched.

For PubMed

1. female*
2. adolescent OR "high school" OR high-school
3. athlete OR basketball
4. ACL OR anterior cruciate ligament
5. reconstruction OR surgery OR injury
6. prevention OR rehabilitation OR physical therapy OR physiotherapy OR neuromuscular OR strength OR plyometric
7. program OR exercis* OR training
8. second* OR repeat OR subsequent
9. rate OR risk OR incidence
10. #1 AND #2 AND #3
11. #4 AND #5 AND #6 AND #7 AND #8
12. #9 AND #10 AND #11
13. #11 AND #12 **(no results found based on PICO question)**
14. #4 AND #5 AND #6 AND #7 **(removed #8)**
15. #9 AND #10 AND #14 AND "adolescent:13-18"[Filter]
16. #9 AND #10 AND #14 AND "female"[Filter]

Databases and Sites Searched	Number of results	Limits applied, revised number of results (if applicable)
PubMed	**76**	**70 – apply filter "adolescents", apply filter "female"**
CINAHL	**349**	**47 – remove apply related words, apply academic journals, apply adolescent: 13-18 years**
Cochrane Library	**3**	
SPORTDiscus	**11**	
PEDro	**2**	**Search: female AND adolescents AND anterior cruciate ligament**

INCLUSION and EXCLUSION CRITERIA

Inclusion Criteria
• Injury reduction expressed in terms of incidence, rate or risk. • Female participants between the ages of 13 and 18 were included in the prevention program. • An ACL prevention program was described by the researchers and employed on the participants.
Exclusion Criteria
• Studies involving males or adults.

RESULTS OF SEARCH

A total of 17 relevant studies were located and categorised as shown in the following table (based on Levels of Evidence, Centre for Evidence Based Medicine, 2011) and (PEDro Scale for randomized controlled trials and the Systematic Reviews: Quality Appraisal Checklist in Jewell, 2015, pp 341-342[8]) quality assessment rating scale.

Summary of articles retrieved that met inclusion and exclusion criteria

Note that this table is arranged differently from the example CAT on Sakai. For each article that meets your inclusion and exclusion criteria, score for methodological quality on an appropriate scale, categorize the level of evidence, and note the study design (e.g., RCT, systematic review, case study). Add more rows as necessary.

Author (Year)	Study quality score	Level of Evidence	Study design
Alentorn-Geli (2009)[9]	**Quality: 1/8** **Applicability: 2/4**	**Level 1b**	**Systematic Review**
Hewett (1999)[10]	**PEDro Score: 3/11**	**Level 2b**	**Prospective, Cluster, non-randomized**
Hewett (2006)[11]	**Quality: 4/8** **Applicability: 2/4**	**Level 1b**	**Meta-analysis**
LaBella (2011)[12]	**PEDro Score: 7/11**	**Level 1b**	**Prospective Cluster RCT**
Mandelbaum (2005)[13]	**PEDro Score: 4/11**	**Level 2b**	**Prospective, Cohort, non-randomized**
Michaelidis (2014)[14]	**Quality: 4/8** **Applicability: 3/4**	**Level 1b**	**Systematic Review**
Kiani (2010)[15]	**PEDro Score: 5/11**	**Level 2b**	**Prospective, Cluster, Cohort, non-randomized**
Noyes (2014)[16]	**Quality: 2/8**	**Level 1b**	**Systematic Review**

	Applicability: 3/4		
Paszkewicz (2012)[17]	**Quality: 5/8 Applicability: 3/4**	**Level 1b**	**Systematic Review**
Olsen (2005)[18]	**PEDro Score: 7/11**	**Level 1b**	**Prospective Cluster RCT**
Pfeiffer (2006)[19]	**PEDro Score: 3/11**	**Level 2b**	**Prospective, Longitudinal, Cohort non-randomized**
Sadoghi (2012)[20]	**Quality: 6/8 Applicability: 2/4**	**Level 1b**	**Systematic Review**
Sugimoto (2012a)[21]	**Quality: 6/8 Applicability: 3/4**	**Level 1b**	**Meta-analysis**
Sugimoto (2012b)[22]	**Quality: 6/8 Applicability: 3/4**	**Level 1b**	**Meta-analysis**
Walden (2012)[23]	**PEDro Score: 6/11**	**Level 1b**	**Prospective Cluster RCT**
Yoo (2010)[24]	**Quality: 7/8 Applicability: 3/4**	**Level 1b**	**Meta-analysis**
Heidt (2000)[25]	**PEDro Score: 6/11**	**Level 1b**	**Prospective Cluster RCT**

BEST EVIDENCE

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

- **Yoo (2010)**[24] – This study is a meta-analysis (level of evidence 1b), that investigated the use of many different ACL prevention protocols on female athletes from a variety of sports, including some studies with basketball players. This included studies on adolescent athletes. It is the highest ranked meta-analysis and included a number of other studies on my list. I felt the information that was synthesized is appropriate for my patient.
- **Labella (2011)**[12] – This study is a cluster randomized control trial (level of evidence 1b), that specifically targeted female adolescent athletes, including basketball players, making it applicable to my patient. Also, on the PEDro scale this study was given a 7/11 based on my appraisal, making it the highest quality RCT on my list. The study looked at neuromuscular program that was used in the schools, so there was a large number of subjects in the study to improve its power.

- **Sugimoto (2012b)**[22] – This study is a systematic review (level of evidence 1b), that reviewed ACL prevention studies (both randomized control trials and quasi-experimental) of female athletes of various sports, including basketball. It was amongst the 2nd highest rated studies based on my appraisal and included a synthesis of a number of other studies included on my list. I chose this study because of it's quality in synthesizing the research**.**

SUMMARY OF BEST EVIDENCE

(1) 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.[24]

Aim/Objective of the Study/Systematic Review:

The purpose of this meta-analysis was to evaluate the effectiveness of ACL prevention programs in reducing the odds of injury in female athletes. Also, the pooled data was further analyzed according to age, sport, period of training (preseason, inseason, or combination), and type of training (plyometric, strength, or balance).[24(825)]

Study Design

[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]

Note: For systematic review, use headings 'search strategy', 'selection criteria', 'methods' etc. For qualitative studies, identify data collection/analyses methods.

- The study is a meta-analysis that pooled data from eligible randomized controlled trials and prospective cohort studies.
- **Search Strategy:** A literature search through Medline performed from June 2007 used combinations of the following keywords: knee injury, ACL injury, gender difference, injury prevention, neuromuscular training, plyometrics, strengthening training, and balance training. The Cochrane Database, additional web-based searches, references from proceedings of the American Academy of Orthopaedic Surgeons and textbooks, and ACL injury prevention experts were also explored for more articles.
- **Selection Criteria:** A selection committee consisting of three orthopaedic surgeons and one biomechanics expert, all with experience in ACL injury cases, evaluated articles to determine eligibility for the meta-analysis.
- **Data Collection:** Data from the studies was pooled into two groups: female athletes trained in an ACL prevention program and those who were untrained. Only studies using an intention to treat analysis were included, meaning athletes were included regardless of whether optimal treatment occurred or not. Subgroups were also created according to age, sport, time of training, and training method. Age was divided into two groups, 18 or less years old or greater than 18 years old. Sport groups included soccer and handball. Time of training during the season was divided into pre-season, in-season, and a combination group (pre- and in-season). Lastly, the type of training was categorized by the presence of plyometric, strengthening and/or balancing exercise in the prevention protocol.
- **Meta-analysis:** In the pooled data, odds ratios were calculated using Mantel-Haenszel common odds ratio estimate (fixed method) and DerSimonian and Laird's methods (D-L) (random method) to predict decreases in the probability of an ACL injury with 95% confidence intervals. In the sub-group analysis, odds ratios and 95% confidence intervals were also calculated. Odds ratios (OR) were calculated for the pooled data. The subgroup analysis used only the Mantel-Haenszel (M-H) common odds ratio estimate.
- **Publication Bias:** The Begg and Mazumdar test and Egger regression asymmetry test were used to identify the potential for publication bias in the overall studies and sub-group analysis (when applicable). A Begg's funnel plot was also created.
- **Test for Heterogeneity:** A chi-square test was used to assess heterogeneity of the studies and sub-groups (when applicable).

Setting

[e.g., locations such as hospital, community; rural; metropolitan; country]

- Female team sport programs in various towns or cities.
- The level of play varied from high school to collegiate athletics.

Participants

[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]

Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article.

In this meta-analysis, seven studies yielded a sample size of 10,618 female athletes, with 4,033 in the trained group and 6,585 in the untrained group. Athletes are described as soccer, volleyball, and basketball athletes ranging in age from 14 to 26 years. One study lists "adult" as the age, making the interpretation from this study questionable.

Intervention Investigated

[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided]

Control

Considered as the "Untrained" group that did not perform an ACL-prevention program at any point during their athletic season.

Experimental

Considered the "trained" group that performed an ACL-prevention program during the pre-season, in-season, or a combination of pre- and in-season. The components of the ACL prevention program were described as plyometric, strengthening, agility, and/or balance exercise. Intensity of the program varied between studies, although specific data was not reported.

Outcome Measures (Primary and Secondary)

[Give details of each measure, maximum possible score and range for each measure, administered by whom, where]

Primary Outcome

- **Odds ratios:** Described as the proportion of injured athletes in the trained group divided by the proportion of injured athletes in the untrained group. Values less than one are favorable for the trained group in reducing the probability of an ACL injury.

Secondary Outcome

- **Number of Uninjured and Injured Athletes:** This was measured in both the untrained and trained groups and analysed across each study, amongst the subject pool as a whole, and within the sub-group analysis.

Main Findings

[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided – if you need to calculate these data yourself, put calculations here and add interpretation later, under 'critical appraisal' on next page]

- **Pooled Data:** The pooled sample revealed an odds ratio of 0.40 [0.27, 0.60] using the M-H method, and 0.49 [0.24, 1.02] using the D-L method.
- **Subgroup Analyses:** In the subgroup of athletes age 18 or younger, the odds ratio was 0.27 [0.14, 0.49] indicating a favorable effect of ACL prevention programs in this population. Additionally, soccer athletes (OR = 0.32 [0.19, 0.56]) and handball athletes (OR = 0.54 [0.30, 0.97]), performing training interventions during the in-season (OR = 0.32 [0.17, 0.59]) and combination of pre-season and in-season (OR = 0.54 [0.30, 0.97]), and including plyometric exercise (OR = 0.37 [0.24, 0.55]) and strengthening exercise (OR = 0.21 [0.11, 0.43]) were all favorable for decreasing the probability of suffering an ACL injury.
- However, ACL prevention programs in the adult population (OR = adult 0.78 [0.23, 2.64], pre-season training (OR = 0.35 [0.1, 1.21], and balancing exercise (OR = 0.63 [0.37, 1.09]) do not significantly decrease the probability of suffering an ACL injury.
- **Publication Bias:** For the pooled data, the Egger test revealed a *P*-value of 0.64, while the Begg's test scored a *P*-value of 0.37. The funnel plot appears symmetrical, but some bias may be present.
- **Test of Heterogeneity:** For the pooled data, results for the test of heterogeneity showed that X^2 equalled 12.55 (*df* = 6), with a *P*-value of 0.051 for the pooled sample. I calculated an I^2 value to be 52%, suggesting moderate to substantial heterogeneity.[26] For the studies included in the subgroup of athletes 18 or younger, the test for heterogeneity showed *P* = 0.10 (*df* = 3), which may reflect low heterogeneity. Other sub-groups with low heterogeneity include the handball group (*P* = 0.35), pre-season training (*P* = 0.40), pre- and in-season training (*P* = 0.35), and plyometric (*P* = 0.10), strengthening (*P* = 0.45), and balancing exercise (*P* = 0.19). Higher amounts of heterogeneity were found in the soccer population studies (*P* = 0.03), and in-season training studies (*P* = 0.01).

Original Authors' Conclusions

[Paraphrase as required. If providing a direct quote, add page number]

- The authors suggest that using ACL prevention programs are effective in preventing ACL injuries in female athletes, especially those 18 years or younger.
- They also conclude that prevention programs are more effective for soccer players compared to handball players. In other sub-group analysis, they believe that pre- and in- season training is more effective than either of them alone. Also, using plyometric and strengthening exercise in the prevention interventions is more important than incorporating balance exercise, and these components should be incorporated in a program.
- Interestingly, the authors included data that was not part of the results section. First, they concluded that the reduction in non-contact ACL injuries in four of the seven studies was stronger evidence of a prevention program's success, with odds ratio and 95% confidence of 0.36 [0.23, 0.54]. The author's also appraised the intervention's intensity, saying that studies using protocols that engaged the athlete with greater exercise intensity were more effective and had an odds ratio of 0.37 [0.24, 0.55].
- Using an intention to treat analysis, as opposed to a per-protocol analysis provided more "real-life" results that because it is assumed all patients do not receive optimal treatment.[24(828)]

Critical Appraisal

Validity

[Methodology, rigour, selection, sources of bias, quality score on methodology quality rating scale (indicate the quality assessment tool used and the maximum possible score on that scale, e.g., 7/10 on PEDro scale), appropriateness of analytical approach (e.g., adjustments for confounding variables, management of missing data).]

Comment on missing information in original paper.

For this meta-analysis, I used the Quality Appraisal Checklist proposed by Jewell.[8] The score for this paper was 5/8. A strength of this review is that all studies were limited to randomized controlled trials and prospective cohort studies that were scrutinized by the selection committee. Authors conducted a comprehensive Medline search, reviewed the Cochrane Database, contacted experts for studies, and performed additional searches through the web, textbooks, and proceedings of the American Academy of Orthopaedic Surgeons, and a selection committee scrutinized the results. While each study was assessed for their quality and provided a letter grade according to their level of evidence and quality, a validated measure was not used to assess quality. Also, study quality results were not shared in the results section of the study. Therefore, the overall method for searching, selecting, and appraising articles is not reproducible based on the information provided, which is a limitation. The investigators provided detailed statistical information regarding publication bias for all of their outcome measures. The authors were able to obtain individual patient data by gathering the exact number of uninjured and injured female athletes in each of the studies presented. Results from the test for heterogeneity of the pooled data indicated no significant heterogeneity in the data (X^2 = 12.55; 6 degrees of freedom; P = 0.057). However, I calculated the I^2 value to be 52%, suggesting moderate to substantial heterogeneity, which can be explained by variability in intervention design and subjects in the sample of each individual study.

Interpretation of Results

[Favourable or unfavourable, specific outcomes of interest, size of treatment effect, statistical and clinical significance, minimal clinically important difference. You may calculate effect size or confidence intervals yourself from the data provided in the article.] Describe in your own words what the results mean.

- In the analysis of the pooled data, the M-H analysis (fixed model) shows a favorable effect for the intervention in decreasing the probability of ACL injuries. However, confidence intervals of the D-L analysis (random model) cross 1, therefore indicating no difference between the control and experimental groups. Based on my understanding of using fixed models versus random models in a meta-analysis, a random model is more appropriate for this study because of the heterogeneous samples from the studies. In this study, there is no significant heterogeneity based on the Chi-squared test, so the fixed model analysis is acceptable.
- A nearly 75% reduction in the odds of an ACL injury was found in the subgroup of athletes age 18 or younger. This result is most relevant to my clinical question and clinically significant.
- Additionally, favorable effects were found in soccer athletes and handball athletes, performing training interventions during the in-season and combination of pre-season and in-season, and including plyometric exercise and strengthening exercise. Therefore, a maintenance program that focuses on plyometric and strength exercises may be important for my patient as she rehabilitates from her ACL injury.

(2) Description and appraisal of Effect of Neuromuscular Warm-up on Injuries in Female Soccer and Basketball Athletes in Urban Public High Schools by Labella CR et al (2011).[12]

Aim/Objective of the Study/Systematic Review:

The purpose of this study was to investigate the ability of girls' high school basketball and soccer coaches to implement an a neuromuscular warm-up, acting as an injury prevention program, and it's effectiveness in reducing lower extremity injuries.

Study Design

[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]

Note: For systematic review, use headings 'search strategy', 'selection criteria', 'methods' etc. For qualitative studies, identify data collection/analyses methods.

- A cluster randomized controlled trial with blinded principal investigator and co-investigators. Research assistants were not blinded.
- **Eligibility Criteria:** Head coaches from girls' soccer and basketball varsity, junior varsity, sophomore, and freshman teams (n=258) were contacted to participate. There was no exclusion criteria.
- **Allocation:** Schools were arranged by socioeconomic status (based on percentage of students eligible for school lunch) and competitive division, and then randomized by an online random number generator.
- **Intervention Overview:** Intervention coaches implemented a 20-minute neuromuscular warm-up before practice and a shorter version for games. Research assistants observed the warm-up biweekly and answered questions for coaches if necessary. Control coaches did not receive any injury education and were instructed to perform practice and games as any other season.
- **Data Collection:** Athlete exposure and injury data was collected by research assistants weekly. If a serious injury occurred, information was verified by MRI and doctor's reports. Personal interviews were conducted by research assistants with any athlete who suffered an injury gather further information on the event, including mechanism of injury. Demographic information about the athlete population was collected via parent survey and pre-participation physical forms prior to the start of the season. The study collected data for the 2006-2007 Chicago public high school girls' soccer and basketball seasons.
- **Statistical methods:** Baseline characteristics were analysed with t-tests for continuous variables and chi-squared tests for categorical variables. Chi-squared and Fisher exact tests were used to compare injury rates between intervention and control groups. For the athlete subset that reported personal information, additional analysis used intent-to-treat Poisson regression models to find associations between the effect of the intervention and injury rates. Adjustments for covariates were made to guard against bias by creating a subset of athletes.

Setting

[e.g., locations such as hospital, community; rural; metropolitan; country]

The study was conducted through the Children's Memorial Hospital and Chicago Public Schools at urban high schools in Chicago amongst high school girls' soccer and basketball teams.

Participants

[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]

Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article.

- 90 girls' high school coaches completed the study with their teams. They were initially contacted by email, telephone, and through a presentation at an annual mandatory coaches meeting.
- 1,492 female soccer and basketball athletes participated in the study. Also, a smaller number of athletes (n = 855) were included in a subset analysis where parental consent was provided to include demographic characteristics obtained via parent survey.
- Average age in the control group was 16.22 (SD, 1.06). In the intervention group it was 16.19 (SD, 1.53).
- There were differences between the intervention and control group. The intervention group athletes had lower body mass indexes (23.09 vs 23.88), different race/ethnicity distribution, more playing experience (4.84 vs 4.37), and were more likely to play other sports and participate in a strength and conditioning program in the previous 3 months (50.9% vs 41.9%).

Intervention Investigated

[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided]

Control

- The control group participated in their basketball or soccer season as originally planned.
- Coaches recorded participation of athletes in practice and games throughout the season. Injuries resulting in lost time in practice or games were recorded. This data was collected weekly by research assistants.
- Immediately following an injury, athletes were interviewed by research assistants to collect information regarding their injury including date, mechanism, body part, type, medical evaluation, treatment, and number of missed games and practice.
- All injuries were verified by MRI or operative notes.

Experimental

- Coaches in the intervention group attended a 2-hour training session led by the investigators and an athletic trainer. They learned the full and abbreviated warm-ups that would be used prior to practice and games, respectively.
- The 20-minute full warm-up consisted of progressive strengthening, plyometric, balance, and agility exercises focused on avoiding dynamic knee valgus and encouraging landing mechanics with flexed hips and knees. The short warm-up only consisted of "dynamic motion exercises."[12(1034)]
- Coaches were taught correct form, how to identify incorrect form, and what external focused verbal cues can be used to improve exercise technique.
- Coaches were provided a DVD of the exercises in the warm-up, as well as a laminated card listing order and frequency of exercises, and educational material about knee injuries.
- Research assistants were available to answer questions.
- Coaches recorded participation of athletes in practice and games throughout the season. Injuries resulting in lost time in practice or games were recorded. This data was collected weekly by research assistants.
- Immediately following an injury, athletes were interviewed by research assistants to collect information regarding their injury including date, mechanism, body part, type, medical evaluation, treatment, and number of missed games and practice.
- All injuries were verified by MRI or operative notes.
- The length of the intervention was the entire 2006-2007 sports season for their respective sports (soccer and basketball).

Outcome Measures (Primary and Secondary)

[Give details of each measure, maximum possible score and range for each measure, administered by whom, where]

Primary Outcome Measure

- **Injury Rate:** Defined as defined as the number of injuries per 1000 AEs. Rates were calculated for all injury classifications.
- Intent-to-treat Poison regression models were used with subset data to find associations of injury classifications.

Secondary Outcome Measure

- **Athlete Exposures (AE):** Defined as participating in all or part of a practice or game. This information was recorded by coaches and collected by research assistants.
- **Injury:** Classified as gradual onset, acute onset, noncontact ankle injuries, noncontact knee sprains, and noncontact ACL injuries which was collected by research assistants during interviews with athletes.

Main Findings

[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided – if you need to calculate these data yourself, put calculations here and add interpretation later, under 'critical appraisal' on next page]

- There were 22,925 AEs in the control group (n = 755 athletes) with 96 lower extremity injuries resulting in a rate of 4.19 lower extremity injuries per 1000 AEs [95% CI, 3.35-5.02 per 1000 AEs].
- There were 28,023 AEs in the intervention group (n=737) with 50 lower extremity injuries resulting in 1.78 lower extremity injuries per 1000 AEs [95% CI, 1.29-2.28 per 1000 AEs].
- Intervention athletes reduced gradual-onset injuries by 65%, acute noncontact injuries by 56%, and noncontact ankle sprains by 66%.
- Noncontact ACL injuries were reduced by 80% when incidence rate ratios (IRR) were adjusted for clustering and covariates in athletes who reported personal information. (IRR = 0.20; CI 95%, 0.04-0.95). However, reduction in ACL injuries did not reach statistical significance before the adjustment. There were four athletes who required surgery due to their injuries, and all were noncontact ACL injuries in the control group.
- Athletes in the lower competitive divisions suffered more injuries than the two higher divisions.
- Taller athletes were associated with an increased risk of injury in the subset analysis.

Original Authors' Conclusions

[Paraphrase as required. If providing a direct quote, add page number]

- The authors conclude that the study provides level I evidence that neuromuscular training reduces ACL injuries after accounting for significant covariates and clustering by team. Overall, coach compliance with the warm-up was considered good (80% of practices used the full warm-up), but many did not use all of the prescribed exercises, lowering the potential protective effect of the intervention group. The authors believe that consistent use of the warm-up will increase its effectiveness in preventing injury.
- Limitations included data collection from only one season and self-reported coaching compliance may have overestimated true compliance of the intervention group. They suggest that more oversight should be used in the next research study. There were no athletic trainers at these public schools and athletes had limited existing medical records due to lack of health insurance, which could have led to an underestimation of injuries. The inability to obtain 100% of personal information resulted in the creation of an athlete subset, which could have misrepresented the entire sample.
- The authors believe that training coaches to perform the neuromuscular warm-up can reduce injuries and is cost-effective.

Critical Appraisal

Validity

[Methodology, rigour, selection, sources of bias, quality score on methodology quality rating scale (indicate the quality assessment tool used and the maximum possible score on that scale, e.g., 7/10 on PEDro scale), appropriateness of analytical approach (e.g., adjustments for confounding variables, management of missing data).]

Comment on missing information in original paper.

7/10 based on Eligibility Criteria: Yes; Random Allocation: Yes; Concealed Allocation: Yes; Baseline Comparison: No; Blind Subjects: No; Blind Therapist: No; Blind Assessors: Yes; Adequate Follow-up: Yes; Intention-to-treat analysis: Yes; Between Group Comparison: Yes; Point Estimates and Variability: Yes. (Eligibility score does not contribute to total score.)

- The randomization and lead investigator blinding are significant strengths of this study, especially since this appears to be lacking in most other studies of ACL prevention programs.
- The limitation of using athlete exposures as an outcome method is that some athletes can participate longer during an athlete exposure compared to other athletes. Therefore, an athlete exposure for one soccer player may be very different than an athlete exposure for a basketball player. This can be attributed to different rules of each game, as well as different skill levels of players (i.e. starters will play more than bench players). Therefore, there not every athlete exposure is the same.
- One significant limitation is that the baseline characteristics of the groups were different. The intervention group athletes had lower body mass indexes, different race/ethnicity distribution, more playing experience, and were more likely to play other sports and participate in a strength and conditioning program in the previous 3 months. This could impact the primary outcome measures in regards of decreased injury rate.
- Also, as mentioned by the authors, creating a subset of athletes may have created a smaller group of athletes that were not similar with the original population studied. No information was provided by the authors in regards to this information.
- Subjects were not blinded because they knew they were receiving the intervention, however it is impossible to blind them in this type of study. Coaches were the "therapists" administering the intervention to their teams making it impossible to blind them.
- Another limitation acknowledged by the authors was a lack of full compliance by the coaches in implementing the neuromuscular warm-up. Therefore, each player in the intervention group may not have received the same dose of treatment.

Interpretation of Results

[Favourable or unfavourable, specific outcomes of interest, size of treatment effect, statistical and clinical significance, minimal clinically important difference. You may calculate effect size or confidence intervals yourself from the data provided in the article.] Describe in your own words what the results mean.

- The results of this study demonstrate that the use a preventative program for decreasing the incidence of ACL injury is favourable. Of four ACL injuries requiring reconstructive surgery in the study, all were in the control group. This result is relevant to my clinical question.
- Additionally, injury prevention programs can reduce overall risk of lower extremity injury in high school girls' athletes, which is favourable.
- Differences in baseline characteristics of the intervention and control groups are a significant limitation in this study, especially if the intervention group contains higher-level athletes who attended more off-season strength and conditioning programs. This would likely decrease the likelihood of injury in the intervention group.

- Taller athletes are at a greater risk of lower extremity injury compared to shorter athletes, which has specific implications for basketball players since they tend to be taller than soccer players. Clearly, this is important to consider since my patient is a basketball player.

(3) Description and appraisal of Evaluation of the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes- a critical review of relative risk reduction and numbers-needed-to-treat analyses by Sugimoto et al (2012b).[22]

Aim/Objective of the Study/Systematic Review:

The purpose of this meta-analysis was to determine the effectiveness of neuromuscular training programs in reducing non-contact and overall ACL injury risk in female athletes through relative-risk-reduction and numbers needed to treat analysis.

Study Design

[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]

Note: For systematic review, use headings 'search strategy', 'selection criteria', 'methods' etc. For qualitative studies, identify data collection/analyses methods.

- The study is a meta-analysis of prospective experimental and quasi-experimental designed studies of neuromuscular training programs designed to reduce the incidence of ACL injuries.
- **Search Strategy:** A literature search was performed between 1995 and 2011 of PubMed and EBSCO (containing CINAHL, MEDLINE, and SPORT Discus) using the following keywords and combinations: knee, anterior cruciate ligament, ACL, prospective, neuromuscular, training, female, and prevention.
- **Selection Criteria:** Studies needed to be in English and be performed on humans. Studies were required to report the number of ACL injuries, have employed a neuromuscular training intervention aimed specifically to reduce ACL injury incidence, use a control group, employ a prospective control trial design, and include female subjects. Abstracts, posters, and unpublished data were not considered.
- **Data Collection:** From each study, the following data was collected: the number ACL injuries in each group (control and intervention), the number of athletes in each group (control and intervention), and the number of athletic exposures for each athlete in each group (control and intervention). Athletic exposure equated to the number of hours and days of participation for each athlete. A 'day' was estimated to be two hours of athlete exposure. Also, data referencing ACL injuries were divided into a subset of contact or non-contact injuries. If this information was not available in the study, the authors contacted the lead author to gather this information.
- **Meta-analysis:** Using collected data on ACL injuries, number of athletes, and athletic exposures, a numbers needed to treat (NNT) and relative risk reduction (RRR) was calculated between the intervention and control groups. 95% confidence intervals were applied to RRR and NNT.
- **Publication Bias:** Egger's regression was used to assess publication bias.

Setting

[e.g., locations such as hospital, community; rural; metropolitan; country]

- Female team sport programs in various towns and cities in multiple countries.
- The level of play varied from high school to collegiate athletics.

Participants

[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]

Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article.

In this meta-analysis, twelve studies yielded a sample size of 18,083 female athletes, with 10,019 in the control group and 8,064 in the intervention group. The athletes were described as soccer, volleyball, handball, and basketball players ranging in age from 14 to 22 years old.

Intervention Investigated

[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided]

Control

This group did not perform an ACL-prevention program at any point prior to or during their athletic season.

Experimental

The intervention group performed a neuromuscular training program designed to reduce the incidence of ACL injuries in female athletes. The components of the ACL prevention program included stretching, plyometrics, weight training, balance training on dynadiscs, mats, and balance/wobble boards, endurance training, agility drills, sports specific drills, power training, and core stability exercises. The application of the intervention occurred in both the off-season and competitive season. During the off-season, intervention frequency was two times per week, three times per week, or daily. During the competitive season, it varied between 1 and 3 times per week. The length of each intervention varied from 10 to 90 minutes, with 15-25 minutes being most common.

Outcome Measures (Primary and Secondary)

[Give details of each measure, maximum possible score and range for each measure, administered by whom, where]

Primary Outcome Measure

- **Relative Risk Reduction (RRR)**: The percentage that the ACL intervention program reduces the risk of ACL injury in the intervention group compared to the control group. 95% confidence intervals were applied.
- **Numbers Needed to Treat (NNT)**: A positive value represents a preventative effect of the ACL intervention programs. 95% confidence intervals were applied.

Secondary Outcome Measure

- **Incidence rate of overall and non-contact ACL injuries:** This information was collected from each study and pooled together for analysis.

Main Findings

[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided – if you need to calculate these data yourself, put calculations here and add interpretation later, under 'critical appraisal' on next page]

- **Study Quality:** Twelve studies were included with an average PEDro scale score of 4.3/10. Two scored 7/10, one was 6/10, two were 5/10, three were 4/10, two were 3/10 and two were 2/10. A lack of concealed allocation, dissimilar groups at baseline, lack of blind subjects, and lack of blind intervention providers were the most common methodological issues. However, blinding subjects and intervention providers would be impossible for this type of study.
- **Data Synthesis:** The compiled data showed a relative risk reduction for non-contact ACL injuries of 73.4% (62.5% to 81.1%) in athletes assigned to a neuromuscular training program compared to the control group. The RRR for all ACL injuries (contact and non-contact) was 43.8% (28.9% to 55.5%) in the intervention group compared to the control group. The data showed that 108 athletes would need to undergo a neuromuscular training program in order to prevent one non-contact ACL injury, and 120 athletes to prevent all ACL injuries.
- **Publication Bias:** Egger's regression intercept was -0.29 indicating no presence of publication bias.

Original Authors' Conclusions

[Paraphrase as required. If providing a direct quote, add page number]

- The author's conclude that an ACL prevention program that focuses on neuromuscular training will reduce the risk of a non-contact ACL injury by 73.4% in female athletes. Similarly, the overall ACL risk would be reduced by 43.8%, which includes both contact and non-contact injuries. Therefore, the author concluded that neuromuscular training programs are effective in the prevention of both contact and non-contact ACL injuries.
- When analysing the neuromuscular training programs that demonstrated a risk reduction of >73.4% of non-contact ACL injuries and >43.8% of overall ACL injuries, the authors concluded that multiple exercises using strengthening, plyometric and balance components combined were better than using only one of the mentioned components.
- The time commitment of preventing ACL injuries using an intervention program with a number-needed-to-treat of 108 for non-contact ACL injuries may too substantial for coaches to use. Therefore, selling the intervention program as a performance enhancing and injury prevention program for all lower extremity injuries could increase compliance by coaches.

Critical Appraisal

Validity

[Methodology, rigour, selection, sources of bias, quality score on methodology quality rating scale (indicate the quality assessment tool used and the maximum possible score on that scale, e.g., 7/10 on PEDro scale), appropriateness of analytical approach (e.g., adjustments for confounding variables, management of missing data).]

Comment on missing information in original paper.

For this meta-analysis, I used the Quality Appraisal Checklist proposed by Jewell.[8] The score for this paper was 6/8. All studies, except one, were prospective in their design, however many of them were not high quality based on the PEDro scale used by the investigators. The one study not prospective was a cohort study with good methodological quality and a PEDro score of 5/10. A weakness is that only half (six studies) were randomized controlled trials and the other are quasi-experimental in design. Also, the study quality was highly variable as reported in the main findings. The authors described their search in PubMed and EBSCO (containing CINAHL, MEDLINE, and SPORT Discus) and the selection process so it could be repeated. A limitation is that only English studies were included and unpublished studies were not included, which could lead to the exclusion of data that would be worthy of inclusion. However, an analysis of publication bias was included by the authors, and it did not reveal any bias. The authors used the PEDro scale, which is a valid tool to analyse the methodological quality of each study and the Centre of Evidence Based Medicine Level of Evidence to grade each study's level of evidence. Each study was scored independently on the PEDro scale between two reviewers and was assigned a level of evidence grade. This information was succinctly summarized within the study to show the validity and quality of each study being considered. Individual patient data was obtained from the studies if available. The authors attempted to make contact with lead authors when individual patient data was not available, but only 1 of 6 studies responded with full information. Therefore, some of the specific ACL injury mechanism information was missing, which is a limitation of this study. Lastly, there were no tests for heterogeneity used in the study. Studies showed varying results based on the data presented, which may have been due to heterogeneous methods employed by each individual study.

Interpretation of Results

[Favourable or unfavourable, specific outcomes of interest, size of treatment effect, statistical and clinical significance, minimal clinically important difference. You may calculate effect size or confidence intervals yourself from the data provided in the article.] Describe in your own words what the results mean.

- The relative risk reduction in the group of athletes who performed some type of neuromuscular intervention program to reduce non-contact ACL injuries was 73.4% (95% CI, 62.5-81.1%). I believe this shows a significant and clinically relevant reduction in non-contact ACL injuries that is favourable and relevant to the patient in my clinical question.
- Also, the relative risk reduction for overall ACL injury is 43.8% (95% CI, 28.9-55.5%), which is also a significant reduction in risk for female athletes. This result is also favourable and relevant to the patient in my clinical question.
- Additionally, the use of multiple components of training, including strengthening, plyometric, and balance exercises, is important for the creation and implementation of a comprehensive ACL-injury prevention program. This is relevant to my patient because it helps guide inclusion of the correct components to help prevent injury.

IMPLICATIONS FOR PRACTICE and FUTURE RESEARCH

IMPLICATIONS FOR PRACTICE

The evidence reviewed supports the use of an ACL-prevention program to decrease the risk ACL injury in my patient, who is a 17-year-old high school girl's basketball player. In the meta-analysis by Yoo et al (2010), the results from the sub-group analysis shows a decrease in ACL injuries in the group using an ACL prevention program on 18 year old or younger female athletes.[24] The randomized controlled trial performed organized by LaBella et al (2011), found that the ACL prevention program reduced the risk of an ACL injury in soccer and basketball players, as well as other lower extremity injuries, supporting the use an ACL injury prevention program during the season.[12] Lastly, the meta-analysis by Sugimoto et al (2012b) also provided results that lower the risk of non-contact ACL injury with the use of an ACL-prevention program that focuses on neuromuscular components in young female athletes.[22] The timing of the ACL prevention program will be important to my patient, as the research appears to show in-season and a combination of pre-season and in-season have provided the best results.[12,24] Therefore, following her rehabilitation and return-to-sport program, a maintenance program will benefit her to reduce injury risk throughout the season. Compliance with the program also appears to be very important, as a study in female soccer players showed increased compliance was associated with increased risk reduction of ACL injuries.[27]

To be most effective, it appears that ACL-prevention programs need specific components. A program that includes combinations of plyometric, strength, and balance exercises appear most successful in reducing ACL injuries according to the evidence presented.[12,22,24] In fact, programs focusing only on balance were not able to reduce ACL injuries.[24] Therefore, creating a program including multiple neuromuscular components that can be implemented during the off-season, pre-season, and in-season, as well as on game-days, can prepare my patient for participation in her sport. Support for this comes from the randomized controlled trial by LaBella, where two variations of the intervention were used on practice days and game-days proved to be effective in reducing the risk of injury. This would allow for an off-season program that continues to build neuromuscular qualities that reduce ACL-injury incidence, and an in-season program that would allow maintenance of the same qualities.

Finally, when looking specifically at basketball players, there is not much evidence at this point. However, in each of the studies, basketball players were part of the subject pool. We know that female basketball athletes tend to be taller than athletes in other sports. Labella et al (2011) showed that being taller was associated with an increased risk of injury. This may imply that an ACL prevention program would be particularly useful for female basketball players.

IMPLICATIONS FOR FUTURE RESEARCH

Based on the evidence reviewed, future research needs more high quality randomized controlled trials on ACL prevention programs. The meta-analysis by Sugimoto found only six studies that were randomized controlled trials.[22] Of all the studies reviewed, only five of studies scored 5 or greater, out of 10, on the PEDro scale. Enacting randomized controlled trials is a significant challenge because of the coordination needed between therapists, coaches, and athletes, and the multitude of potential training options for preventing ACL injuries. However, there is a gap in the literature due to the lack of high-quality randomized controlled trials.

ACL prevention programs need a more consistent methodology to decrease heterogeneity in ACL-prevention programs. In the meta-analysis by Yoo et al (2010), the authors reported various training methods with components including plyometric exercise, strengthening, balance activities, and agility drills. Each study performed a different program.[24] This heterogeneity was also found in the Sugimoto et al (2012b) meta-analysis.[22] Developing ACL-prevention programs that are comprehensive in composition (contain strength, plyometric, agility and balance training) and implementing the intervention in multiple research studies, on multiple populations, with more homogenous methodology, will improve the body of literature regarding ACL prevention. It is hard to tell whether some ACL-prevention programs simply lack the intensity and correct components necessary to create neuromuscular improvements due to this heterogeneity.

For my patient, more quality studies need to be performed on sport-specific populations. Considering that girls' soccer and basketball are among the two sports where female ACL injury incidence is highest[3], I was surprised by the lack of literature pertaining to ACL-prevention programs in basketball. In the meta-analysis by Yoo et al (2010), two of the seven studies included basketball players.[24] In the meta-analysis by Sugimoto et al (2012b), only three of the twelve included studies used basketball players in their subject pool.[22] And in all five of the studies that did include basketball, they were not the only type of athlete involved, which could further dilute the effect that ACL prevention programs could have on basketball players. Therefore, creating a neuromuscular training program that is sport-specific to basketball and implemented on a population of these athletes would be beneficial to closing knowledge gaps in this area of study.

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