2012

# The Effectiveness of Injury-Prevention Programs in Reducing the Incidence of Anterior Cruciate Ligament Sprains in Adolescent Athletes

Jeffrey Paszkewicz
*Old Dominion University*

Tristen Webb
*Old Dominion University*

Brian Waters
*Old Dominion University*

Cailee Welch McCarty
*Old Dominion University*

Bonnie Van Lunen
*Old Dominion University*, bvanlune@odu.edu



## Original Publication Citation

Paszkewicz, J., Webb, T., Waters, B., McCarty, C. W., & Van Lunen, B. (2012). The effectiveness of injury-prevention programs in reducing the incidence of anterior cruciate ligament sprains in adolescent athletes. *Journal of Sport Rehabilitation, 21*(4), 371-377. doi:10.1123/jsr.21.4.371

*Journal of Sport Rehabilitation,* 2012, 21, 371-377


# The Effectiveness of Injury-Prevention Programs in Reducing the Incidence of Anterior Cruciate Ligament Sprains in Adolescent Athletes

**Jeffrey Paszkewicz, Tristen Webb, Brian Waters, Cailee Welch McCarty, and Bonnie Van Lunen**

***Clinical Scenario:*** There is a high incidence of anterior cruciate ligament (ACL) injury in adolescents participating in pivoting sports such as soccer, basketball, and handball. Most ACL injuries in athletes are noncontact injuries, with a mechanism of sudden deceleration, change in direction, or landing from a jump. These mechanisms coupled with an increase in contraction of the quadriceps have been shown as risk factors for ACL injuries. Injuries to the ACL may require surgery, a long rehabilitation, and the potential for reinjury. Studies have shown reductions in lower extremity injury rates using training protocols that focus on landing mechanics, balance training, strength training, and/or agility training. There has been some thought that starting preventive training programs with adolescent athletes may be the most effective approach to reducing adolescent ACL injuries. ***Focused Clinical Question:*** Can lower extremity injury-prevention programs effectively reduce ACL injury rates in adolescent athletes?

***Keywords:*** youth, preventive training program, knee injury

## Clinical Scenario

There is a high incidence of anterior cruciate ligament (ACL) injury in adolescents participating in pivoting sports such as soccer, basketball, and handball. Most ACL injuries in athletes are noncontact injuries, with a mechanism of sudden deceleration, change in direction, or landing from a jump. These mechanisms coupled with an increase in contraction of the quadriceps have been shown as risk factors for ACL injuries. Injuries to the ACL may require surgery, a long rehabilitation, and the potential for reinjury. Studies have shown reductions in lower extremity injury rates using training protocols that focus on landing mechanics, balance training, strength training, and/or agility training. There has been some thought that starting preventive training programs with adolescent athletes may be the most effective approach to reducing adolescent ACL injuries.

## Focused Clinical Question

Can lower extremity injury-prevention programs effectively reduce ACL injury rates in adolescent athletes?

The authors are with the Dept of Human Movement Sciences, Old Dominion University, Norfolk, VA.

## Summary of Search, "Best Evidence" Appraised, and Key Findings

- The literature was searched for studies of level 2 evidence or higher that investigated the effect of injury-prevention training programs on knee-sprain incidence in adolescent athletes.
- The literature search returned 10 possible studies related to the clinical question; 4 studies met the inclusion criteria and were included.
- Two high-quality cluster randomized controlled trials and 2 prospective cohort studies were included.
- Of the included studies, 2 demonstrated reductions of ACL injuries of the intervention group and 2 showed no statistical difference between the intervention group and control group.

## Clinical Bottom Line

There is moderate evidence to support the use of a supervised injury-prevention training program that focuses on developing neuromuscular control of the lower extremity through neuromuscular strengthening exercises, plyometrics, and proprioception exercises. The program should include sessions in the preseason and in-season to reduce the rate of ACL injuries in adolescent athletes.

**Strength of Recommendation**: There is grade B evidence that supervised preseason and in-season lower extremity injury-prevention training programs incorporating neuromuscular strengthening exercises, plyometrics, and proprioception exercises are effective in reducing the rate of ACL sprains in adolescent athletes.

## Search Strategy

### Terms Used to Guide Search Strategy

- **P**atient/Client group: *adolescent* or *youth*
- **I**ntervention/Assessment: *prevention* or *prevention program*
- **C**omparison: *intervention*
- **O**utcome: *ACL injury* or *injury* and *incidence* or *risk*

### Sources of Evidence Searched

- The Cochrane Library
- PEDro Database
- Medline
- CINAHL
- SPORTDiscus
- Additional resources obtained via review of reference lists and hand search

## Inclusion and Exclusion Criteria

### Inclusion Criteria

- Level 2 evidence or higher
- Studies investigating the overall rate of ACL injury as the primary objective outcome measure
- Subjects who were actively participating in sport at the time of the study
- Limited to English language
- Limited to humans
- Limited to the past 10 years (2002–2011)

### Exclusion Criteria

- Participants more than 18 years of age
- Studies that did not report specific details of the intervention protocol
- No use of a control group
- Studies using protective equipment as part of the intervention

## Results of Search

Four relevant studies[1–4] were located and categorized as shown in Table 1 (based on Levels of Evidence, Centre for Evidence-Based Medicine, 2009).

**Table 1 Summary of Study Designs of Articles Retrieved**

| Level of evidence | Study design | Number located | Reference |
|---|---|---|---|
| 1b | Cluster randomized controlled trial | 2 | Steffen et al[1]<br>Olsen et al[2] |
| 2b | Prospective cohort | 2 | Pfeiffer et al[3]<br>Mandelbaum et al[4] |

## Best Evidence

The studies in Table 2 were identified as the best evidence and selected for inclusion in this clinically appraised topic (CAT). These studies were selected because they were graded with a level of evidence of 2 or higher, they examined an injury-prevention training intervention in adolescent athletes, and the effect of the intervention on the outcome of interest (rate of ACL injuries) was described.

## Implications for Practice, Education, and Future Research

Based on this appraisal, two[2,4] of the four[1–4] studies displayed a significant reduction in ACL injury risk. None of the 4 studies showed an increased risk of ACL injury after the preventive training program. The findings indicate that preventive training programs that focus on developing neuromuscular control of the lower extremity are moderately effective in reducing the risk of ACL sprains in adolescent athletes. The designs of the preventive training programs in each study differed in specific points of emphasis, including implementation of strengthening exercises, plyometrics, balance, and participant compliance in completing the required sessions.

The cluster randomized controlled trial[2] that demonstrated a significant reduction in ACL injuries used a preventive training program that incorporated a warm-up, balance exercises, plyometric exercises, strength and power exercises, and instruction emphasizing technique in planting, cutting, and jumping balance. The cohort study[4] that demonstrated a significant reduction in ACL injuries used a preventive training program that incorporated a warm-up, stretching, strengthening exercises, plyometric exercises, and sport-specific agility. The cluster randomized controlled trial[1] that did not report a decrease in ACL injury rate used a preventive training program that included core stability, balance exercises, plyometric exercises, and strengthening exercises. The other cohort study[3] that did not find a reduction in ACL sprains used a preventive training program that incorporated a progression of plyometric exercises and agility. Even though all 4 of the studies were performed in a

**Table 2 Characteristics of Included Studies**

| | Steffen et al[1] | Olsen et al[2] | Pfeiffer et al[3] | Mandelbaum et al[4] |
|---|---|---|---|---|
| Study design | Cluster randomized controlled trial | Cluster randomized controlled trial | Cohort | Cohort |
| Participants | 109 soccer teams with a total of 2020 female players age 13–17 y (mean 15.4 ± 0.8).<br>947 subjects in the control group and 1073 subjects in the intervention group.<br>Block-randomized with 4 teams in each block into an intervention group and a control group; the teams were matched by region.<br>Subjects were eligible if they were registered by the team as participating in the U17 league system (age 16 and under).<br>Subjects were excluded if they reported an injury at the start of the season.<br>48 subjects dropped out. | 120 team handball clubs with a total of 1837 subjects age 15–17 y.<br>879 subjects (778 female and 101 male) in the control group and 958 subjects (808 female and 150 male) in the intervention group.<br>Block-randomized teams, with 4 clubs in each block to an intervention or control group. The clubs were matched by region, playing level, and sex and number of players.<br>68 subjects dropped out of the intervention group and 51 subjects dropped out of the control group.<br>No inclusion or exclusion criteria. | 112 teams at 15 high schools with a total of 1439 high school sophomore- to senior-level female athletes (soccer, basketball, and volleyball at the varsity, junior varsity, and sophomore levels) for 2 consecutive seasons.<br>862 subjects in the control group and 577 subjects in the intervention group.<br>Schools were placed into either the intervention group or the control group based on their willingness to incorporate the KLIP training into their daily practice routines.<br>Schools needed to have an athletic trainer available to assist with the study. | *Year 1:* 147 soccer teams with a total of 2946 female subjects age 14–18 y from the same league. 1041 female soccer players (52 teams) were in the intervention group and 1905 (95 teams) were in the control group.<br>*Year 2:* 157 soccer teams with a total of 2757 female players age 14–18 y. 844 female athletes (45 teams) were in the intervention group and 1913 (112 teams) were in the control group.<br>The 2 groups were age and skill matched during both years.<br>The teams who wished to be a part of the soccer training program were the teams enlisted into the intervention group. |

*(continued)*

**Table 2 *(continued)***

| | Steffen et al[1] | Olsen et al[2] | Pfeiffer et al[3] | Mandelbaum et al[4] |
|---|---|---|---|---|
| Intervention investigated | All coaches and players received a detailed brochure describing the intervention program and how the exercises should be performed, as well as common errors. The program was introduced to the teams by an instructor of the study.<br>The coaches were asked to use the program in the team setting every training session for 15 consecutive sessions and thereafter once a week during the rest of the season, replacing any warm-up routine normally used by the team.<br>The program lasted about 20 min, including 5 min of jogging that was not a part of the intervention protocol before starting the exercises.<br>The "11" program included 10 exercises focusing on core stability, balance, dynamic stabilization, plyometrics, and eccentric hamstrings strength. The 11th component, a focus on fair play, was not emphasized.<br>The coaches and players were instructed to watch each other closely during the training sessions and give continuous feedback, and coaches provided compliance information.<br>No variation or progression.<br>No blinding of subjects or therapists. | The clubs received an exercise book, 5 wobble boards, and 5 balance discs. The instructors visited with each team once at the start of the season and again midway through the season (4 mo later).<br>Coaches were to use the program in the team setting at the beginning of every training session for 15 consecutive sessions and then once a week throughout the remainder of the season.<br>The program consisted of 4 different sets of exercises with the exercise ball, including the use of the wobble board and balance mat for warm-up, technique, balance, strength, and power. Each set of exercises increased in difficulty.<br>The warm-up was defined in the intervention protocol and included jogging, backward running with sidesteps, forward running with knee lifts and heel kicks, sideways running with crossovers ("carioca"), sideways running with arms lifted ("parade"), forward running with trunk rotations, forward running with intermittent stops, and speed running.<br>The focus of the exercises was to improve awareness and control of knees and ankles during standing, running, cutting, jumping, and landing.<br>Players were instructed to spend 4–5 min on each exercise group for a total duration of 15–20 min. They were also encouraged to provide each other with feedback.<br>No blinding of subjects or therapists. | Intervention groups received personal instruction in the implementation of the KLIP program, an instructional videotape, and printed handouts.<br>Coaches were asked to incorporate the KLIP in the team setting at either the beginning or the end of practice. The intervention was implemented 2 times per week. It was examined over the course of 2 y.<br>The 20-min intervention program focused on development of sound body mechanics when decelerating during running with directional changes and when landing on 1 or 2 feet.<br>The program was sequential and progressive as it encompassed 4 phases with each subsequent phase based on skills developed in previous phases.<br>There was no defined warm-up within or prior to the intervention.<br>Drills incorporated into the KLIP involve jumping and landing mechanics, plyometric activities, and agility exercises.<br>Exercises were established for a 2-wk period, and athletes progressed once they demonstrated proficiency in a given set of skills. | Each team in the intervention group was mailed an educational videotape about the program and a supplemental literature packet.<br>The Prevent Injury and Enhance Performance program was introduced and described to coaches at a mandatory league meeting.<br>Coaches used the intervention program in the team setting before athletic activity.<br>The program video consisted of education and demonstration of 3 basic warm-up activities, 5 stretching techniques for the trunk and lower extremity, 3 strengthening exercises, 5 plyometric activities, and 3 soccer-specific agility drills.<br>The warm-up was defined in the intervention protocol and included jogging, shuttle running, and backward running.<br>Emphasis was placed on proper technique components of landing.<br>The intervention lasted 20 min and was used as a warm-up program.<br>Compliance forms were used to track adherence to the program. |

**Table 2 *(continued)***

| | Steffen et al[1] | Olsen et al[2] | Pfeiffer et al[3] | Mandelbaum et al[4] |
|---|---|---|---|---|
| Outcome measures | *Primary outcome:* Overall injury rate in both groups.<br>*Secondary outcomes:* Proportion of injured players and the incidences of ankle, knee, groin, hamstrings, and other injuries in both groups during the same study period. | *Primary outcome:* An acute injury to the knee or ankle in both groups.<br>*Secondary outcomes:* Any injury to the lower limbs, any injury to the upper limbs, and all injuries | *Primary outcome:* noncontact ACL injury in both groups.<br>*Secondary outcomes:* Compliance with the intervention and injury incidence expressed as the number of noncontact ACL injuries per 1000 player-exposures. | *Primary outcome:* noncontact ACL injury in both groups.<br>*Secondary outcomes:* Total number of athlete exposures (game and practice). |
| Main findings | Average player attendance was 67% ± 10% at each intervention session. Each subject participated in an average of 15 sessions.<br>9 ACL injuries occurred (0.07 injuries/1000 h, 95% CI 0.02–0.11), 4 in the intervention group and 5 in the control group (RR 0.8, 0.2–2.9; $P$ = .73).<br>No difference in overall injury incidence between the intervention group and the control group. The rate ratio for the intervention vs the control group was 1.0 (CI 0.8– 1.2, $P$ = 0.94) for all injuries, 1.1 (0.9–1.3, $P$ = .54) for acute match injuries and 0.7 (0.5–1.1, $P$ = .12) for acute training injuries.<br>Compliance analysis revealed no differences in injury incidence. | 87% compliance in the intervention and control groups. Each subject participated in an average of 27 intervention sessions.<br>9.9% (95) of subjects in the intervention group sustained an injury, whereas 19% (167) of subjects in the control group sustained an injury, 0.49 (0.36-0.68), $P$ < .0001.<br>6.9% (66) of subjects in the intervention group sustained a lower extremity injury, whereas 13.1% (115) of subjects in the control group sustained a lower extremity injury, 0.49 (0.36-0.73), $P$ < .0001.<br>3 ACL injuries in the intervention group (n = 958) and 10 ACL injuries in the control group (n = 879). | The average number of KLIP training sessions per player was 18, 23, and 22 on the basketball, soccer, and volleyball teams, respectively. Percentage compliance was not reported.<br>3 noncontact ACL injuries occurred in the intervention group and 3 occurred in the control group. There were 38,662 player-exposures in the control group, yielding an ACL injury incidence of 0.078 per 1000 exposures. There were 17,954 player-exposures in the intervention group, yielding an ACL injury incidence of 0.167 per 1000 exposures.<br>The odds of injury were equivalent for the 2 groups (odds ratio = 2.05; 95% confidence interval = 0.21 to 21.7). | Average number of intervention sessions and percentage compliance were not reported.<br>During the first year, there were 37,476 exposures with 2 noncontact ACL tears for the intervention group and 68,580 exposures with 32 noncontact ACL tears for the control group.<br>During the first year the injury incidence for the intervention group was 1.9/1000 players compared with 16.8/1000 players in the control group. The resultant rate ratio was equivalent to 0.11, which was statistically significant at $P$ = .0001 (95% CI, 0.03-0.48).<br>During the second year, there were 30,384 exposures with 4 noncontact ACL tears for the intervention group and 68,868 exposures with 35 noncontact ACL tears for the control group.<br>During the second year the injury incidence for the intervention group was 4.74/1000 players compared with 18.3/1000 players in the control group. The resultant rate ratio was equivalent to 0.26, which was statistically significant at $P$ = .005 (95% CI, 0.09–0.73). |

*(continued)*

**Table 2 *(continued)***

| | Steffen et al[1] | Olsen et al[2] | Pfeiffer et al[3] | Mandelbaum et al[4] |
|---|---|---|---|---|
| Level of evidence | 1b | 1b | 2b | 2b |
| Validity score | PEDro 7/10 | PEDro 7/10 | NA | NA |
| Conclusion | Injury rates were not different between the intervention and control groups, but this may be attributed to low compliance to the program.<br>The program was not varied and did not include progressions, and this may have affected the outcome. | The incidence of knee and ankle injuries can be reduced by at least 50% when including a structured warm-up program designed to improve awareness and control of knees and ankles during landing and pivoting movements.<br>A high compliance (87%) could be a factor in contributing to the success of the program. | A 20-min plyometric-based program that is completed twice a week throughout the season produces no differences in ACL injury rate for adolescent females. | The incidence of ACL injury is consistently lower in the intervention group than the control group.<br>A preventive training program that focuses on developing neuromuscular control of the lower extremity through strengthening exercises, plyometrics, and sports-specific agility may address the proprioceptive and biomechanical deficits that are demonstrated in the high-risk female athletic population. |

Abbreviations: KLIP, knee-ligament-injury prevention; ACL, anterior cruciate ligament; RR, rate ratio.

team setting as part of the regular training or practice session, lasted about 20 minutes, and were supervised by a coach, the 2 studies[2,4] that demonstrated significant reductions in ACL injuries incorporated a standardized warm-up consisting of defined running tasks within the intervention protocol.

Adolescent ACL-injury-prevention programs should consider a supervised preseason phase and in-season phase that incorporates a dynamic warm-up, stretching exercises, lower extremity strengthening exercises, plyometrics, balance, and sport-specific agility with emphasis on proper landing technique stressing a "soft landing" and deep hip and knee flexion[2]. Furthermore, it is important to consider progressions in exercises throughout the duration of the program. Clinicians and coaches should stress to the adolescent athletes that participating in each session is important, and their compliance will be helpful in preventing injury.[1,2] Supervised injury-prevention programs are easy to incorporate into a warm-up before structured activity and can be incorporated at a low cost to the clinician and team.

Future research regarding adolescent ACL-injury-prevention programs should include well-designed prospective randomized controlled trials that allow for blinding of the subjects and assessors to improve study quality,[1–4] longer subject follow-up periods, and longer intervention periods that extend over consecutive years.[1,3,4] Although the incorporation of a standardized warm-up was associated with reductions in ACL injury,[2,4] other key factors such as participant compliance with the intervention protocol may also be a factor in reduction of ACL injuries. More prospective studies over a longer period of time while tracking participant compliance are needed to determine if the intervention is effective at decreasing ACL injury rate in adolescent athletes.[1,2] Future research should also investigate the effect of similar aspects of ACL-injury-prevention training programs (ie, strengthening, balance, plyometrics, stretching, and agility) on ACL injury rates between adolescent males and females and compare variations (different sets, repetitions, frequencies, duration, and exercises) to determine the most effective ACL-injury-prevention training program. This CAT should be reviewed in 2 years or when additional best evidence becomes available to determine whether additional information has been published that may change the clinical bottom line for the research question posed in this review.

## References


1. Steffen K, Myklebust G, Olsen OE, Holme I, Bahr R. Preventing injuries in female youth football—a cluster-randomized controlled trial. *Scand J Med Sci Sports*. 2008;18:605–614.
2. Olsen O, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomized controlled trial. *BMJ*. 2005;330:449–452.
3. Pfeiffer RP, Shea KG, Roberts D, Grandstrand S, Bond L. Lack of effect of a knee ligament injury prevention program on the incidence of noncontact anterior cruciate ligament injury. *J Bone Joint Surg Am*. 2006;88(8):1769–1774.
4. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med*. 2005;33:1003–1010.