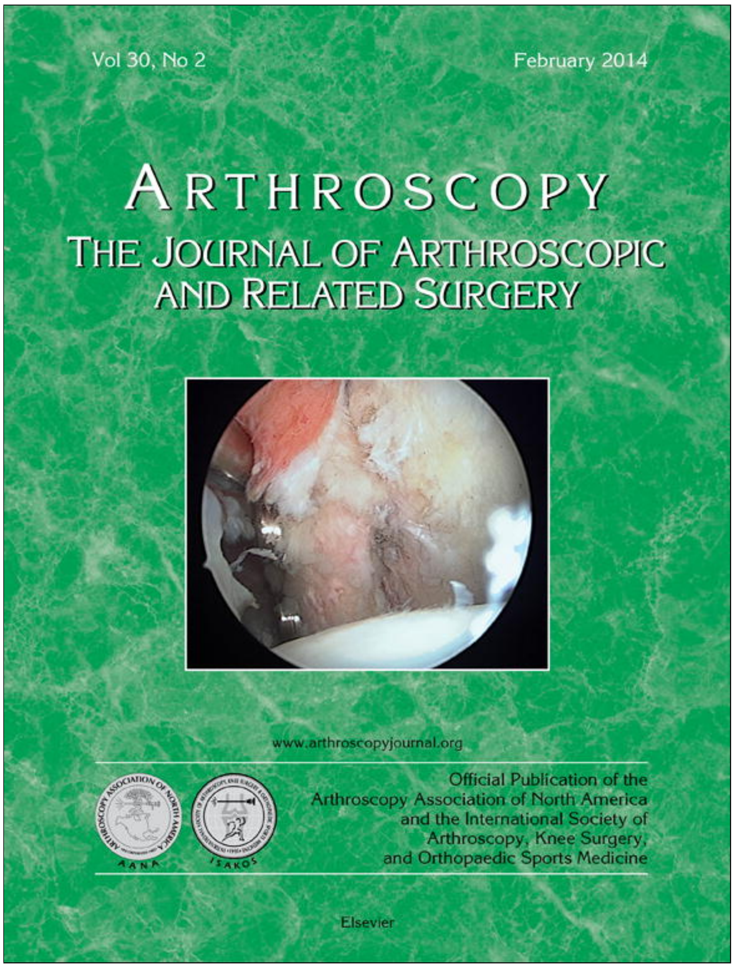
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Systematic Review

Neuromuscular Retraining Intervention Programs: Do They Reduce Noncontact Anterior Cruciate Ligament Injury Rates in Adolescent Female Athletes?

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Purpose: The purpose of this study was to identify neuromuscular training intervention programs that significantly reduced the incidence of noncontact anterior cruciate ligament (ACL) injury rates in female adolescent athletes. **Methods:** A systematic search of PubMed was conducted to determine the outcome of ACL neuromuscular retraining programs in a specific population. The inclusion criteria were English language, published from 1994-2013, original clinical trials, all evidence levels, female athletes aged 19 years or younger, and noncontact ACL injury incidence rates determined by athlete-exposures. **Results:** Of 694 articles identified, 8 met the inclusion criteria. Three training programs significantly reduced noncontact ACL injury incidence rates in female adolescent athletes. These were the Sportsmetrics, Prevent Injury and Enhance Performance, and Knee Injury Prevention programs. The estimated number of athletes who needed to train to prevent 1 ACL injury in these 3 studies ranged from 70 to 98, and the relative risk reduction ranged from 75% to 100%. Five programs did not significantly reduce noncontact ACL injury incidence rates. The ACL injury incidence rates for control subjects were lower in these studies (0.03 to 0.08 per 1,000 athlete-exposures) than in those investigations that had a significant effect (0.21 to 0.49 per 1,000 athlete-exposures). There was wide variability among all programs in the frequency, duration, and timing of training; how training was conducted, supervised, or controlled; the components of the program; how exposure data were calculated; noncontact ACL injury incidence rates in the control groups; and compliance with training. **Conclusions:** Three ACL intervention programs successfully reduced noncontact ACL injury incidence rates in female adolescent athletes. Pooling of data of all ACL intervention programs is not recommended because of numerous methodologic differences among studies. **Level of Evidence:** Level II, systematic review of Level I and II studies.

Each year in the United States, anterior cruciate ligament (ACL) tears occur in an estimated 1 in 3,500 individuals[1] and approximately 125,000 to 200,000 arthroscopic-assisted ACL reconstructions are performed. Most patients who undergo ACL reconstruction are athletes aged younger than 25 years who are frequently involved in high school, collegiate, or league sports.[2] At least two-thirds of ACL tears are noncontact in nature and occur when an athlete is cutting, pivoting, accelerating, decelerating, or landing from a jump.[3-5] The costs of treatment of ACL tears are substantial, and athletes who have concomitant meniscal tears that require resection or other ligament tears that must be reconstructed are at increased risk of premature osteoarthritis.[6-8]

The initial reports of a higher incidence of ACL injuries in female athletes compared with male athletes participating in soccer and basketball appeared in the medical literature in 1994[9] and 1995.[10] Since then, multiple investigations involving high school and collegiate athletes and military recruits have appeared supporting this dilemma.[11-16] Prodromos et al.[16] conducted a meta-analysis entailing 33 articles and found that the mean ACL injury rate for female participants was significantly greater than that for male participants in basketball (0.28 and 0.08, respectively; $P < .0001$), soccer (0.32 and 0.12, respectively; $P < .0001$), and handball (0.56 and 0.11, respectively; $P < .0001$).

Reduced knee flexion angles, valgus collapse at the knee, increased hip internal rotation, and increased internal or external tibial rotation are frequently

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reported at the time of or just before ACL injury. A noncontact ACL rupture most likely occurs immediately after the initial foot strike (commonly with a flatfoot position) because of internal rotation and adduction of the hip, high quadriceps forces, and a knee flexion angle lower than 30°. The subsequent knee abduction (valgus) position often occurs as a result of the pivot-shift subluxation event just after the ACL has ruptured.[17]

There is not enough time for an athlete to alter the body or position of the lower extremity to prevent a noncontact ACL injury. In an analysis of video sequences of this injury, Koga et al.[18] postulated that the ACL ruptures within 40 milliseconds after initial ground contact. Because of this problem, intervention programs have been developed that involve neuromuscular retraining with the goal of altering body positioning and movement patterns to avoid at-risk positions or circumstances believed to cause ACL injuries in athletes. Since the first of these programs was published in 1996,[19] at least 50 have followed that focused on female athletes.[20] There are many differences in these programs with regard to their components, the frequency and duration of training, when training is conducted with regard to the sport season, who conducts the training sessions, athlete compliance, and their ability to successfully alter targeted neuromuscular indices.

The purpose of this study was to systematically review all published ACL intervention programs to determine which programs were successful in significantly reducing the risk of this injury. We chose to focus only on noncontact ACL injuries because these are the type of injuries that these programs attempt to prevent. Second, we analyzed the effectiveness of training only in adolescent female athletes because female athletes aged 18 years or younger appear to have a greater potential of achieving a positive effect from training compared with older athletes.[21] Third, only studies that assessed injury incidence rates according to athlete-exposures were considered. Using injury incidence rate data is a well-known and accepted epidemiologic concept that accounts for variation in exposure between athletes and teams.[22] We hypothesized that we would find intervention programs that significantly reduced the risk of noncontact ACL injuries in female adolescent athletes.

Methods

Literature Search

From January 1994 through May 2013, we searched the Medline and Cochrane databases for all published literature using the following key words and phrases: anterior cruciate ligament injury, ACL injury prevention, ACL neuromuscular retraining, and ACL training. Inclusion criteria were English language, clinical trials of all kinds, Level I to Level IV evidence, female adolescent athletes, noncontact ACL injuries, and injury incidence rates determined according to athlete-exposures. The age limit was 19 years, and studies were included if the age of the athletes was simply indicated as "high school." We also included general review articles, current concepts, commentaries, systematic reviews, and meta-analyses obtained from our search. These articles' reference lists were reviewed to find any other original study that had not otherwise been obtained. In addition, the reference lists of the articles that met the inclusion criteria were searched.

The exclusion criteria were studies that involved only male athletes or that combined data of female and male athletes together, studies that included contact ACL injuries or that combined data of contact and noncontact ACL injuries together, studies that did not provide the number of athlete-exposures, and studies that involved adult athletes. In addition, any study that did not involve athletic training (e.g., cognitive awareness workshops) was not included. Case reports and abstracts from meetings were also excluded.

Data Abstraction

Each study that met the inclusion criteria was abstracted for information regarding (1) the number of trained athletes, (2) the number of untrained (control) athletes, (3) the number of athlete-exposures in trained athletes, (4) the number of athlete-exposures in control athletes, (5) the methods for calculation of athlete-exposures, (6) the number of noncontact ACL injuries in trained athletes, (7) the number of noncontact ACL injuries in control athletes, (8) the results of statistical analysis of the effect of training, (9) the age of athletes, (10) the components of training programs, (11) the duration of each training session (in minutes), (12) the timing of training sessions (preseason, in season, or both), (13) the number of days per week training was conducted, (14) the total number of sessions offered, (15) the total number of weeks training was conducted, (16) the total number of hours training was conducted, (17) personnel responsible for supervising or conducting the training sessions, (18) compliance (attendance) data for training, and (19) the sports that athletes participated in at the time of training or on the completion of training.

Data Analysis

The noncontact ACL injury incidence rates per 1,000 athlete-exposures were either taken directly from the studies if available or calculated if required. The *P* values obtained from the comparison of injury incidence rate ratios between the trained and control groups were also derived directly from the individual studies, with the exception of the updated Sportsmetrics data from our center. For these data, an independent statistician not

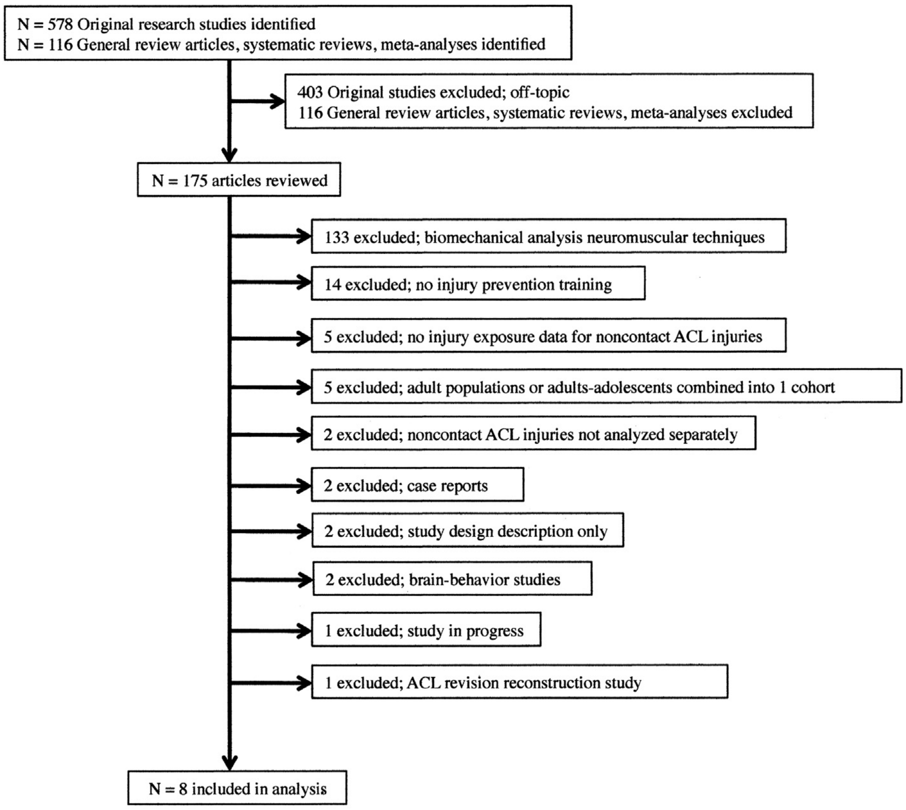

Fig 1. Flowchart of number of studies reviewed.

involved in any of the studies calculated the incidence rate ratios and *P* values from a 2-tailed test to determine whether the difference in injury rates between trained and control athletes was significant. We also calculated the relative risk reduction for each program, which is an estimate of the percentage of risk that is reduced for trained athletes compared with untrained athletes. The number needed to treat was also determined, which is an

Table 1. ACL Intervention Training Programs

Program (Year), Country	Program Type and Timing	Supervision of Training	Times per Week	Total No. of Weeks	Sport	Age
Sportsmetrics (1999), United States	Individual program Preseason	Highly trained instructors	3	6	Soccer, basketball, volleyball	14-18 yr
Sportsmetrics (2012), United States	Individual program Preseason	Highly trained instructors	3	6	Soccer, basketball, volleyball, field hockey, lacrosse, softball	14-18 yr
Olsen (2005), Norway	Warm-up In season	Players	15 consecutive practices and then 1/wk	30	Team handball	15-17 yr
PEP (2005), United States	Warm-up In season	NP	3	12	Soccer	14-18 yr
KLIP (2006), United States	Beginning or end of practice In season	NP	2	15	Soccer, basketball, volleyball	High school
The "11" (2008), Norway	Warm-up Preseason and in season	Coaches, players	15 consecutive practices and then 1/wk	30	Soccer	<17 yr
HarmoKnee (2010), Sweden	Warm-up Preseason and in season	NP	1-2	39	Soccer	13-19 yr
KIPP (2011), United States	Warm-up In season	Coaches	3.3	13	Soccer, basketball	High school
Walden (2012), Sweden	Warm-up In season	Coaches	2	30	Soccer	12-17 yr

KIPP, Knee Injury Prevention program; KLIP, Knee Ligament Injury Prevention program; NP, not provided; PEP, Prevent Injury and Enhance Performance program.

estimate of the number of athletes who need to participate in an intervention program to prevent 1 ACL injury.[23,24]

Results

Literature Search

Our search initially identified 578 original research studies. We also found 116 general review articles, current concepts, commentaries, systematic reviews, and meta-analyses that were reviewed for additional studies but were not included in the final study. A total of 403 articles were excluded because they were off-topic. We reviewed the abstracts and content of the remaining 175 articles, 167 of which were also excluded, as shown in Fig 1. This left 8 articles that were included in this investigation, published from 1999 to 2012.[25-32]

Intervention Programs and Athlete Characteristics

The articles in this study described 8 different ACL intervention training programs: the Sportsmetrics program,[32] the Olsen program,[25] the Prevent Injury and Enhance Performance program (PEP),[26] the Knee Ligament Injury Prevention program,[27] the "11" program,[28] the HarmoKnee program,[29] the Knee Injury Prevention program (KIPP),[30] and the Walden program.[31] Table 1 shows the basic elements of training of these programs and includes an update of the original Sportsmetrics program that incorporated 30 additional minutes of agility and speed training[33] in comparison with the original program that was previously published.[32] The updated program did include the same plyometrics, strength training, and flexibility components as previously described. The individual components of all 8 programs are detailed in Appendix Table 1.

Seven of the training interventions were designed to replace the traditional "warm-up" portions of team practices and were performed throughout the season.[25-31] One program used highly trained instructors to conduct training,[32] 3 used coaches,[28,30,31] 1 used players (watching each other),[25] and 3 did not indicate whether training was supervised.[26,27,29] The programs differed in the number of minutes of training per session (Fig 2), the total number of training sessions conducted (Fig 3), and the total number of hours training was performed (Fig 4).

There were 8,396 trained athletes who had 519,313 exposures, as well as 10,091 control athletes who had 598,618 exposures. The determination of exposure varied among the studies; 4 studies indicated that 1 practice or game represented 1 exposure,[26,27,30,32] 2 investigations used actual hours of practice or competition,[25,31] and 2 studies used calculations involving several factors to determine exposures.[28,29] Soccer

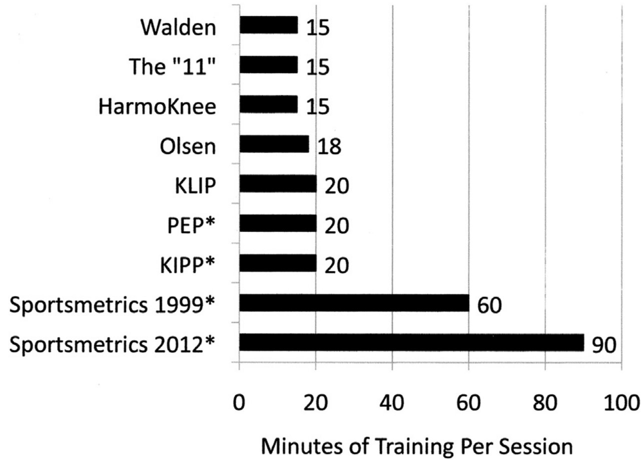

Fig 2. Number of minutes per training session for each ACL intervention program. The asterisks denote programs that significantly reduced the noncontact ACL injury incidence rates. (KLIP, Knee Ligament Injury Prevention program.)

players were the most commonly trained athlete, followed by basketball players. Four programs took place in the United States,[26,27,30,32] 2 in Norway,[25,28] and 2 in Sweden.[29,31]

In all studies, teams were invited to participate in the investigation. After agreement, randomization of the trained and control groups was performed in 4 studies.[25,28,30,31] In the other 4 studies, athletes who trained did so on a voluntary basis and control subjects were obtained from other teams participating in the same league.[26,27,29,32]

Effective of Intervention Programs

Of the 8 programs, 3 significantly reduced the noncontact ACL injury incidence rates (Table 2): Sportsmetrics program, PEP, and KIPP. The relative risk reduction ranged from 75% to 100%, and the number

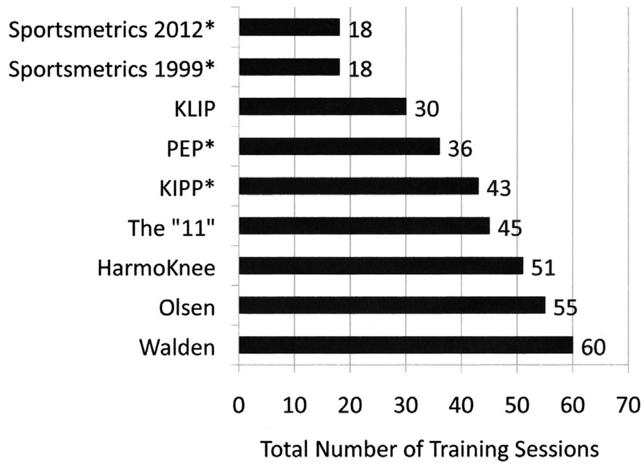

Fig 3. Total number of training sessions offered for each ACL intervention program. The asterisks denote programs that significantly reduced the noncontact ACL injury incidence rates. (KLIP, Knee Ligament Injury Prevention program.)

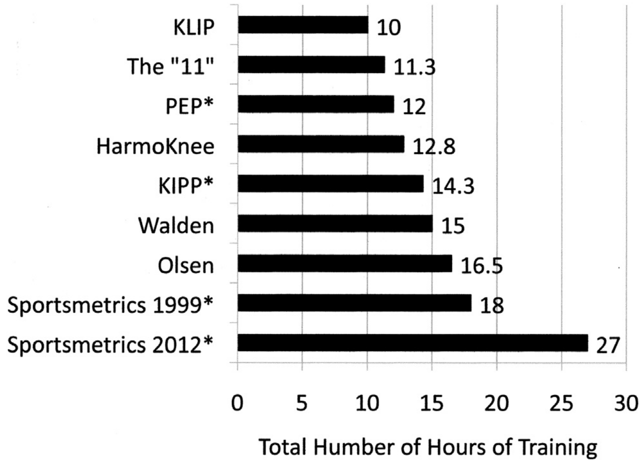

Fig 4. Total number of hours of training offered for each ACL intervention program. The asterisks denote programs that significantly reduced the noncontact ACL injury incidence rates. (KLIP, Knee Ligament Injury Prevention program.)

of athletes needed to train to prevent 1 noncontact ACL injury ranged from 70 to 98.

Five programs did not significantly reduce the noncontact ACL injury incidence rates (Table 3). On analysis of the data from the control groups, the ACL injury incidence rates were lower in these studies (0.03 to 0.08 per 1,000 athlete-exposures) than in those investigations that had a significant effect (0.21 to 0.49 per 1,000 athlete-exposures).

Five studies included compliance data on attendance of training sessions, which were provided for either individual athletes or entire teams (Table 4). The "11" program[28] and Walden program[31] reported low attendance rates. Seventy percent of the athletes in the Sportsmetrics program completed all training sessions.[32] The Knee Ligament Injury Prevention program reported that player attendance rates ranged from 60% to 77%, depending on the sport.[27] The HarmoKnee program reported that 94% of the participating teams attended at least 75% of the training sessions.[29]

Discussion

The main finding of this systematic review was that 3 neuromuscular retraining intervention programs significantly reduced the noncontact ACL injury incidence rates in female adolescent athletes. These were the Sportsmetrics program, PEP, and KIPP. The number of athletes who needed to train to prevent 1 ACL injury in these 3 studies ranged from 70 to 98, and the relative risk reduction ranged from 75% to 100%. Although the number of athletes needed to treat appears somewhat high, in our experience, many individuals participate in sports year-round with very little time off. They will achieve, within a few years, a high number of exposures (in both practice and games) that places them at risk of ACL injury. This is especially true in our geographic region for soccer players, who play both indoors and outdoors and who frequently begin competition at a very young age. In fact, there are leagues that recruit boys and girls beginning at the ages of 3 to 4 years to develop soccer-specific skills and play in weekly small-sided games, with sessions offered year-round. For these athletes, by the time they are in high school, they will have already been exposed to well over 1,000 hours of soccer. These high rates of exposures validate ACL neuromuscular intervention programs in the adolescent athlete.

Wide variability existed among the 8 programs in this study in the number of sessions and the total number of hours of training offered, how training was conducted and controlled, the components of the programs, and how athlete-exposures were calculated. In addition, the noncontact ACL injury incidence rates in the control groups in the programs that appeared to be ineffective were much lower than those found in the programs that significantly reduced the risk of injury. These lower-than-expected ACL injury incidence rates were either because of small cohorts[27] or because too few noncontact ACL injuries occurred to reach significance levels.[25,29,31] One group of authors speculated that the low compliance rate with training was the most likely reason their program was ineffective.[28] A few investigators questioned the effectiveness of coach-led instruction, with no control established on the quality of instruction or progression of the program as devised by the study investigators.[28,31]

There is a lack of consensus in the available epidemiologic data regarding noncontact ACL injury incidence rates in adolescent female athletes.[16] In our review these rates in control groups ranged from 0.03 to 0.49 per 1,000 athlete-exposures. Of the 4 investigations that were performed in the United States, 3 showed higher incidence rates that ranged from 0.22 to 0.49 per 1,000 athlete-exposures.[26,30,32] The 2 studies from Norway reported incidence rates of 0.03 and 0.06 per 1,000 athlete-exposures,[25,28] and the 2 investigations from Sweden reported rates of 0.05 and 0.07 per 1,000 athlete-exposures.[29,31] Whether the differences in ACL incidence rates between the United States and Scandinavia represent regional or cultural differences or are due to other factors remains unknown.

Although only 3 of the programs in this review significantly reduced the rate of noncontact ACL injuries, other programs appeared to be successful in reducing the rate of other types of lower limb injuries. The Olsen program significantly reduced the combined incidence of all lower limb injuries classified as moderate and major, all acute injuries, all acute ankle and knee injuries, and all knee ligament injuries.[25] The HarmoKnee program reduced the combined incidence of all types of acute knee injuries and all knee injuries that occurred in noncontact situations. The Walden

Table 2. Intervention Training Programs That Significantly Reduced Noncontact ACL Injury Rates

	Trained Athletes				Control Athletes						
Program (Year)	No. of Athletes	No. of NC ACL	No. of AE	NC ACL Injury Incidence Rate†	No. of Athletes	No. of NC ACL	No. of AE	NC ACL Injury Incidence Rate†	*P* Value	Relative Risk Reduction (95% CI)	Number Needed to Treat* (95% CI)
Sportsmetrics (1999)	366	0	17,222	0	463	5	23,138	.22	<.05	100 (NA to 100)	93 (50 to 722)
Sportsmetrics (1999 + 2012‡)	700	1	36,724	.03	1,120	13	61,244	.21	.03	88 (6 to 98)	98 (59 to 302)
PEP (2005)	1,885	6	67,860	.09	3,818	67	137,448	.49	<.0001	82 (58 to 92)	70 (52 to 105)
KIPP (2011)§	485	2	20,345	.10	370	6	12,467	.48	.04	75 (−25 to 95)	83 (−503 to 38)

AE, athlete-exposures; CI, confidence interval; NC, noncontact.
*Positive value to benefit and negative value to harm.
†Calculated per 1,000 athlete-exposures.
‡Unpublished data.
§Data provided from personal contact with senior author.

Table 3. Intervention Training Programs That Did Not Significantly Reduce Noncontact ACL Injury Rates

	Trained Athletes				Control Athletes						
Program (Year)	No. of Athletes	No. of NC ACL	No. of AE	NC ACL Injury Incidence Rate†	No. of Athletes	No. of NC ACL	No. of AE	NC ACL Injury Incidence Rate†	*P* Value	Relative Risk Reduction (95% CI)	Number Needed to Treat* (95% CI)
Olson (2005)	808	1	93,812	.01	778	5	87,483	.06	NS	81 (−65 to 98)	193 (−1,078 to 88)
KLIP (2006)	577	3	17,954	.17	862	3	38,662	.08	NS	−49 (−638 to 70)	−582 (−114 to 187)
The "11" (2008)	1,073	3	66,423	.05	947	2	65,725	.03	NS	−32 (−691 to 78)	−1,462 (−200 to 276)
HarmoKnee (2010)	777	0	66,981	0	729	5	66,505	.07	NS	100 (NA to 100)	146 (78 to 1,153)
Walden (2012)	2,479	5	149,214	.03	2,085	7	129,084	.05	NS	40 (−89 to 81)	746 (−586 to 228)

AE, athlete-exposures; CI, confidence interval; KLIP, Knee Ligament Injury Prevention program; NC, noncontact.
*Positive value to benefit and negative value to harm.
†Calculated per 1,000 athlete-exposures.

Table 4. Compliance With Training Programs*

Program (Year)	Compliance
Sportsmetrics (1999)	70% of athletes completed entire 6-wk program; 100% completed ≥4 wk of program
KLIP (2006)	Players participated in mean of 60% (basketball), 77% (soccer), and 73% (volleyball) of training sessions
The "11" (2008)	14 teams (24%) completed >20 training sessions (of 45 total sessions offered)
HarmoKnee (2010)	45 teams (94%) completed ≥75% of training sessions
Walden (2012)	Players participated in mean of 21.7% of training sessions

KLIP, Knee Ligament Injury Prevention program.
*The other programs did not report compliance or attendance data.

program significantly reduced the incidence of all ACL injuries when contact and noncontact injuries were combined.[31]

There have been other systematic reviews published regarding the topic of ACL injury intervention training. However, none of these have focused solely on noncontact ACL injuries in adolescent female athletes. Grimm et al.[34] reviewed 10 randomized controlled trials of knee injury prevention programs and concluded that none showed a reduction in ACL injury incidence. This review included studies with male athletes or that combined genders together, investigations with adult and adolescent athletes, and studies with any knee injury, and it included only Level I trials. Herman et al.[35] assessed warm-up intervention programs to determine their effectiveness in preventing any lower limb injury. The investigations in this review focused on all types of ACL injuries, included cohorts with both genders combined, as well as populations of adult and adolescent athletes. Stojanovic and Ostojic[36] reviewed the effectiveness of 9 programs in reducing the rate of ACL injuries. The investigations in this review involved populations of male athletes or both genders combined, adult and adolescent athletes, and all types of ACL injuries.

Several meta-analyses have been published recently regarding the effectiveness of ACL injury intervention training.[16,21,23,24,37-40] The problem inherent with these investigations is that data are pooled from training programs that are vastly different in all of the factors that we have previously discussed, including frequency, duration, and timing of training; how training is conducted, supervised, or controlled; the components of the training program; and how exposure data are calculated. In addition, the populations of these studies vary widely in terms of age and gender of the cohorts, the sports in which the athletes participated, and compliance with training when it was tracked. Moreover, if one only considers the effectiveness of the programs in reducing noncontact ACL injury incidence rates, even greater differences appear. This is the reason we chose to perform a systematic review and not a meta-analysis. Combining all ACL intervention training programs in a meta-analysis may allow for a sweeping generalization to be made that all ACL injury prevention programs are effective. In essence, an overestimate of the magnitude of the treatment effect may occur.[41] The sensitivity of the effectiveness of individual training programs is lost, and care must be taken to understand the implications of the findings of these types of analyses.

In our review, 5 studies tracked and reported compliance with training. In 1 study, athletes recorded their training by documenting the number of repetitions of each jump for each session.[32] In 3 investigations, coaches tracked player attendance at practices and games on a prospective basis.[27,28,31,32] In 1 study, coaches submitted estimates of compliance (<50%, 50%, 75%, or 100%) at the end of preseason training and again at the end of the season.[29] Although the data showed tremendous variation in player attendance, only 1 of these 5 programs significantly reduced the noncontact ACL injury rate incidence. The issue of problems with player and coach compliance with ACL intervention training has been addressed by other authors.[42,43] One potential incentive is to offer programs that enhance athletic performance indices, such as vertical jump height, hip and hamstring strength, speed, and agility.[19,20,44-47]

We focused this review on the impact of neuromuscular retraining in adolescent female athletes. Many investigators have raised the issue of the potential of a positive influence of this type of training in younger individuals, perhaps even more than what may be accomplished in collegiate or adult athletes.[21,48-50] This is because gender-specific differences become evident during puberty and maturation in strength and neuromuscular factors that are believed to place adolescent female athletes at a higher risk of ACL injury.[51-58] These factors include an imbalance in quadriceps and hamstring strength, increased anterior knee laxity, and increased hip internal rotation and a valgus lower limb alignment position on landing from a jump. Many studies have shown that it is feasible to improve these and other kinematic or kinetic factors in female athletes, such as landing forces,[19,59] knee flexion angles,[60] the quadriceps-hamstring strength ratio,[19,44,61,62] and lower limb alignment on landing.[61-64]

Neuromuscular "warm-up" intervention programs offer advantages such as ease of implementation on a large-scale basis, conduction of training by coaches, and short time commitments to complete training. However, there are potential drawbacks including little to no supervision of training, poor compliance if coaches are not convinced of the program's effectiveness, and failure to improve neuromuscular indices. When PEP was studied in collegiate athletes, the investigators noted that training may require repeated use for several weeks for athletes to show improvements in strength, balance, and proprioception.[65] This conclusion came from the study data, which showed that higher rates of ACL injuries occurred early compared with later in the soccer season. The authors suggested that it may be prudent to conduct training during the offseason or in preseason practices to produce the desired cumulative neuromuscular effect that would influence ACL injuries during games. Our experience shows that a formal program composed of several plyometric jumps and strength, flexibility, and agility exercises that is supervised by trained instructors is required to achieve the desired changes in neuromuscular indices.[19,61] After 6 weeks, athletes may then continue training with a shorter warm-up program, which is completed before every practice.[66]

Limitations

The limitations of this systematic review include those inherent in determining the results of studies of varying design, including frequency, duration, and timing of training; how training was conducted, supervised, or controlled; the components of the training program; and how exposure data were calculated. Identifying the essential elements of ACL intervention training that are responsible for the reduction of injury incidence is not possible because of these inconsistencies. Some of the studies had a potential selection bias because coaches and teams volunteered to train and may have had higher motivation levels than those who chose not to participate.

Conclusions

Three ACL intervention programs successfully reduced noncontact ACL injury incidence rates in female adolescent athletes. Pooling of data of all ACL intervention programs is not recommended because of numerous methodologic differences among studies.

Acknowledgment

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Appendix Table 1. ACL Intervention Training Program Components

Program (Year)	Dynamic Warm-up	Plyometrics	Balance	Strengthening	Agility Drills	Flexibility
Sportsmetrics (1999)	None	Weeks 1-2: 7 jumps Weeks 3-4: 9 jumps Weeks 5-6: 7 jumps	None	9 exercises; abdominal, back, lower extremity, upper extremity	None	9 exercises performed as warm-up
Sportsmetrics (2012)	10 exercises	Weeks 1-2: 7 jumps Weeks 3-4: 9 jumps Weeks 5-6: 7 jumps	None	Based on equipment available: targets core, lower extremity, upper extremity	Sport specific, 30 min in duration	11 exercises
Olsen (2005)	8 jogging, running drills	None	5 exercises on balance mat	2 exercises: quadriceps, hamstring	2 drills	None
PEP (2005)	3 jogging, running drills	5 jumps	None	3 exercises: quadriceps, hamstring, gastroc-soleus	3 drills	5 exercises
KLIP (2006)	None	Weeks 1-2: 4 jumps Weeks 3-4: 6 jumps Weeks 5-6: 6 jumps Week 7 to end: 6 jumps	None	None	4 drills	None
The "11" (2008)	1 jogging exercise	5 jumps	4 exercises, 3 performed on balance mat	4 exercises: 2 core stability, 2 hamstring	None	None
HarmoKnee (2010)	5 exercises	4 jumps	None	6 exercises: 3 core stability, 3 lower extremity	None	6 "muscle activation" exercises
KIPP (2011)	17 exercises	Week 1: 8 jumps Week 2: 9 jumps Week 3: 9 jumps Week 4 and onward: 8 jumps	None	10 exercises: core, lower extremity, upper extremity	3 drills	None
Walden (2012)	None	1 jump for each of 4 levels (1 per session)	None	5 exercises: core, lower extremity	None	None

KIPP, Knee Injury Prevention program; KLIP, Knee Ligament Injury Prevention program; PEP, Prevent Injury and Enhance Performance program.