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THE ANTERIOR CRUCIATE LIGAMENT INURY PREVENTION PROGRAM: A META-ANALYSIS

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The purpose of this study was to evaluate the effect of a neuromuscular protocol on the prevention of anterior cruciate ligament (ACL) injury by performing meta-analysis. An extensive literature review was conducted to identify relevant studies, and eventually, only seven randomized controlled trials or prospective cohort studies were included in the analysis. Subgroup analysis revealed that an age under 18, soccer rather than handball, pre- and in-season training rather than either pre or in-season training, and the plyometrics and strengthening components rather than balancing were significant. Meta-analysis showed that pre- and in-season neuromuscular training with an emphasis on plyometrics and strengthening exercises was effective at preventing ACL injury in female athletes, especially in those under 18 years of age.

KEY WORDS: anterior cruciate ligament, injury prevention program, meta-analysis.

INTRODUCTION: Anterior cruciate ligament (ACL) injuries in athletes are common, and female athletes are 4–6 times more prone to these injuries than their male counterparts at similar levels of exertion, despite the fact that the majority of ACL injuries occur in males (Arendt & Dick, 1995; Hewett et al., 2006).
Several different preventive programs have been attempted (Heidt et al., 2000; Hewett et al., 1999; Mandelbaum et al., 2005; Myklebust et al., 2003; Petersen et al., 2005; Pfeiffer et al., 2006; Soderman et al., 2000), and each of these is based on different design concepts and emphasizes different components of preventive exercise including plyometrics, strengthening, balancing, endurance, and stability. However, the overall effectiveness of preventive exercise with respect to enhancing neuromuscular control and preventing ACL injuries in female athletes remains to be verified (Hewett et al., 2006). Furthermore, it has not been determined which program is most effective, and how a program should be scheduled, and it is not known which biomechanical component of protocol plays a consequential role. They also encompass different level of commitment, which should be taken into due consideration for the professional athletes lie in a unique situation (Hewett et al., 2006).
The purpose of this study was to evaluate the effectiveness of ACL injury prevention programs for female athletes using meta-analysis approach, and to identify the essential components of the prevention programs. We hypothesized that neuromuscular training program is effective at preventing ACL injury, and that more effective training protocols could be devised by identifying contributory components by analyzing previously proposed protocols.

METHODS: An evaluation committee consisting of three orthopedic surgeons and one biomechanical investigator, all of whom had considerable experience in the care of the ACL injury participated in the study. An extensive search of the literature was performed. As of June 2007, a computerized Medline search was conducted using multiple Boolean operators and combinations of the following eight keywords: knee injury, ACL injury, gender difference, injury prevention, neuromuscular training, plyometrics, strengthening training, and balance training. The Cochrane Database for Systemic Reviews was also searched to identify any studies that may have been published in the orthopedic, rehabilitation, or biomechanical literature. In addition to the web-based search, three investigators performed a manual search of Journals published in English or Korean. The proceedings of the American Academy of Orthopaedic Surgeons and textbooks also were scrutinized manually. Finally, contents experts interested in ACL injury preventive neuromuscular training programs were contacted for additional studies that may have been missed.

Identified articles were evaluated by grading level of evidence, as follows: (1) randomized controlled trial, (2) prospective cohort study, (3) retrospective case control study, (4) case series, (5) case report or expert opinion. Only randomized controlled trials and prospective cohort studies were included. Each member of the evaluation committee scrutinized the identified articles and categorized each one by marking A: included in the current study, B: considered including after committee discussion; favorable, C: decided after committee discussion; unfavorable, D: excluded from the study, according to the relevance of the study.

A total of 2,215 articles were identified from the keyword search and 2,184 studies were excluded after reviewing abstracts. A review of the remaining 31 investigations by evaluation committee ruled out 24 studies, and left 7 eligible studies by Hewett et al. (1999), Heidt et al. (2000), Soderman et al. (2000), Myklebust et al. (2003), Mandelbaum et al. (2005), Peterson et al. (2005), and Pfeiffer et al. (2006).

To assess the overall effects of preventive programs by pooling the data, we documented numbers in the trained and untrained groups and the incidences of ACL injury in each group. To identify the significant components of the preventive programs, the subgroup analyses were conducted on parameters included in more than one study. Ages was divided by 18 years for devoted college athletic competition was implemented from that age. The types of sports included were soccer and handball. The training times were classified as pre-season, in-season, and both the pre- and in-seasons. The biomechanical components of the preventive programs were plyometrics, strengthening, and balancing exercises.

A meta-analysis was performed on an intention-to-treat basis. For each study, odds ratios (OR) and 95% confidence intervals (CI) were calculated from the frequency tables of individual studies analyzed by Mantel–Haenszel common OR estimate. The DerSimonian and Laird's methods were used as random-effects model to obtain summary ORs and 95% CIs. Heterogeneity between studies was tested using the chi-square test. Publication bias was assessed using the Egger regression asymmetry test and the Begg and Mazumdar adjusted rank correlation test (Begg & Mazumdar, 1994; Egger et al., 1997). The Egger test makes more assumptions and is more sensitive to many types of bias than the Begg and Mazumdar test (Macaskill et al., 2001). Subgroup analyses were performed in the same manner using ORs and 95% CIs. All statistical analyses were performed using STATA (version 9.2 [Special Edition]; Stata Corp., College Station, TX, USA).

RESULTS: Five of the seven studies supported the efficacy of the preventive programs, while the other two studies did not. The meta-analysis conducted by pooling the seven eligible studies showed that the incidence of ACL injury was 34 injuries out of 3,999 participants in trained group, and 123 injuries out of 6,462 participants in untrained group with an OR of 0.40 and a 95% CI of [0.27, 0.60] in the fixed model, which demonstrated the effectiveness of the preventive training. No significant heterogeneity was found among studies, and no significant publication bias was evident.

The OR [95% CI] of subjects under the age of 18 was 0.27 [0.14, 0.49] and exercise preventive program among these subjects proved to have a more favourable effect than on adults with 0.78 [0.230, 2.64]. Exercise preventive program had more effect on soccer players, 0.32 [0.19, 0.56] than on handball players, 0.54 [0.30, 0.97]. Pre- and in-season exercise preventive program 0.54 [0.30, 0.97] was effective, while only pre-season exercise preventive program, 0.35 [0.10, 1.21], or only in-season exercise preventive program 0.32 [0.17, 0.59] were not. The plyometric 0.37 [0.24, 0.55] and strengthening components of exercise preventive program protocol (0.21 [0.11, 0.43] vs. 0.69 [0.41, 1.15]) were effective whereas balancing (0.63 [0.37, 1.09] vs. 0.27 [0.14, 0.49]) was not.

DISCUSSION: The mechanism of ACL injury can be divided into contact and non-contact. The non-contact mechanism constitutes to 70% of overall incidence (McNair et al., 1990). The contact type of ACL injury is determined by the disposition of the knee and the nature of the external force at the time of injury, which cannot be prevented by preventive exercise. Neuromuscular preventive programs target noncontact ACL injuries (Hewett et al., 2006). Five of the seven identified studies in the current study compared non-contact ACL injury (Myklebust et al., 2003), while the other two (Soderman et al., 2000; Heidt et al., 2000) studies provided no information on non-contact or contact type of injury. Moreover, the number of injured ACLs after a second intervention season was not documented in Myklebust's study (Myklebust et al., 2003). The OR and 95% CI of the remaining four studies (Hewett et al., 2006; Mandelbaum et al., 2005; Petersen et al., 2005; Pfeiffer et al., 2006) which focused only on non-contact ACL injury were 0.36 and [0.23, 0.54], which is even more affirmative for preventive training.

The intensity of each study protocol deserves attention for it must be at a certain level to have a positive effect (Hewett et al., 2006). Program intensities were very different for the Soderman's (Soderman et al., 2000) and the Hewett's (Hewett et al., 1999) protocols. The balance board training used for female soccer players in Soderman's prospective randomized study (Soderman et al., 2000) was a home-based program followed by an additional 10–15 min of standard physical training, initially conducted daily for 30 days and then at 3 times per week for the remainder of the season. The results showed no significant differences between training and control groups (Soderman et al., 2000). The other protocols required more concentrated participation and higher degrees of exercise intensity. Hewett et al. (1999) incorporated a comprehensive exercise of high intensity program. Training session times in the reviewed studies varied from 10 to 75 min. Hewett et al. (75 min) and Heidt et al. (2000) (60 min) implemented comprehensive protocols, which are probably too difficult to execute in-season period, whereas Pfeiffer et al. (2006) (20 min), Peterson et al. (2005) (10 min), Mandelbaum et al. (2005) (20 min), Myklebust et al. (2003) (15 min), Soderman et al. (2000) (10–15 min) proposed a relatively short programs, which might be integrated into a regular exercises in-season, causing less burden for the athletes. Great care should be taken when pooling the data during meta-analysis due to the different intensities of intervention. The odds ratio and the 95% CI from the six studies excluding Soderman's study were 0.37 and [0.24, 0.55], respectively, indicating that training programs of high intensity had a more favourable effect on ACL injury prevention.

The prevention of non-contact ACL injury should focus on neuromuscular–biomechanical factors for they are the only components modifiable by training. Exercise protocols should include warming-up, plyometrics, strengthening, balancing, agility, flexibility, postural adaptation, and an athletic performance enhancement program. In our subgroup analysis, the plyometric, strengthening, and balancing components were found to be the major three components of interest. Plyometric exercises increase power, muscle strength, and speed (Mandelbaum et al., 2005), whereas strengthening exercises including walking lunge. Russian hamstrings, single toe raise increase the muscle power to stabilize the knee joint. The effect of the balancing exercises could be enhanced by proprioceptive exercises (Myklebust et al., 2003). Neuromuscular exercise programs that combine plyometric, strengthening, and balancing have been shown to decrease the ACL injury risk and also to enhance the athletic performance (Myklebust et al., 2003). Hewett et al. (1999) reported that the plyometric exercises have a positive effect on the prevention of ACL injury and that the balancing exercises alone without other biomechanical components do not. On the other hand, Pfeiffer et al. (2006) concluded that plyometric training does not have a favourable effect on the preventions of ACL injury. It has also been reported that a combination of strengthening and balancing exercises has synergistic benefit by enhancing the dynamic stability and decreasing the injury risk (Paterno et al., 2004). Although the optimal combination of neuromuscular-biomechanical components remains to be verified, our study shows that plyometric and strengthening components are probably necessary factors of any training program.

CONCLUSION: This meta-analysis shows that ACL injury preventive exercise programs are effective in female athletes, especially in those under 18 years of age, and for soccer players rather than handball players. Plyometric and strengthening exercises were found to be essential components of such training protocols, whereas balancing exercises were not.

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