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Literature review

Effects of knee injury primary prevention programs on anterior cruciate ligament injury rates in female athletes in different sports: A systematic review

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A R T I C L E I N F O

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A B S T R A C T

Background: Anterior Cruciate Ligament (ACL) injury is frequently encountered in sports.
Purpose: To analyze the effects of ACL injury prevention programs on injury rates in female athletes between different sports.
Methods: A comprehensive literature search was performed in September 2012 using Pubmed Central, Science Direct, CINAHL, PEDro, Cochrane Library, SCOPUS, SPORTDiscus. The key words used were: 'anterior cruciate ligament', 'ACL', 'knee joint', 'knee injuries', 'female', 'athletes', 'neuromuscular', 'training', 'prevention'. The inclusion criteria applied were: (1) ACL injury prevention training programs for female athletes; (2) Athlete–exposure data reporting; (3) Effect of training on ACL incidence rates for female athletes.
Results: 13 studies met the inclusion criteria. Three training programs in soccer and one in handball led to reduced ACL injury incidence. In basketball no effective training intervention was found. In season training was more effective than preseason in ACL injury prevention. A combination of strength training, plyometrics, balance training, technique monitoring with feedback, produced the most favorable results.
Conclusion: Comparing the main components of ACL injury prevention programs for female athletes, some sports-dependent training specificity issues may need addressing in future studies, related primarily to the individual biomechanics of each sport but also their most effective method of delivery.

1. Introduction

Anterior cruciate ligament (ACL) tear, is one of the most common knee injuries in sports (McCarthy, Voos, Nguyen, Callaghan, & Hannafin, 2013; Yu & Garrett, 2007), usually occurring in a multitude of sports such as basketball, soccer, handball, alpine skiing and tennis (Bahr & Holme, 2003; Paszkewicz, Webb, Waters, Welch McCarty, & Van Lunen, 2012). Extrapolating the data of a study to the whole US collegiate population, an annual average of more than 2000 ACL injuries in 15 different sports has been reported (Hootman, Dick, & Agel, 2007).

A 2–8 times higher incidence of ACL injury in female compared to male athletes has been documented (Agel, Arendt, & Bershadsky, 2005; Arendt & Dick, 1995; Bjordal, Arnły, Hannestad, & Strandt, 1997; Hootman et al., 2007; Mountcastle, Posner, Kragh, & Taylor, 2007), therefore a significant amount of research is focusing on female participants of various ages and sports (Myer, Sugimoto, Thomas, & Hewett, 2013; Sugimoto, Myer, McKeon, & Hewett, 2012). A difference in ACL incidence rates has been reported for both sexes for different sports. Specifically, for females the injury rate-reported in number of injuries/1000 athlete-exposures (1 exposure = 1 game or practice) was 0.28 for soccer, 0.23 for basketball, relatively smaller for volleyball (0.09) and the highest for gymnastics (0.33) (Hootman et al., 2007).

Scientific studies support that females are at increased risk for an ACL injury due to sex specific anatomical and hormonal differences as well as sex disparities in neuromuscular (NM) factors (Alentorn-Geli et al., 2009; Griffin et al., 2006; Hewett, Myer, & Ford, 2006). Studies examining the relation of female hormones and increased risk of ACL injury in females have not yet concluded on the relative importance of this factor (Beynnon, 2008; Hewett, Zazulak, & Myer, 2007). Additionally, although studies have investigated the relation of sex specific anatomical differences in relation to an ACL injury, those differences remain non-modifiable (Alentorn-Geli et al., 2009; Hewett, Myer, et al., 2006; Uhorchak, Scoville, Williams, Arciero, St Pierre, & Taylor, 2003).

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Neuromuscular (NM) control of knee joint stability as a risk factor has received particular attention, since between-gender differences in movement and muscle activation patterns have been purportedly related to an increased risk of ACL injury especially in females (Chappell, Creighton, Giuliani, Yu, & Garrett, 2007; Chappell, Yu, Kirkendall, & Garrett, 2002; Ford, Myer, & Hewett, 2003; Ford, Myer, Toms, & Hewett, 2005; Hewett et al. 2005; McLean, Lipfert, & Van Den Bogert, 2004). Many studies have reported that female athletes perform several sporting maneuvers such as landing from a jump, cutting and pivoting with decreased hip and knee flexion, increased knee valgus, increased hip internal rotation, increased external rotation of the tibia and less knee joint stiffness resulting from high quadriceps to hamstrings activity compared with their male counterparts (Chappell et al., 2007; Chappell et al., 2002; Colby, Francisco, Yu, Kirkendall, Finch, & Garrett, 2000; Decker, Torry, Wyland, Sterett, & Richard Steadman, 2003; DeMorat, Weinhold, Blackburn, Chudik, & Garrett, 2004; Huston & Wojtys, 1996; McLean, Huang, Su, & Van Den Bogert, 2004; Padua, Carcia, Arnold, & Granata, 2005; Pollard, Davis, & Hamill, 2004).

It has been shown that NM risk factors are modifiable through neuromuscular training, leading to improved sport performance also (Chappell & Limpisvasti, 2008; Chimera, Swanik, Swanik, & Straub, 2004; Herman, Weinhold, Guskiewicz, Garrett, Yu, & Padua, 2008; Lephart et al., 2005; Myer, Ford, Brent, & Hewett, 2006; Myer, Ford, Brent, & Hewett, 2007; Myer, Ford, Palumbo, & Hewett, 2005; Paterno, Myer, Ford, & Hewett, 2004), however the success of injury prevention programs incorporating aspects of NM training is variable (Sugimoto, Myer, McKeon, et al., 2012).

Given that most ACL injuries occur in non-contact situations (Paszkewicz et al., 2012; Renstrom et al., 2008) usually during cutting or pivoting maneuvers (Arendt & Dick, 1995; Krosshaug et al., 2007; McLean, Huang, et al., 2004; McLean, Huang, & Van Den Bogert, 2005; McLean, Walker, Ford, Myer, Hewett, & van den Bogert, 2005; Olsen, Myklebust, Engebretsen, & Bahr, 2004) and single-leg landing (Arendt & Dick, 1995; Krosshaug et al. 2007; Olsen, Myklebust, et al., 2004), the different biomechanical demands of sports defined by the frequency of occurrence of such events, may also need to be taken into account. The difference in incidence rates in females between different sports (Hootman et al., 2007) may partly be explained by differences in the biomechanical demands of sports themselves (Cowley, Ford, Myer, Kernozek, & Hewett, 2006; Munro, Herrington, & Comfort, 2012; Xie, Urabe, Ochiai, Kobayashi, & Maeda, 2013), different fatigue development in those sports (Chappell, Herman, Knight, Kirkendall, Garrett, & Yu, 2005; Delextrat, Gregory, & Cohen, 2010; Frisch, Urhausen, Seil, Croiser, Windal & Theisen, 2011), environmental factors (Alentorn-Geli et al., 2009; Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2003), protective equipment used (Beynnon, 2008) and even whether athletes are considered as 'high' or 'low' risk for contracting an ACL injury through participation in a particular sport, based on the risk factor of increased knee abduction moment when performing a drop vertical jump (Myer et al. 2007).

Therefore, the success of injury prevention programs for the different sports was decided as the topic of this systematic review in order to analyze the content of successful programs and their method of delivery. Issues examined were the compliance level (Soligard et al., 2010; Sugimoto, Myer, Bush, Klugman, McKeon, & Hewett, 2012), the inclusion of multiple training components, training volume, incorporation of sports-specific drills (Myer et al., 2006) and whether these were also practiced in a field environment (McLean, 2008; Shultz, Schmitz, Benjaminse, Chaudhari, Collins, & Padua, 2012), and whether adequate feedback on sports-specific performance was provided to promote motor reprogramming (Benjaminse & Otten, 2011; Powers & Fischer, 2010).

2. Materials and methods

2.1. Study selection

The inclusion criteria for the randomized and non-randomized controlled studies used in this systematic review were the following:

(1) ACL injury prevention training programs for female athletes;
(2) Athlete–exposure data, expressed in hours. 1 athlete-exposure (1 A–E): 1 athlete participating in 1 practice or game & 1 A–E = 2 h (Hewett, Ford, & Myer, 2006; Hootman et al., 2007);
(3) Effect of training on ACL incidence rates for female athletes

The exclusion criteria were the following:

(1) Studies testing the effects of ACL injury prevention training programs only on male athletes.
(2) Studies only using video awareness or cognitive training techniques.
(3) Studies that focused on the effects of neuromuscular training following ACL reconstruction.

2.2. Search strategy

A systematic search was performed in September 2012 in the following electronic databases: Pubmed Central, Science Direct, CINAHL, PEDro, Cochrane Library, SCOPUS, SPORTDiscus. All databases were searched in the English language from the earliest records available, for studies including human subjects. The following key words were used: 'anterior cruciate ligament', 'ACL', 'knee joint', 'knee injuries', 'female', 'athletes', 'neuromuscular', 'training', 'prevention' (Table 1). The reference lists of the relevant studies were also reviewed to identify other potentially relevant studies. Additional sources for hand searching included sport injury textbooks (Olsen et al., 2004). The abstracts of the potentially relevant studies were reviewed. For studies with no available abstract, information was taken from the article title. If an abstract did not give adequate information as to whether the study met the inclusion criteria the full text of the study was reviewed.

2.3. Methodological quality evaluation of studies

Two reviewers (MM & GK) independently rated the methodological quality of included studies that were RCTs with the PEDro scale (Physiotherapy Evidence Database, 2012). Studies with a score

Table 1
Stepped PubMed host search strategy with the number of studies.

Step	Strategy	No.
#1	Anterior cruciate ligament[T/AB]	9809
#2	ACL [T/AB]	8331
#2	Knee joint [T/AB]	13449
#3	Knee injuries [T/AB]	1164
#4	(((#1) OR#2) OR#3) OR#4	26125
#5	Female[T/AB]	413407
#6	Athletes[T/AB]	22822
#7	(#5) OR#6	433276
#7	Neuromuscular [T/AB]	38100
#8	Training [T/AB]	218550
#9	Prevention [T/AB]	324143
#10	((#7) OR#8) OR#9	569577
#11	((#4) AND#7) AND#10 (Limits: Human, English)	342

[T/AB], Title and Abstract.