

Material and methods

Aim of the current systematic review

The aim of the current systematic review is to systematically underpin the risk factors predisposing to ACL injury among football players, according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines, as well as to the “Muscle, Ligament and Tendon Journal” guidelines⁸.

Search strategy

Two Authors independently screened the literature, using a string of keywords such as “ACL injury”, “football players” and “risk factors”, properly connected by Boolean operators. When appropriate, medical subject headings (MeSH) and wild-card options were used. Target journals were hand-searched, in order to increase the chance to get all relevant articles. For each article, the following pieces of information were extracted and recorded on an *ad hoc* Excel spreadsheet. Search strategy is detailed in Table I, to which the reader is kindly referred for further details.

Results

After screening 267 articles 21 have been included and synthesized in the current systematic review. Characteristics of included studies are shown in Table II.

Gender

Quisquater⁹ et al. found that female gender was associated with ACL injury risk. This was in agree with Roos et al.¹⁰, who showed that female population resulted in an OR of 1.6 (95% CI 1.3-2.1). Other studies confirmed this finding and found that interaction between female gender and another parameter was associated with higher ACL injury rate¹¹⁻¹³. A meta-analysis carried out by Prodromos et al.¹⁴ found that female: male ratio in ACL injured football players was 2.67.

ACL injury rate is equal to 0.063 events per 1,000 hours of exposure time¹¹, being higher among female subjects (0.10/1,000 hours of exposure/match, versus 0.05 among male players)^{11,12}.

Age

Some studies have found that age over 18 years could be considered as a risk factor of ACL injury. Allen¹⁵ et al. found that relatively older age (OR 1.5 per year; p=0.03) was associated with ACL graft tear but not with contralateral ACL injury. Conversely, Roos et al.¹⁰ found that younger age was associated with higher ACL injury rate.

Anatomic and biomechanical factors

Several anatomic and biomechanical factors are associated with ACL injury risk in the extant literature. However, few studies have rigorously assessed these relationship among ACL-injured football players. Söderman et al.¹⁶ found that joint laxity, low postural

Table I. Search strategy used in the study

Search strategy items	Details
Searched databases	Pubmed/MEDLINE, Scopus, ISI
Searched string	(“anterior cruciate ligament” OR ACL) AND (lesion OR tear OR rupture OR injury) AND (soccer OR football) AND risk
Inclusion criteria	P: Articles investigating anterior cruciate ligament injuries in football players competing at any level. I: None (only observational, non-interventional studies were synthesized). C: With non-injured football players. O: Strength of the association between a risk factor and anterior cruciate ligament injury. Primary articles
Exclusion criteria	P: Articles investigating athletes in general and for which data relative to football players only could not be extracted. I: Articles dealing with the impact/effectiveness of prevention programs or interventions. C: With other sport disciplines. O: Articles studying risk factors of knee injury not focusing on anterior cruciate ligament rupture or for which data specifically related to anterior cruciate ligament could not be extracted; articles investigating electromyography, electromechanics, biomechanics, kinetics and kinematics of anterior cruciate ligament in non-injured football players, linking the findings with putative mechanisms of ACL injury; articles investigating tests for predicting risk factors of anterior cruciate ligament injury in football players; articles focusing on treatment and management of anterior cruciate ligament in football players from a clinical/surgical standpoint; articles studying return to play after anterior cruciate ligament injury in football players. Review articles
Time filter	None set
Language filter	None set
Target journals	American Journal of Sports Medicine; British Journal of Sports Medicine

Table II. Characteristics of included studies.

Reference	Study design	Evidence level	Participants	Country	Risk factor	Strength of the association
Ahldén et al., 2012	Case series	4	18.000	Swedish	Previous ACL injury	Association
Allen et al., 2016	Case-control	4	90 female players (out of 180 athletes)	USA	Previous ACL injury	Association
Balazs et al., 2015	Meta-analysis	1	10 studies	USA	Synthetic surfaces	No association
Ejorald et al., 1997	Retrospective cohort study	4	176 patients with ACL reconstruction	Norway	Previous ACL injury	Association
Brophy et al., 2010	Retrospective observational study	4	93 (41 male, 52 female)	USA	Gender, dominant leg	Association
Brophy et al., 2015	Case series	4	55 videos of ACL injuries	USA	Gender, playing position	Association
Dragoo et al., 2012	Descriptive epidemiology study	5	NCAA ISS men's football database from the 2004-2005 through 2008-2009 seasons		Scrimmages compared with regular practices,	Association
Faude et al., 2006	Cohort study	4	143 female players from the National League	Germany	Previous ACL injury, playing position	Association
Ficek et al., 2013	Case-control	4	91 polish professional soccer players	Poland	Genetic risk (COL1A1 polymorphism)	Association
Ficek et al., 2014	Case-control	4	91 male soccer players	Poland	Genetic risk (COL12A1 polymorphism)	No association
Hägglund and Waldén	Randomized controlled trial	1	4.556 soccer players	Sweden	Familial predisposition	Association
Lundblad et al., 2016	Case-control	4	101 elite male soccer players	Sweden	Previous ACL injury	Association
Murray et al., 2016	Retrospective cohort study	4	Four major high school sports in Minnesota	USA	Neuromuscular training	Association
Nicolini et al., 2014	Cross-sectional study	4	440 athletes from different sport activities	Brazil	Age and gender	Association
Prodromos et al., 2007	Meta-analysis	4	25 articles	USA	Gender	Association
Quisquater et al., 2013	Retrospective database-based study	4	56.364 injury reports	Belgium	Gender, age	Association
Roos et al., 1995	Retrospective database-based study	4	188,152 injuries reports	Sweden	Gender, age, playing position, experience	Association
Senişik et al., 2011	Case-control	4	64 elite soccer players	Turkey	Posterior tibial slope	Association
Söderman et al., 2001	Randomized controlled trials	1	221 female soccer players	Sweden	Anatomic and biomechanical factors	Association
Thomson et al., 2015	Meta-analysis	1	4,972 male athletes	UK	Shoe-surface traction	Association
Waldén et al., 2013	Prospective cohort study	4	1,357 European professional soccer players	Sweden	Regional differences (climatic factors)	Association

sway of the legs, hyperextension of the knee joint, and a low hamstring-to-quadriceps ratio during concentric action were factors associated with higher ACL injury rate. Mohamed et al.¹⁷ investigated ACL injury risk in U-23 female soccer players of South Africa, carrying out a case-control study, and found that anatomic factors such as Q-angle, pelvic width, and intercondylar notch were not predictor of ACL injury. Senişik et al.¹⁸ carried out a case-control study, recruiting 64 elite soccer players and 45 sedentary controls, and found that posterior tibial slope was a risk factor of ACL injury.

Genetic risk factors

Ficek et al.^{19,20} examined the association of the collagen, type I, alpha 1 (COL1A1) -1997G/T and +1245G/T polymorphisms, both individually and as haplotypes, with ACL injury in 91 male Polish professional soccer players (aged 23 ± 3 years) with surgically diagnosed primary ACL ruptures *versus* 143 healthy soccer players. After collecting oral epithelial cells, the Authors found that polymorphisms haplotype was associated with reduced risk for ACL rupture (Hap.score -1.98, $p=0.048$). The same Authors investigated also whether the COL12A1 A9285G polymorphism was associated with ACL ruptures in the same sample and found no relationship between COL12A1 polymorphism and risk of ACL injury. Without focusing on polymorphisms, Häggglund and Waldén²¹ performed a randomized controlled trial (RCT) recruiting 4,556 players aged 12-17 years and found that familial predisposition of ACL injury was significantly associated with ACL tear (HR 3.57 [95% CI 1.48-8.62]).

Experience

Being collegiate athletes exposes to higher ACL injury risks. Conversely, Roos¹⁰ et al. found that being elite players was a risk factor (OR 3.3 [95% CI 1.7-6.1]). According to the meta-analysis of Prodromos et al.¹⁴, the collegiate soccer tear rate was 0.32 for female players and 0.12 for male players.

Training and competition effects

Competition was a factor associated with ACL injury in several studies, such as in the study carried out by Quisquater et al.⁹. Dragoo et al.²² found that the risk during game was 10.09 (95% CI, 8.08-12.59) times higher than the risk during practice. In its turn, considering more specifically practice, the injury rate was significantly greater during scrimmage compared with regular practice and walk-through. According to Murray et al.²³, neuromuscular training could decrease ACL injury risk. Prodromos et al.¹⁴ performed a meta-analysis and found that neuromuscular training reduced the ACL tear incidence in soccer by 0.24.

Playing position

Faude et al.²⁴ found that injury incidence was higher in defenders (9.4 injuries per 1,000 hours exposure) and strikers (8.4/1000 hours) than goalkeepers (4.8/1000 hours) and midfielders (4.6/1000 hours).

Brophy et al.²⁵ reviewed 55 videos of ACL injuries and found that most ACL injuries occurred when the opposing team had the ball and the injured athlete was defending (73%). Females were more likely to be defending when they injured their ACL (87 *versus* 63% for males, $p=0.045$). The most common playing action was tackling (51%), followed by cutting (15%). Most injuries occurred due to a contact mechanism (56%) with no significant difference for sex. Females were more likely to suffer a noncontact injury in their left knee (54%) than males (33%) ($p=0.05$). Roos et al.¹⁰ found that playing in the forward position was associated with an OR of 1.8 [95% CI 1.4-2.5].

Rural versus urban team

Interestingly, Murray et al.²³ found that playing in rural *versus* urban team was associated with a decreased risk of sustaining ACL injury.

Dominant leg

Faude et al.²⁴ found that injury risk was higher for dominant legs, especially in case of contact injuries. Brophy et al.²⁶ performed a retrospective observational study, assessing 93 soccer players (41 males, 52 females). When limited to a non-contact injury mechanism, half of the injuries occurred in the preferred kicking leg and the contralateral leg. When stratifying for gender, females were more likely to injure the ACL in their supporting leg, whereas males tended to injure their kicking leg (74.1 *versus* 32%, $p < 0.002$).

Sporting surface

According to Dragoo et al.²² the rate of ACL injury on artificial surfaces was 1.39 (95% CI, 1.11-1.73) times higher than the injury rate on grass surfaces. Balazs et al.²⁷ performed a systematic literature review and synthesized 6 cohort studies. No increased risk of ACL ruptures when playing on synthetic surfaces was found.

Shoe-surface interaction

Thomson et al.²⁸ performed a meta-analysis assessing whether higher shoe-surface interaction could represent a risk factor for ACL injury. They pooled together three prospective studies and obtained an OR of 2.73 [95% CI 2.13-3.15].

Previous ACL injury

Lundblad et al.²⁹ performed a case-control study recruiting 101 elite male soccer players previously injured. History of ACL tears was not associated with a risk of being injured again in the 90-day period after returning to play (OR 1.20 [95% CI, 0.66-2.17], $p=0.65$), as well as being absent for an ACL injury (OR 1.14 [95% CI, 0.64-2.01], $p=0.77$). Brophy et al.²⁶ carried out a cohort study in 100 soccer athletes (55 males, 45 females) and found that females were more likely to have future ACL surgery (20 *versus* 5.5%, $p=0.03$), after re-injuring their ACL or injuring their contralateral ACL. ACL reconstruction on the non-dominant limb was a risk factor for future ACL in-

jury (16 versus 3.5%, $p=0.03$). According to Ahldén et al.³⁰, Faude et al.²⁴ recruited 143 female soccer players from the German National League and found that the risk of a new ACL rupture was increased in players with a previous rupture (OR 5.24, $p=0.01$). Allen et al.³¹ in a cohort of 90 female players found that returning to play after ACLR was associated with a higher risk of sustaining graft tears compared with those who did not return to soccer (15 versus 0%, $p=0.04$). However, there was no significant difference regarding contralateral ACL tears (19% for returning players versus 9% for those who did not return, $p=0.34$). From an etiopathogenetic standpoint, high ACL re-injury rate could be explained by:

1) a premature return to play; 2) an incorrect transition between rehabilitation period to training, which may cause an overloading of the neo-ligament tissues that are not healed or completely remodelled yet; 3) a high motivation of the athlete to show to the coach his/her full recovery, after being absent because of the injury, resulting in a high-intensity level of playing and, as a such, exposing himself/herself to re-injury; 4) an altered knee kinematics and a diminished proprioception; 5) other concomitant injuries at knee joint level; 6) a neo-ligament inclined lower than 50° or higher than 60°; 7) a bad placement of the tibial tunnel (that should be positioned at 40-45% of the tibial plateau); 8) a neo-ligament with an inclination lower than 50° or higher than 60° and 9) an aggressive playing style.

Other factors warranting further investigations

Waldén et al.³² found that ACL injury incidence was lower in the northern European teams with a statistically significant difference (rate ratio 0.43, 95% CI 0.25 to 0.77), especially for noncontact ACL injury (rate ratio 0.19, 95% CI 0.09 to 0.39). ACL injuries may have climate or surface risk factors (possibly related to types and structure of grass and shoe-surface traction) that are universal across different football codes²³.

Conclusions

Football represents a popular sport and ACL injuries are quite common among football players. Despite the importance of such topic, the body of research exhibits a low-fair level of evidence. Only 1 study was a RCT. Further, whilst some risk factors have been highly studied and, therefore, are well-established in the etiopathogenetic framework of ACL rupture, for others the extant literature shows, instead, contrasting findings. Some findings, like regional differences among football players, warrant supplemental investigations. As such, further studies in the field are urgently needed.

Conflicts of interest

The Authors declare no conflicts of interest concerning this article.

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