

## Risk Factors and Prevention Strategies of Anterior Cruciate Ligament Injuries in Young Females Athletes

Cristina Forcada, Aleix Pons, Roberto Seijas, Andrea Sallent, Andrea Dominguez, Oscar Ares, Pedro Álvarez

Cristina Forcada, Aleix Pons, Roberto Seijas, Oscar Ares, Pedro Álvarez, Basic Sciences Department, International University of Catalonia, Spain

Aleix Pons, Andrea Sallent, Vall Hebron Hospital, Barcelona, Spain

Roberto Seijas, Pedro Álvarez, Orthopedic Surgery. Garcia Cugat Foundation Quiron Hospital Barcelona, Spain

Andrea Dominguez, Medical student. Autonomia University of Barcelona, Spain

Oscar Ares, Hospital Clinic Barcelona, Spain

Oscar Ares, Hospital Teknon Barcelona, Spain

**Conflict-of-interest statement:** The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

**Open-Access:** This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

**Correspondence to:** Roberto Seijas, MD, PhD, Quiron Hospital Barcelona, Pza. Alfonso Comín 5-7, 08035 Barcelona, Spain.

Email: [roberto6jas@gmail.com](mailto:roberto6jas@gmail.com)

Telephone: +34932172252

Fax: +34932381634

Received: February 9, 2017

Revised: April 19, 2017

Accepted: April 21 2017

Published online: June 28, 2017

### ABSTRACT

**AIM:** Anterior cruciate ligament (ACL) injuries are more common in young female athletes than in males, and its frequency is increasing.

The aim of the present study is to determine the risk factors that promote these injuries and study the available strategy to prevent ACL injuries in young female athletes.

**MATERIALS AND METHODS:** Different database were used to perform the research (PubMed, Cochrane Plus, Trip Database), using the following keywords: anterior cruciate ligament injury, risk factors, prevention, female and athlete.

**RESULTS:** Risk factors for ACL injuries include: dry weather, high temperatures, playing indoors, artificial boil, sleepless, fatigue, stress, sport specialization, burnout, low self-esteem, incorrect pivoting and landing techniques. Avoiding or modifying these risk factors could prevent ACL injuries as well as performing a specific neuromuscular training.

**CONCLUSION:** There are different ways to prevent ACL injuries that have been proven to be effective, a passive one avoiding the risk factors, and active one, by practicing a specific neuromuscular training.

**Key words:** Anterior cruciate ligament injury; Risk factors; Prevention; Female; Athlete

© 2017 The Author(s). Published by ACT Publishing Group Ltd. All rights reserved.

Forcada C, Pons A, Seijas R, Sallent A, Dominguez A, Ares O, Alvarez P. Risk Factors and Prevention Strategies of Anterior Cruciate Ligament Injuries in Young Females Athletes. An Ephemeral Trend or the Forthcoming 'Gold Standard'? *International Journal of Orthopaedics* 2017; 4(3): 734-739 Available from: URL: <http://www.ghrnet.org/index.php/ijo/article/view/1980>

### INTRODUCTION

The incidence of anterior cruciate ligament (ACL) injuries produced during sport practice in female athletes progressively increases during adolescence, reaching its peak incidence during the mid-to late teens<sup>[1]</sup>. During the past years, women have increased their participation in sports competition, and thus raising the number of non-contact ACL injuries within this population<sup>[2]</sup>.

ACL injuries among female athletes occur between three to eight times more often than in male competitors and, in general, women experience more sports injuries than men when comparing both groups according to activity and hours played<sup>[3]</sup>. Several studies show that there is a multifactorial cause for this difference<sup>[2,3]</sup>. Besides increased sport practice among women, there are other risk factors that make this group more vulnerable to suffer them<sup>[3]</sup>.

The non-contact ACL injuries are the most common ones. These usually respond to two pathophysiological patterns: (1) deceleration of the foot when it is planted on the ground with the hip in internal rotation and with a valgus knee, and (2) anterior displacement of the tibia with contraction of the quadriceps in a position close to the total length of the knee<sup>[3]</sup>.

Several studies have shown an inverse relationship between the athlete's age when starting a specific training program and the incidence of them<sup>[1]</sup>.

The aim of the present study is to review the risk factors and the methods of prevention of ACL injuries in young female athletes.

## METHODS

Research and selection phases are detailed in Figure 1, as well as the inclusion criteria. During February 2015 the literature search was performed using different computerized database (PubMed, Cochrane Plus, and Trip Database), using the following keywords: anterior cruciate ligament injury, risk factors, prevention, female and athlete.

Forty-nine studies were obtained with this research method. Later on, studies were selected according to the type of study, participants included and the results measured in them.

## RESULTS

Six articles that accomplish the inclusion criteria were found: one metaanalysis, three systematic reviews and two clinical randomized assays. Among these studies, two report risk factors of ACL injuries and six preventing strategies (Table 1).

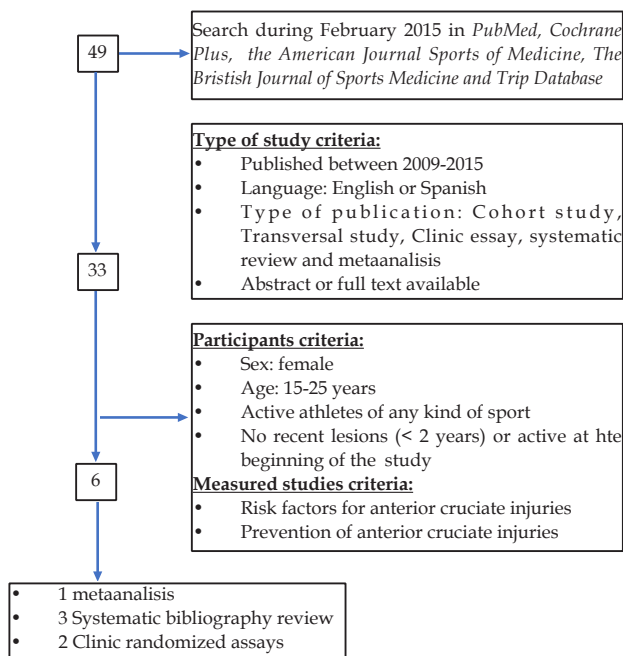


Figure 1 Summary of research and selection phases.

Table 1 Studies included in the revision and their main characteristics.

Author (year)	Type of study	Variables	Comment
Laible <i>et al</i> [2] (2014)	Bibliographic revision	Risk factors (environmental, anatomical, hormonal, neuromuscular technical) for ACL injuries. Prevention programs	It is concluded that most injuries are non-contact. They explain rules to prevent such injuries.
Myer <i>et al</i> [4] (2013)	Clinical assay randomized to double blind	Frontal plane in knee angle ("FPKA"). The FPKA is calculated using a 2D images recorded during a vertical jump.	77 participants. CG: feedback during sprint is augmented. IG: feedback during jumping is augmented.
Myer <i>et al</i> [1] (2013)	Metaanalysis	To review the influence of age on the onset of NTM implementation in the effectiveness to prevent ACL injuries.	14 clinic essays were included. OR is used to compare them.
Sugimoto <i>et al</i> [5] (2012)	Metaanalysis	To review the compliance in NMT to reduce the incidence of ACL injuries.	6 publications were included. IRR was used.
Myer <i>et al</i> [6] (2012)	Bibliographic revision	To detect the mechanisms that increase the risk of ACL injuries.	Specific NMT are proposed.
Elliot <i>et al</i> [3] (2010)	Bibliographic revision	Risk factors (the over-use, butnout, alimentary habits, sleepless, fatigue, substance abuse, stress) for ACL injuries.	Evaluates extended models to prevent ACL injuries.

CG: Control Group; IG: Intervention Group; FPKA: Frontal Plane knee Angle; NMT: Integrative neuromuscular training; OR: Odds Ratio; IRR: incidence odds ratio.

Table 2 Risk factors and prevention of ACL injuries in young female athletes.

Risk factors	Prevention
Environmental factors: dry weather, high temperature, artificial boil, sports center	Environmental factors: wet weather, low temperatures and natural boil
Anatomical factors: BMI, small intercondilar femoral area, genu recurvatum and genu varo, excessive foot pronation, hamstrings weak compared to quadricpes	Anatomical factors: correct BMI
Hormonal factors and dietary habits: pre-ovulatory and ovulatory menstrual phase, calcium and carbohydrates deficit	Hormonal factors and dietary habits: use of OCPs, correct calcium and carbohydrates intake
Sleepless, fatigue, stress and low self-esteem	Proper sleep higiene, avoid fatigue, stress and good self-esteem
Neuromuscular factors: weakened articular system, strength or proprioception deficit, augmented dorsiflexion angle, augmented trunk angle and decreased trunk, hip and knee angle.	Neuromuscular factors: correct sport condition, harmonic balance of hamstrings and quadricpes
Sport technique: pivoting in straight position, decreased flexion angle, valgus knee and flat foot when landing	Sport diversification
Sportive specialization, overuse and burnout	

BMI: Body Mass Index; OCPs: Oral contraceptives.

### Risk factors

Risk factors are summarized in Table 2.

#### (1) Environmental factors

Dry weather<sup>[2,7]</sup>, high temperature<sup>[2,8]</sup>, artificial boil and playing indoors are factors that have been related with an increased risk of ACL injuries for sports players.

Playing indoor is associated with a number of injuries 6 times higher than playing outside<sup>[2,9]</sup>.

#### (2) Anatomical factors

The anatomical elements can be classified into modifiable and non-modifiable. The BMI (Body Mass Index) is perhaps the only modifiable factor within the anatomical. Some studies have shown that an increase in the ideal BMI is associated with an increased risk of ACL injuries<sup>[2,10,11]</sup>, while others argue that there is no relationship between BMI and ACL injuries<sup>[2,12]</sup>. Other factors theoretically unchangeable that are also related with an increase in ACL injuries are: a smaller femoral intercondylar area than usual<sup>[2,13]</sup>, genu recurvatum and varu, excessive foot pronation<sup>[2,14]</sup> and an altered alignment of the lower extremities resulting from the difference of pelvic ratio diameter and femoral length<sup>[3,15,16]</sup>.

Having strong quadriceps with relatively weak hamstrings is also a risk factor for developing these lesions<sup>[2]</sup>.

#### (3) Hormonal factors, dietary habits

The OCPs (Oral Contraceptives) act as a protective factor in ACL injuries<sup>[2]</sup>.

Nutritional deficiencies are common, especially calcium deficit and carbohydrates as factors favoring these injuries<sup>[3]</sup>.

#### (4) Sleep, fatigue and stress

Sleep deprivation along with the resulting increase in fatigue<sup>[3,17]</sup>, stress<sup>[3,18]</sup> and the lack of self-esteem<sup>[3,19]</sup> have been related with an increase in the risk of ACL injury.

#### (5) Neuromuscular factors

The following are risk factors for ACL injury: weakened joint, muscle fatigue, decreased strength, proprioception deficits, high angle dorsiflexion and trunk flexion angles, hip and knee decreased<sup>[2]</sup>. There are also factors in the sport technique that have also been associated with increased ACL injuries such as: pivoting in straight position, decreased knee flexion angle, augmented knee valgus and flat foot when landing<sup>[2]</sup>.

#### (6) Sports specialization, overuse and burnout

There exists a positive relationship between ACL injuries and: training volume, over-use<sup>[3,20]</sup> and a long time of sport playing<sup>[3,21]</sup>. On top of that, over-training athletes can lead to a psychological state known as burnout<sup>[22]</sup> which also favors the appearance of ACL injuries.

#### (7) Substance abuse

There is lack of evidence to reach a conclusion<sup>[3]</sup>.

### Prevention

#### (1) Modification of risk factors

To reduce ACL injuries in young female athletes it should be taken into account (Table 2): (1) The optimal climate is wet and cold, and preferably with natural boil and outdoors<sup>[2]</sup>. (2) To maintain a correct BMI<sup>[2,10,11]</sup>. (3) The use of OCPs is protective<sup>[2]</sup>. (4)

End up sport practice when fatigue appears<sup>[2]</sup>. (5) Strengthen the hamstrings and quadriceps to maintain a proper muscular balance<sup>[2]</sup>. (6) Diversification of sport is recommended. Otherwise, it is recommended to limit the exercise of an exclusive sport to 5 days per week, with at least two months a year break<sup>[3,23]</sup>. (7) Avoiding burnout is essential<sup>[3,22]</sup>. (8) To maintain correct intakes of carbohydrates and calcium<sup>[3]</sup>. (9) To maintain proper sleep hygiene, low stress levels and good self-esteem<sup>[3]</sup>.

#### (2) Specific neuromuscular training

It should be a multifactorial program where skills training include: strength, lower extremity plyometric, agility, proprioception, neuromuscular conditioning and making quick decisions during the game.

This training should be established during the pre-season and continued during it.

This type of training would be good to introduce it schools at the age of pre-teen.

## DISCUSSION

### Risk factors

When studying the environmental factors, the factors included were climate, the type of footwear and the surface where the sport was practiced<sup>[2,7-9]</sup>. According to Laible *et al* the main pathophysiological basis that explains the influence of the environment is the evidence that an increase in the friction coefficient between the shoe and the pitch will increase the risk of injury for the player<sup>[2]</sup>. Different studies show how such friction coefficient increases (and therefore the risk of ACL) when there is a dry climate<sup>[7]</sup>, high temperature<sup>[8]</sup>, artificial grass or indoor playing<sup>[9]</sup>. Although it is known that friction between the shoe and the playing surface is involved in sports injuries, to our knowledge, there has not been published any study yet that specifically evaluates it<sup>[2,8]</sup>. According to the studies reviewed, more research is needed in this area<sup>[2,3]</sup>.

The anatomy of the player is difficult to change, and therefore the possible intervention is limited<sup>[2]</sup>. The BMI is perhaps the only modifiable anatomical factor. Literature regarding the influence of BMI on ACL injuries in female athletes is controversial. Some studies show that an increase in the BMI of the subject is related to an overextended position when landing, which itself has been implicated as an independent risk factor for ACL injuries<sup>[2,10,11]</sup>. However, as Laible *et al* reported in their study, there is literature supporting the no relationship between BMI and ACL injuries<sup>[2,12]</sup>. It is important to emphasize that the literature that holds up that there is no relationship between ACL and BMI, are based on studies where are only included young female athletes, a group of population that their BMI is often not very far from the advisable for their height and age. Also note that the combination of strong quadriceps and hamstrings favor relatively weakened anterior displacement of the tibia which increases the stress in the LCA and this favor ligament injuries<sup>[2]</sup>.

Regarding hormonal factors, ACL cells show both estrogen and progesterone receptors, which are influenced by the menstrual cycle. Zazulak and colleagues found that an increased knee laxity was found in the immediate phase of the pre-ovulatory and ovulatory menstrual cycle<sup>[2,24]</sup>. This increase in the knee's laxity is associated with an increased risk of injury. In women not taking OCPs, there is a significant positive relationship between the pre-ovulatory phase of the menstrual cycle and the increase in the number of ACL injuries. This relationship does not exist in women taking OCPs, which made them conclude that the OCPs act as protectors in

preventing ACL injuries, and in general, ligaments injuries<sup>[2]</sup>. There are extrinsic factors such as dietary habits, stress and the amount of sport performed which also affect the menstrual cycle and hormone levels<sup>[2]</sup>.

Nutritional deficiencies injuries among young female athletes are common, unhealthy dietary practices are not unusual in this group of population<sup>[3,25,26]</sup>. Correct carbohydrate intake is required (the deficit of it leads to muscular fatigue<sup>[3,27]</sup>) and calcium<sup>[3,28]</sup>. The triad in female athletes that include: eating disorder, menstrual irregularities and low bone mass are consequences of extreme adverse effects that may result from sport overuse<sup>[29]</sup>. Certain studies relate these nutritional deficiencies with increased ACL injuries, however, stress fractures and other injuries result from overuse are frequent<sup>[3,30,31]</sup>.

Sleep deprivation is common among young people, especially in women<sup>[3,17]</sup>. Sleep deprivation has been linked to a decrease in athletic abilities<sup>[3,32]</sup>. To the date, the impact of lack of sleep and fatigue influence in the rate of injury has not been studied. However, it is considered that the great disturbance in sleep that exists in this population and the consequent increased fatigue, would be injury predictors of young women athletes<sup>[3]</sup>. Stress causes alterations in attention, decision-making and muscle tension<sup>[3]</sup>. Women seem to be more vulnerable than men to suffer stress<sup>[3,33]</sup> as well as lack of self-esteem. Low self-esteem appears to increase the risk of injury<sup>[3,19]</sup>. However, more research is needed on this area.

The neuromuscular control refers to the unconscious activation of all systems involved in a joint response to a sensory stimulus. Unconscious muscle activation is crucial in many sports, including changes of direction, quickly accelerations and decelerations. And this deficit has been associated with increased ACL injuries<sup>[8]</sup>. Are risk factors for ACL injury: weakened articular system, muscle fatigue, decreased strength, proprioception deficits, high dorsiflexion angle and trunk, hip and knee flexion angles decreased<sup>[2]</sup>. Recent studies have shown gender-specific differences in the patterns of neuromuscular activation that could predispose women to suffer more injuries during sport practice<sup>[3,15,16]</sup>.

There are factors related to the sport technique that have also been associated with an increase in ACL injuries. The main ones described are: pivoting in straight position, decreased angle of knee flexion at landing, increased knee valgus and flat foot when landing<sup>[2]</sup>.

Sport specialization entails adverse effects, both mental and physical, and women seem to be more prone to suffer such consequences. In 2007, the American Academy of Pediatrics' Council on Sports Medicine and Fitness published a document warning that focusing on one sport and the resulting over-training leads to an increase in injuries<sup>[23]</sup>. The relationship between the volume of training and overuse is also known<sup>[20]</sup>, and greater duration of the sport practice<sup>[21]</sup>, act as factors that predispose to ACL injuries in female players. Besides, overtraining can lead to athletes to a psychological state of burnout that includes chronic fatigue, unrefreshing sleep, irritability, musculoskeletal discomfort and lack of motivation for training. All these factors are associated with an increase in ACL injuries<sup>[22]</sup>.

The relationship between substance abuse such as alcohol, snuff and marijuana in relation to the incidence of injuries in young female athletes has not been studied, perhaps because in this population it is infrequent to abuse from these substances<sup>[3]</sup>. However, it is known that the effect of alcohol, snuff and marijuana decreases coordination and the ability to respond to stimuli of the subject that consumes them<sup>[3,34]</sup>.

## Prevention

By modifying or avoiding the risk factors explained, we can avoid

increasing the baseline risk of players to suffer ACL injuries. With special interest we would like to point out: play with wet and cold weather, preferably with natural boil and outdoors<sup>[2]</sup>, maintain a correct BMI<sup>[10,11]</sup>, to take OCPs<sup>[2]</sup>, to strengthen hamstrings to maintain a proper balance of hamstrings and quadriceps<sup>[2]</sup>, to stop sport practice at the onset of muscle fatigue<sup>[2]</sup>, to encourage sport diversification<sup>[23]</sup>, to avoid the state of burnout<sup>[22]</sup>, to maintain high levels of intake of carbohydrates and calcium are protective<sup>[30]</sup>, to maintain proper sleep hygiene, low stress of levels and good self-esteem<sup>[3]</sup>.

In general, well-designed multifactorial programs have shown a decreased incidence of ACL injuries in its participants. Training components often include strength, lower extremity plyometric (exercises usually include high speed in order to promote fast and powerful muscle contractions), agility, own body awareness (proprioception), conditioning neuromuscular training and making quick decisions during the game. This model works with the theory that through conscious practice landing techniques in a controlled environment the body learns "how to land" and that muscle memory will take over when the player can not focus on the technique landing, that is what happens during a match<sup>[2]</sup>.

The programs that have demonstrated more effectiveness usually are established before the season and continue during it<sup>[3]</sup>. Although there is no specific study where the optimal length that should have this intervention is investigated this intervention<sup>[2]</sup>.

The number of athletes training to prevent ACL injury is estimated in 65%, which is a favorable ratio, and argues in favor of the extension and use of these training<sup>[36]</sup>.

High compliance is also required for this measure to be effective<sup>[3,35]</sup>. Sugimoto *et al* conducted a metaanalysis where patients were classified according to whether their compliance with the neuromuscular training was high (> 66.6%), moderate (66.6 to 33.3%) or low (< 33.3%). Patients with moderate compliance have a 3.1 times higher risk of ACL injury, and those with low compliance have a higher risk of 4.9; compared with the high compliance group. This information enhances the importance of maintaining a high compliance when specific neuromuscular training is used to prevent ACL injuries<sup>[5]</sup>. Are associated with poor compliance: limited available timetable, lack of supervision and the use of little variety in the training exercises<sup>[5]</sup>.

When should the training be started is a widely discussed issue. Some suggest that the start of specific neuromuscular training should begin before the onset of puberty, so that the athletes integrate correct neuromuscular activation mechanisms and consolidate them<sup>[2]</sup>. It has shown a greater benefit to initiate the training program prior to the appearance of the already mentioned factors that increase the risk of injury. Thus, the risk reducing of ACL injuries is from the 72% if the training begins in preteens or teenagers, compared to a 52% risk reduction if it is began at the end of adolescence<sup>[11]</sup>. Current information suggests that the optimal time window to optimize risk reduction LCA injuries is before the start of neuromuscular deficits, and the peak of incidence of these injuries is set after the start of the body maturation of female athletes (adolescence).

One of the main limitations that are found when it is tried to implement this specific training is that many teams do not have access to gym or to the use of special equipment. Mandelbaum *et al* performed a study where only traditional outfit of a football team (soccer balls and cones) were used, so that the use of this program could be more realistic, feasible cost – effective<sup>[2]</sup>. However, the main problem is that many coaches do not consider the use of this specific neuromuscular training as a priority. On top of that, the use of these

programs involves many times and efforts, especially when the outcome expected to get is the result of not getting any result, that it is, not having ACL injuries.

## CONCLUSIONS

There are many identified risk factors contributing to ACL injuries, some are modifiable and others are not. According to the review carried out, the considered as protectors: playing with wet and cold weather, preferably with natural boil and outdoors<sup>[2]</sup>, maintain a correct BMI<sup>[10,11]</sup>, maintaining high levels of intake of carbohydrates and calcium<sup>[30]</sup>, taking OCPs pills<sup>[2]</sup>, to stop sport practice at the onset of muscle fatigue<sup>[2]</sup>, strengthen hamstrings and maintain proper balance quadriceps-hamstring<sup>[2]</sup>, diversify sport practice<sup>[23]</sup>, avoiding burnout state<sup>[22]</sup> and to maintain proper sleep hygiene, low stress levels and good self-esteem<sup>[3]</sup>.

It would be advisable to practice screening of the presence of risk factors of their players in order to detect the existence of the same and then modify them.

In the group ambit it has been shown that the use of a specific neuromuscular training, if applied properly, reduces the incidence of ACL injuries. The pre-adolescence might be the best time to start these prevention programs, as best results are achieved better when the program is initiated earlier. There is a great variety described about the type of exercise, frequency and its duration, which makes it difficult to provide specific advice on what would be the best protocol.

The aim of the present review was to describe the risk factors and the strategies to prevent within the female population, more frequently affected by ACL injuries. Our take-home message should be directed to coaches and physical trainers of the main modifiable factors that can prevent ACL injury. Proprioceptive, plyometric work that can easily be performed with few means, may decrease injuries among the female population regarding ACL.

## REFERENCES

1. Myer GD, Sugimoto D, Thomas S, Hewett TE. The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a meta-analysis. *Am J Sports Med.* 2013 Jan; **41(1)**: 203-215. [DOI: 10.1177/0363546512460637]. Epub 2012 Oct 9. Review. [PMID: 23048042]; [PMCID: PMC4160039]
2. Laible C, Sherman OH. Risk factors and prevention strategies of non-contact anterior cruciate ligament injuries. *Bull Hosp Jt Dis (2013).* 2014; **72(1)**: 70-75. Review. [PMID: 25150329]
3. Elliot DL, Goldberg L, Kuehl KS. Young women's anterior cruciate ligament injuries: an expanded model and prevention paradigm. *Sports Med.* 2010 May 1; **40(5)**: 367-376. [DOI: 10.2165/11531340-000000000-00000]. Review. [PMID: 20433210]
4. Myer GD, Stroube BW, DiCesare CA, Brent JL, Ford KR, Heidt RS Jr, Hewett TE. Augmented feedback supports skill transfer and reduces high-risk injury landing mechanics: a double-blind, randomized controlled laboratory study. *Am J Sports Med.* 2013 Mar; **41(3)**: 669-677. [DOI: 10.1177/0363546512472977]. Epub 2013 Jan 31. [PMID: 23371471]; [PMCID: PMC4166501]
5. Sugimoto D, Myer GD, Bush HM, Klugman MF, Medina McKeon JM, Hewett TE. Compliance with neuromuscular training and anterior cruciate ligament injury risk reduction in female athletes: a meta-analysis. *J Athl Train.* 2012 Nov-Dec; **47(6)**: 714-723. [DOI: 10.4085/1062-6050-47.6.10]. [PMID: 23182020]; [PMCID: PMC3499896]
6. Myer GD, Ford KR, Brent JL, Hewett TE. An integrated approach

- to change the outcome part II: targeted neuromuscular training techniques to reduce identified ACL injury risk factors. *J Strength Cond Res.* 2012 Aug; **26(8)**: 2272-2292. [PMID: 22580980]; [PMCID: PMC4159730]
7. Scranton PE Jr, Whitesel JP, Powell JW, Dormer SG, Heidt RS Jr, Losse G, Cawley PW. A review of selected noncontact anterior cruciate ligament injuries in the National Football League. *Foot Ankle Int.* 1997 Dec; **18(12)**: 772-776. [PMID: 9429878]
8. Torg JS, Stilwell G, Rogers K. The effect of ambient temperature on the shoe-surface interface release coefficient. *Am J Sports Med.* 1996 Jan-Feb; **24(1)**: 79-82. [PMID: 8638758]
9. Hoff GL, Martin TA. Outdoor and indoor soccer: injuries among youth players. *Am J Sports Med.* 1986 May-Jun; **14(3)**: 231-233. [PMID: 3752363]
10. Hewett TE, Myer GD, Ford KR. Anterior cruciate ligament injuries in female athletes: Part I, mechanisms and risk factors. *Am J Sports Med.* 2006 Feb; **34(2)**: 299-311. Review. [PMID: 16423913]
11. Brown CN, Yu B, Kirkendall DT, Garrett WE. Effects of increased body mass index on lower extremity motion patterns in a stop-jump task. *J Athl Train.* 2005; **42**: S26.
12. Kucera KL, Marshall SW, Kirkendall DT, Marchak PM, Garrett WE Jr. Injury history as a risk factor for incident injury in youth soccer. *Br J Sports Med.* 2005 Jul; **39(7)**: 462. [PMID: 15976172]; [PMCID: PMC1725262]
13. Dienst M, Schneider G, Altmeyer K, Voelkerling K, Georg T, Kraumann B, Kohn D. Correlation of intercondylar notch cross sections to the ACL size: a high resolution MR tomographic in vivo analysis. *Arch Orthop Trauma Surg.* 2007 May; **127(4)**: 253-260. Epub 2006 Jun 21. [PMID: 16807752]
14. Loudon JK, Jenkins W, Loudon KL. The relationship between static posture and ACL injury in female athletes. *J Orthop Sports Phys Ther.* 1996 Aug; **24(2)**: 91-97. [PMID: 8832472]
15. Grunbaum JA, Kann L, Kinchen SA, Williams B, Ross JG, Lowry R, Kolbe L. Youth risk behavior surveillance--United States, 2001. *MMWR Surveill Summ.* 2002 Jun 28; **51(4)**: 1-62. [PMID: 12102329]
16. Zebis MK, Andersen LL, Bencke J, Kjaer M, Aagaard P. Identification of athletes at future risk of anterior cruciate ligament ruptures by neuromuscular screening. *Am J Sports Med.* 2009 Oct; **37(10)**: 1967-1973. [DOI: 10.1177/0363546509335000]. Epub 2009 Jul 2. [PMID: 19574475]
17. Mercer PW, Merritt SL, Cowell JM. Differences in reported sleep need among adolescents. *J Adolesc Health.* 1998 Nov; **23(5)**: 259-263. [PMID: 9814385]
18. Byrne DG, Davenport SC, Mazanov J. Profiles of adolescent stress: the development of the adolescent stress questionnaire (ASQ). *J Adolesc.* 2007 Jun; **30(3)**: 393-416. Epub 2006 Jun 5. [PMID: 16750846]
19. Blackwell B, McCullagh P. The relationship of athletic injury to life stress, competitive anxiety and coping resources. *Athletic Train* 1990; **25**: 23-27
20. Brooks JH, Fuller CW, Kemp SP, Reddin DB. An assessment of training volume in professional rugby union and its impact on the incidence, severity, and nature of match and training injuries. *J Sports Sci.* 2008 Jun; **26(8)**: 863-873. [DOI: 10.1080/02640410701832209]. [PMID: 18569552]
21. Steffen K, Pensaard AM, Bahr R. Self-reported psychological characteristics as risk factors for injuries in female youth football. *Scand J Med Sci Sports.* 2009 Jun; **19(3)**: 442-51. [DOI: 10.1111/j.1600-0838.2008.00797.x]. Epub 2009 Apr 24. [PMID: 18435692]
22. Pratt HD, Patel DR, Greydanus DE. Behavioral aspects of children's sports. *Pediatr Clin North Am.* 2003 Aug; **50(4)**: 879-899, ix. Review. [PMID: 12964699]
23. Brenner JS; American Academy of Pediatrics Council on Sports Medicine and Fitness.. Overuse injuries, overtraining, and burn-

- out in child and adolescent athletes. *Pediatrics*. 2007 Jun; **119**(6): 1242-1245. Review. [PMID: 17545398]
24. Zazulak BT, Paterno M, Myer GD, Romani WA, Hewett TE. The effects of the menstrual cycle on anterior knee laxity: a systematic review. *Sports Med*. 2006; **36**(10): 847-862. Review. [PMID: 17004848]
  25. Neumark-Sztainer D, Story M, Hannan PJ, Croll J. Overweight status and eating patterns among adolescents: where do youths stand in comparison with the healthy people 2010 objectives? *Am J Public Health*. 2002 May; **92**(5): 844-851. [PMID: 11988458]; [PMCID: PMC1447172]
  26. Wilkinson EC, Mickle SJ, Goldman JD. Trends in food and nutrient intakes by adolescents in the United States. *Family Econ Nutr Rev* 2003; **15**: 15-27
  27. Mercer TH, Gleeson NP, Wren K. Influence of prolonged intermittent high-intensity exercise on knee flexor strength in male and female soccer players. *Eur J Appl Physiol*. 2003 Jun; **89**(5): 506-508. Epub 2003 May 7. [PMID: 12734758]
  28. Drinkwater BL, Bruemner B, Chesnut CH 3rd. Menstrual history as a determinant of current bone density in young athletes. *JAMA*. 1990 Jan 26; **263**(4): 545-8. [PMID: 2294327]
  29. Katrin Muradas, Laura Costa, Roberto Seijas, Pedro Álvarez-Díaz, Oscar Ares, Andrea Sallent, Ramon Cugat. Female athlete triad syndrome: prevention. *Int Journal of Orthopaedics* 2015; **2**(1): 205-209 Available from: URL: <http://www.ghrnet.org/index.php/ijo/article/view/1052>
  30. American College of Sports Medicine Position Stand. The female athletic triad [online]. Available from URL: <http://www.acsm-msse.org/pt/pt-core/template-journal/msse/media/0597.pdf> [Accessed 2009 May 5]
  31. Golden NH. A review of the female athlete triad (amenorrhea, osteoporosis and disordered eating). *Int J Adolesc Med Health*. 2002 Jan-Mar; **14**(1): 9-17. Review.[PMID: 12467202]
  32. Reilly T, Edwards B. Altered sleep-wake cycles and physical performance in athletes. *Physiol Behav*. 2007 Feb 28; **90**(2-3): 274-84. Epub 2006 Oct 25. Review.[PMID: 17067642]
  33. Byrne DG, Davenport SC, Mazanov J. Profiles of adolescent stress: the development of the adolescent stress questionnaire (ASQ). *J Adolesc*. 2007 Jun; **30**(3): 393-416. Epub 2006 Jun 5. [PMID: 16750846]
  34. Moskowitz H. Adverse effects of alcohol and other drugs on human performance. *Alcohol Health Res World* 1985; **9**(4): 11-5 URL: <http://worldcat.org/issn/0090838X>
  35. 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 Oct; **18**(5): 605-14. [DOI: 10.1111/j.1600-0838.2007.00703.x. Epub 2008 Jan 14. [PMID: 18208428]
  36. Abernethy L, Bleakley C. Strategies to prevent injury in adolescent sport: a systematic review. *Br J Sports Med*. 2007 Oct; **41**(10): 627-38. Epub 2007 May 11. Review. [PMID: 17496070]; [PMCID: PMC2465167]

**Peer reviewer:** Javier Munoz-Marin