Review

Evolution of injury prevention training monitoring

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Summary

Today, no one doubts the relationship between training loads and their influence on sports injuries. Object of study: literature review on training load and injury prevention in team sports that allow us to advance our knowledge of it.
It has made an electronic literature review in 2015 on the basis of Web of Science (WOS), Pubmed and Scopus. The search strategies and key words were "training load", "prevention injuries" and the combination by the term AND/& with control team sports. The "n" has been discussed "training load" (49) "prevention injuries & training load & Control & team sports" (16) "prevention injuries & training load" (204). 5 thematic blocks were obtained: Control and monitoring of training (13.6%), prevention of injuries (39.2%), prevention of anterior cruciate ligament (15.2%), injury incidence (18.4%) and others (13.6%).
The load control should collect quantitative and qualitative data from the training and the rest of the day. The general and specific strength tranining, with particular attention to eccentric work, proprioceptive, neuromuscular control and coordination form the pillars on which a plan for injury prevention is based. Continuous review of rules of the game and the protective material should be considered because it may allows to reduce the incidence of injury. It should continue with biomechanical studies and video to enable further progress in understanding the causes and factors of injuries. Epidemiological studies are needed about the incidence of injury in the general population to give us the magnitude of the problem. Further work is needed to promote the prevention of injury from the global perspective of the athlete from childhood.

Key words:
Load. Training. Prevention. Injuries. Team sports.

Evolución de la prevención de lesiones en el control del entrenamiento

Resumen

En la actualidad, nadie duda de la interrelación entre las cargas de entrenamiento y su influencia en las lesiones deportivas. Objeto de estudio: realizar una revisión bibliográfica sobre el control del entrenamiento y la prevención de lesiones en los deportes colectivos que nos permitan avanzar en el conocimiento del mismo.
Se ha realizado una revisión bibliográfica electrónica en el año 2015 en las bases de datos *Web of Science* (WOS), Pubmed y Scopus. Las estrategias de búsqueda y palabras clave fueron "training load", "prevention injuries" y la combinación mediante el término AND/& con control, team sports. La "n" analizada ha sido "training load" (49), "prevention injuries & training load & control & team sports" (16), "prevention injuries & training load" (204). De la revisión se obtuvieron 5 bloques temáticos: control y monitorización del entrenamiento (13,6%), prevención de lesiones (39,2%), prevención del ligamento cruzado anterior (15,2%), incidencia lesional (18,4%) y otros (13,6%).
El control de la carga debe recoger datos cuantitativos y cualitativos tanto del entrenamiento como fuera del mismo. Los trabajos de fuerza general y específica, con especial atención al trabajo excéntrico, control propioceptivo y la coordinación neuromuscular conforman los pilares en los que se sustenta un plan de prevención de lesiones. Debe tenerse en cuenta la revisión continua tanto de las reglas del juego como del material de protección ya que puede permitir disminuir la incidencia lesional. Se deben seguir realizando estudios biomecánicos y de vídeo que permitan seguir avanzando en el conocimiento de las causas y factores de las lesiones. Es necesario estudios epidemiológicos de la incidencia lesional en la población en general que nos den la magnitud del problema. Es necesario seguir trabajando en fomentar la prevención de lesiones desde la perspectiva global del deportista desde la infancia.

Palabras clave:
Carga. Entrenamiento. Prevención. Lesiones. Deportes de equipo.

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Introduction

In the second half of the 20th century, sport gained significant importance, so much so that different modalities have gradually become professionalised, and an increasing amount of people take part, thus increasing the occurrence of injury (OI). Knowledge regarding training has shifted from a fundamentally empirical-based "trial and error" system, to one which calls for the application of scientific methods, and the monitoring and recording of training loads and the OI, as well as an analysis of a possible link between the two.

Over the past two decades, objectives have evolved. According to Platonov (1993)[1] the main aim was to optimise the preparation process and competitive activity, in accordance with the objective assessment of the different aspects of maturity and the functional possibilities of the body's most important systems. For Viru and Viru (2003)[2] the aim was to obtain information about the real effects of the session to discover the type of work that is most suited to each athlete. García *et al*. (2010)[3] take that even further and establish that the aim is to implement adaptations and corrections to the training in a much more specific way, customising the training session, improving the process and obtaining the best results possible from each athlete, whilst minimising the risk of injury.

If the athlete for whatever reason, whether physical, psychic or emotional, is not alright, performance will be affected This change from understanding variables in an isolated way to interlinking them, brings us to the holistic theories in which neither the training or the athlete can be understood without taking into account everything that is occurring in the process and around the individual in question (Figure 1).

The objective of training shifts from trying to achieve the peak state of fitness without truly considering the possible consequences, to attaining the best possible state of fitness at all times and minimising the risk of injury. Of course, for this concept the sport in question must be considered, as well as the characteristics of competition.

Antecedents

Controlling the training load

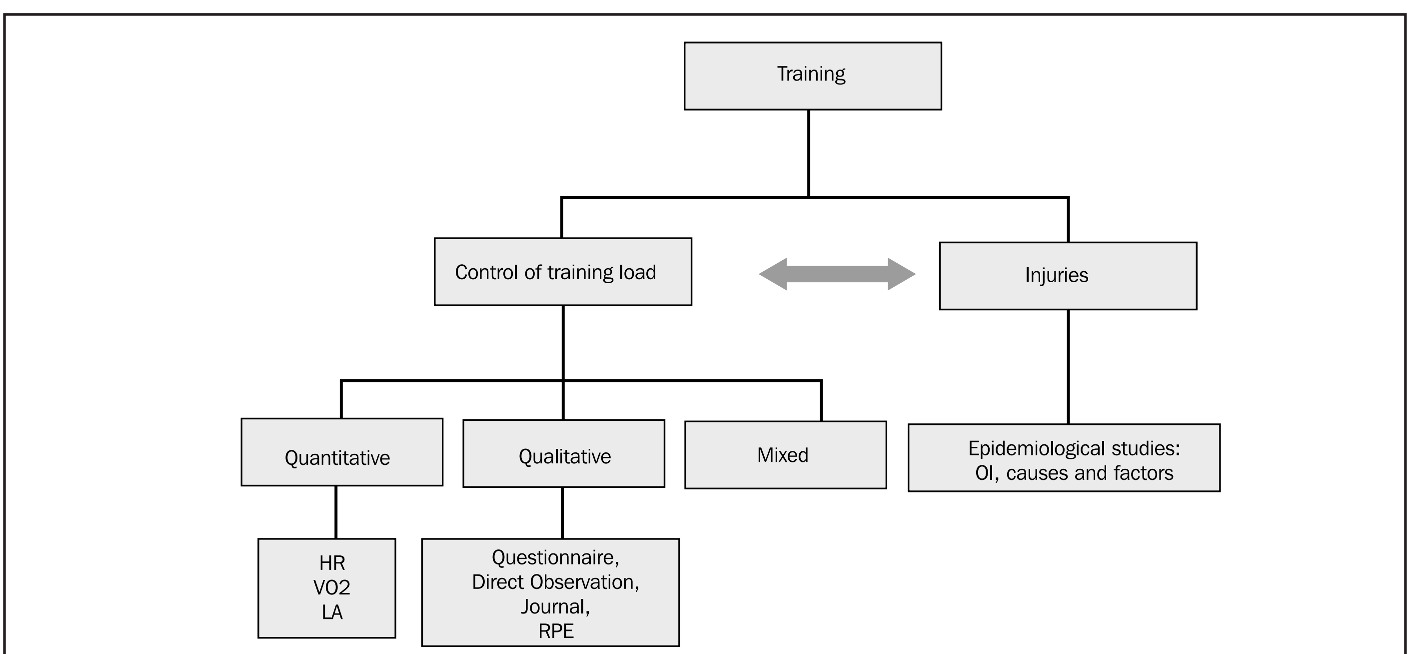
Controlling the physical factor has mainly focused on the study of the internal training load with regards to physiological parameters such as heart-rate (HR)[4-13,] oxygen consumption (VO2)[14-23] and blood lactate (LA)[24-30], as objective and quantitative measures.

In recent years, some authors[31-33] take the psychological factor into account based on the elaboration of neuromuscular information and strategic factors that involve the training load applied to the player. They are considered *qualitative* methods, and in daily practice they are presented as an effective way of discovering how planned training loads affect the players[34]. Some of these control methods are training logs[34,35], questionnaires[36,37], direct observation[38,39] and the rating of perceived exertion.

Rating of Perceived Exertion

Borg is considered to be the benchmark for "Rating of Perceived Exertion" (RPE) studies in the physiology of exercise, both for being the pioneer in this field as well as for being the most cited[40-44].

Figure 1. Interlinked analysis of the training process.



HR: Heart rate; VO2: Oxygen consumption; LA: Lactate; RPE: Rating of Perceived Exertion

Borg's RPE Scales from 1962[40] and 1982[42] have been used in numerous studies to control and evaluate exertion made, both in team sports[45-48] as well as individual sports[49].

Already in the design of the RPE Scale (Borg, 1962)[40], the author established that to perform a more complete assessment, use of a "double scale" was necessary, based on the athlete's perception and the foresight of the technical team, allowing for the difference in the training load assessment from each part to be established numerically. The results from different studies in athletics[50], swimming[51], basketball[52] and handball[53] have concluded that the double scale reveals how the player is dealing with the training load with regards to the amount planned, making it possible to adjust the plan in accordance with the information received immediately, thus reducing the risk of injury.

The correlations obtained from studies between the RPE method and other means of quantifying the internal training load in team sports have been very high, as demonstrated in studies that compare the RPE methods and HR[54-58], RPE and VO2[59-61] and RPE and LA[62-65].

Preventing injury

The body is not designed for some actions and movements, resulting in injuries in sporting practice, which can be one of the worst health consequences for the athlete. An injured player means zero performance within the team, as the player cannot compete, or at least not in optimum conditions[66].

Currently, no-one questions the relationship between training loads and their influence on sporting injuries. Increased training, accumulated fatigue, a mismatch between the prescribed and perceived training load, may result in a considerable increase in sporting injuries.

Injury and performance are two words that should be mutually exclusive. However, the words injury, training, planning and control should be intrinsically related, though it has not always been this way.

At this stage we propose the necessity to revalue the prevention of injuries. Why discuss prevention? Preventive strategies are justified for both medical and financial reasons[66]. Injuries among elite athletes imply a high sporting and financial cost. In the English professional league a loss of 74.7 million pounds was estimated from injuries acquired during the monitoring of two seasons[67].

When it comes to planning the training process, prevention has transformed from being considered an implicit aspect within the programme to having its own fundamental position around which everything else is based. An injured player is not operational, and thus is not useful in competition.

Today, the group responsible for establishing injury prevention strategies: medical team, physical trainers and coaches have to participate in continuous training to allow them to identify the individuals prone to injury and preventive programmes to ensure the risk of injury is as low as possible.

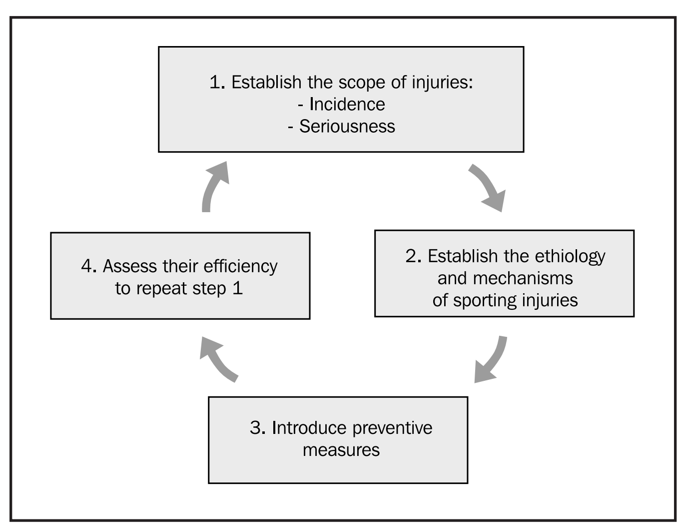
Collecting injury data

Before initiating a sporting injury prevention measure or programme, first their magnitude must be defined. Secondly, the mechanisms and factors that intervene in their occurrence must be identified. Finally, measures that may reduce the OI risk should be established and their efficiency assessed (Figure 2).

Various epidemiological studies have examined the OI, causes and factors in different sports. It should always be noted that comparisons between studies become complicated unless the same data collection methodology has been used in the process[68,69]. Methodological consensus must be attained, such as the Injury Consensus Group via the International Federation of the Football Association Medical Assessment and Research Centre (F-MARC)[70], defining each variable specifically and thus enabling the comparison of results with other studies that employ the same methodology[71,72]. In the review carried out by Parkkari *et al.* (2001)[68] a sequence is suggested for collecting injury data, establishing the most important points to consider:

- Clearly define what constitutes an injury and standardise it.
- Type of sporting event and the activity being undertaken at the time of injury.
- Sporting level (recreational vs. competitive).
- Location where the injury took place.
- Mechanism of the injury, acute or through overuse.
- Level of supervision.
- Nature of the injury (severe sprain, fracture, etc.).
- Part(s) of the body injured.
- The seriousness of the injury (affected activity, working time lost, treatment needs, treatment costs, permanent damage, deterioration or disability).
- The characteristics of the injured person.
- Treatment needed (duration and nature).
- The use of protective equipment.
- Adherence to the game rules (foul play and injuries).
- Cost of the injury (direct, indirect).
- Display data should be established (population at risk and display time).

Figure 2. Sporting injury prevention sequence[68,69].



– Calculate simplicity (vs. training the data collection personnel) and the time needed (is it realistic?) for collecting data.
– Recognise the limitations or error sources (also when giving results).

The study objective of this work is to perform a bibliographical review of the control of training and the prevention of injuries in team sports, which will allow us to make progress in the understanding of this particular field.

Method

An electronic bibliographic review was performed in 2015 by the authors of this article. The methodological quality of the studies was not assessed, given that the review only considered works published on well-known and prestigious databases: Web of Science (WOS), Pubmed and Scopus, thus the quality indicator was considered sufficient. Search strategies and key words established were *"training load"*, *"prevention injuries"* and their combinations using the term AND/& with *"control", "team sports".* All the articles selected were exported onto the Endnote programme to facilitate their classification by contents.

A meta-analysis was not applied to this review. It was a systematic review with the main aim of producing a summary of the most relevant studies undertaken in the target matter, determining the following steps: operative definition of the research issue; procedures for searching for the literature; precise definition of the selection criteria of the studies; and codification of the information taken from the studies. To do this, the numerous perspectives associated with traditional reviews had to be reduced down, clarifying all the decisions and procedures applied in the selection, critical assessment and synthesis of the relevant studies in this field. No specific data was extracted from any of the studies reviewed in this study, as our main interest was to establish the themes addressed by the scientific studies, as opposed to analysing their results.

Three specific search strategies were followed:

Training load

The following results were obtained from the searches carried out regarding training loads:

– Training load / Filtered to the *"sport sciences"* area: 36860/6298 (WOS); 7777 (Pubmed); 12795 (Scopus).
– Training load & control / Filtered to the *"sport sciences"* area: 11252/1390 (WOS); 1992 (Pubmed); 3338 (Scopus).
– Training load & team sports / Filtered to the *"sport sciences"* area: 257/221 (WOS); 20 (Pubmed); 249 (Scopus).
– Training load & control & team sports / Filtered to the *"sport sciences"* area: 59/49 (WOS); 14 (Pubmed); 33 (Scopus).

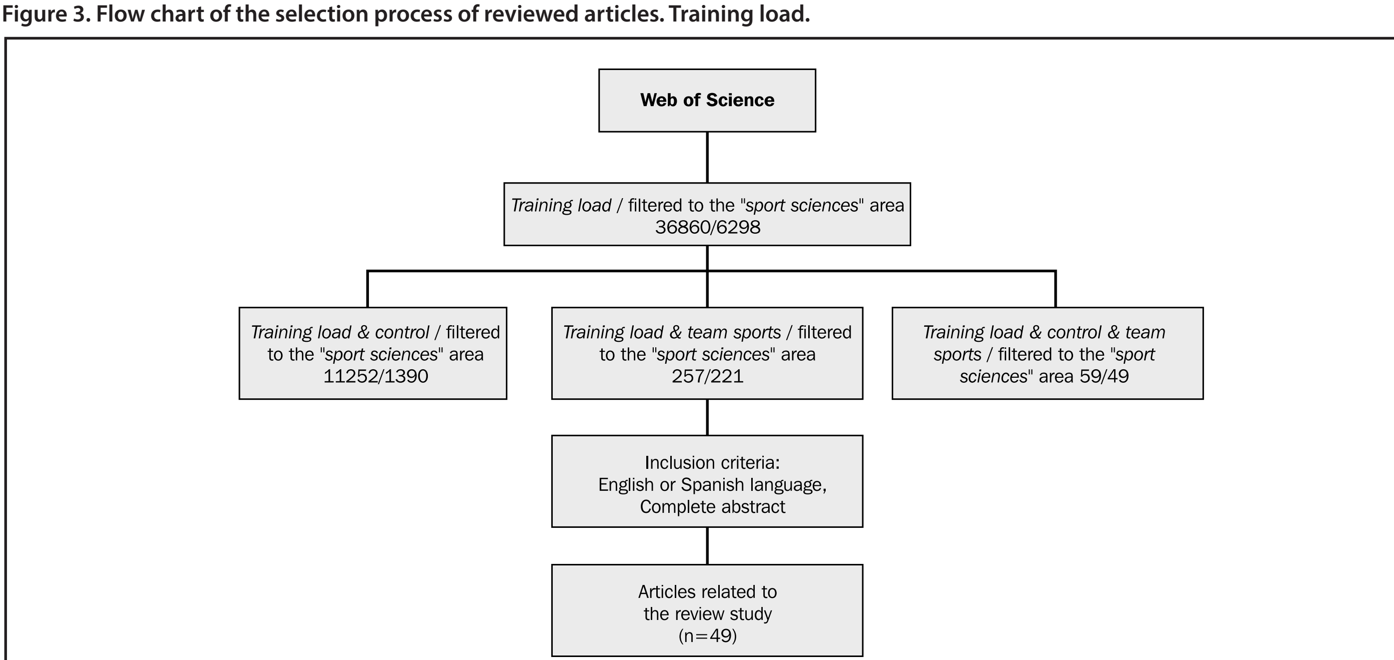
The WOS search was chosen as it produced the greatest number of results upon introducing the words *"Training load & control & team sports"* and filtered to the *"sport sciences"* area with n=49. Inclusion criteria were: English or Spanish language, access to complete abstract (Figure 3).

Prevention of injuries

The following results were obtained from the searches carried out for prevention of injuries:

– Prevention injuries/Filtered to the *"sport sciences"* area: 152035/14376 (WOS); 96929 (Pubmed); 66574 (Scopus).
– Prevention injuries & control /Filtered to the *"sport sciences"* area: 106565/7894 (WOS); 84138 (Pubmed); 13120 (Scopus).

Figure 3. Flow chart of the selection process of reviewed articles. Training load.



- Prevention injuries & team sports /Filtered to the *"sport sciences"* area: 737/645 (WOS); 499 (Pubmed); 583 (Scopus).
- Prevention injuries & control & team sports /Filtered to the *"sport sciences"* area: 424/400 (WOS); 352 (Pubmed); 95 (Scopus).

Due to the high number of results produced, this search was not used to analyse the study, rather the decision was taken to move on to the combination of key research words.

Training load & Prevention injuries

The following results were obtained from the searches carried out regarding the combination of training load and prevention of injuries:

- Prevention injuries & training load /Filtered to the *"sport sciences"* area: 353/204 (WOS); 145 (Pubmed); 172 (Scopus).
- Prevention injuries & training load & control /Filtered to the *"sport sciences"* area: 232/136 (WOS); 116 (Pubmed); 44 (Scopus).
- Prevention injuries & training load & team sports /Filtered to the *"sport sciences"* area: 23/21 (WOS); 5 (Pubmed); 14 (Scopus).
- Prevention injuries & training load & control & team sports / Filtered to the *"sport sciences"* area: 17/16 (WOS); 4 (Pubmed); 3 (Scopus).

The WOS search was selected due to the greater number of results produced. First, the search results were related to all the Prevention injuries & training load & control & team sport/Filtered to the *"sport sciences"* area producing n=16. Upon reviewing the articles and observing that they were all included within the previous review *"Training load & control & team sports"* n=49, the search made in WOS with the words *"Prevention injuries & training load"* and filtered to the *"sport sciences"* area AND was chosen, producing n=204.

With the aim of focusing on prevention, the inclusion criteria were established as: English or Spanish language, complete article, and discussing prevention in sport, rejecting any that made reference to epidemiological studies. The sample was thus narrowed down to n=76 (59 original articles and 17 revised) (Figure 4).

Results

The results obtained from the reviews undertaken *"Training load & control & team sports"* and *"Prevention injuries & training load"* were classified by contents (Table 1).

The review grouped the articles into 5 themed blocks:

1. Control, training monitoring with 13.6%.
2. Prevention of injuries with 39.2%. It was deemed appropriate to divide this into:
   - Training measures with 31.2%. This included everything related to general strength work, physical control (core), balance, proprioception, neuromuscular, eccentric work and warming up (FIFA programme).
   - Other measures 8%.
3. Prevention of anterior cruciate ligament with 15.2%.
4. Injury frequency. Epidemiology with 18.4%.
5. Others with 13.6% which after being reviewed were rejected as they did not make reference to the study objective.

Figure 4. Flow chart of the selection process of the reviewed articles. Training load-control-prevention injuries-team sports.

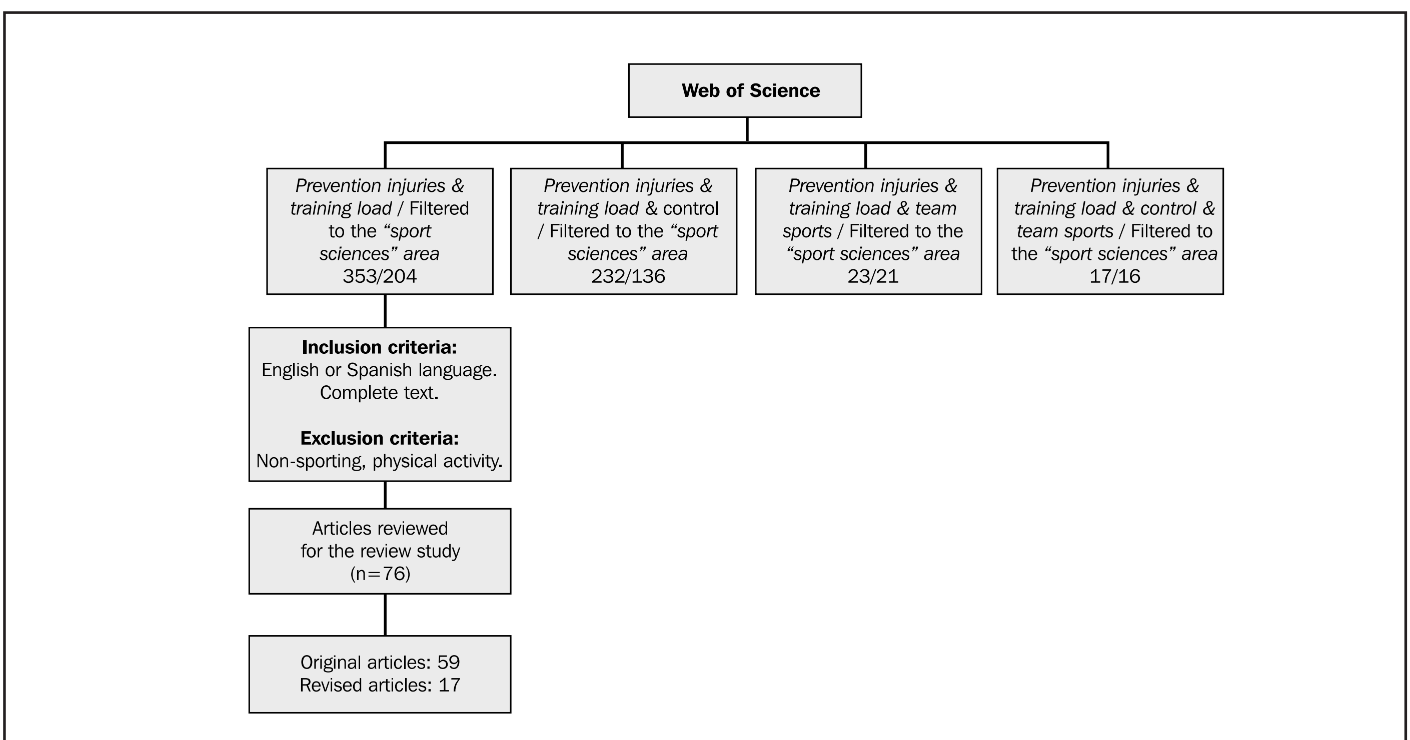


Table 1. Results of the bibliographic reviews classified by subject.

	Training load & control & team sports	Prevention injuries & training load	Total	%
Control, training monitoring	15	2	17	**13.6**
Prevention of injuries				
Measures in the training				
General strength	0	6	6	4.8
Physical control. Core.	3	2	5	4.0
Balance. Proprioception. Neuromuscular	2	16	18	14.4
Eccentric work	0	4	4	3.2
Warming up (FIFA programmes)	0	6	6	4.8
			39	**31.2**
Other measures				
Blood test- Supplementing	2	0	2	1.6
Biomechanical analysis	1	1	2	1.6
Rules and subject matter	0	3	3	2.4
Public Health	0	1	1	0.8
Educational Intervention	0	2	2	1.6
			10	**8.0**
Prevention of ACL	9	10	19	**15.2**
Injury frequency. Epidemiology	13	10	23	**18.4**
Others	4	13	17	13.6
N	49	76	125	100

Discussion

We are going to focus on the first three blocks, leaving the fourth (injury frequency) unanalysed, as they constitute epidemiological studies that discuss the magnitude of the problem and do not refer to any specific objective within the control study of training load and prevention of injuries.

Table 2 shows the studies found about Control, discusses monitoring training.

As we have seen in the introduction, currently, the monitoring and control of training loads has shifted from the control of external and internal loads, registering variables such as HR, RPE, TRIMPS, monotony and fatigue indices[74,75,80-84,87], to the use of the double scale (RPE of the player and the technical team) to establish whether or not there are deviations between the foreseen training load and that carried out[77], to the use of new technology, such as GPS which allows the distance covered and speed to be measured, establishing that from accumulated periods at high speeds, the injury rate increases up to 2.7[84], and other applications to standardise data collection from training loads and injuries such as the *"Training and Injury Prevention Platform for Sports"* (TIPPS)[78,80].

The holistic approach[88] requires a control not only of training loads from the perspective of training itself, but also the perspective of resting times. The athlete and the training are considered to be a complete unit from which peak performance can be expected[79,86]. The importance of optimising and controlling recovery becomes vital. Effective recovery by elite athletes following intense training can determine their success or failure. Ways of controlling these variables have been explored, by monitoring hours of sleep, rest, recovery[89] and stress using questionnaires such as RESTQ-Sport[76] or *"Profile mood states"* (POMS)[85] among others.

The training programme should be based on a certain volume and intensity to ensure that players can maintain their fitness level, perfect their game skills, internalise psychological qualities and carefully look after their health[90], avoiding acquiring an injury requiring a compulsory break from the sport. All this with the aim of controlling the variables that favour the monitoring of training, preventing overtraining, and therefore preventing injuries.

General strength programmes

A generic base of strength is essential for increasing sporting performance and for reducing the risk of injuries.

The articles reviewed are experimental studies in which over a period of time a certain type of training is implemented with or without a control group. In almost all cases the conclusions establish that the risk of injury reduces considerably[68,69,99], even if some suggest that a general strength programme alone is not enough to reduce the OI[97,98], requiring the application of other measures such as retraining movement and giving suitable feedback[96].

Table 2. Control, training monitoring.

	Authors, Journal & Reference	Year	Article	Objective / Hypothesis
			Training load & control & team sports (n=15)	
(74)	Henderson, Brendan.; Cook, Jill.; Kidgell, Dawson J. *Journal of sports science and medicine* 14(3):494-500	2015	Game and training load differences in elite junior Australian football	Assess the differences in the measurements of external and internal physical training loads during competition and training (Australian football)
(75)	Gallo, Tania.; Cormack, Stuart.; Gabbett, Tim. *Journal of sports sciences* 33(5):467-75	2015	Characteristics impacting on session rating of perceived exertion training load in australian footballers	Establish the relationship between the training load and external qualification session of perceived exertion (Australian football)
(76)	Matos, Felipe de Oliveira.; Samulski, Dietmar Martin.; Perrout de Lima, Jorge Roberto. *Revista brasileira de medicina do esporte* 20(5):388-93	2014	High loads of training affect cognitive functions in soccer players	Explore the behaviour of the psychological and physiological variables, the indicators of possible states of stress and recovery, and use these as markers to avoid the loss of performance and over-training (Football)
(77)	Rodriguez-Marroyo, Jose A.; Medina, Javier; Garcia-Lopez, Juan. *Journal of strength and conditioning research* 28(69):1588-94	2014	Correspondence between training load executed by volleyball players and the one observed by coaches	Compare the training load executed by players with that observed by trainers (Volleyball)
(78)	Lion, Alexis.; Theisen, Daniel.; Windal, Thierry. *Bulletin de la societe des sciences medicales du grand-duche de luxembourg* (3):43-55	2014	Moderate to severe injuries in football: a one-year prospective study of twenty-four female and male amateur teams	Assess the seriousness of injuries produced during a season among amateur teams (Football)
(79)	Binnie, Martyn John.; Dawson, Brian.; Arnot, Mark Alexander. *Journal of sports sciences* 32(11):1001-12	2014	Effect of sand versus grass training surfaces during an 8-week pre-season conditioning programme in team sport athletes Effect of sand versus grass training surfaces during an 8-week pre-season conditioning programme in team sport athletes	Compare the intensity of training on two different surfaces: grass and sand
(80)	Malisoux, Laurent.; Frisch, Anne.; Urhausen, Axel. *Journal of science and medicine in sport* 16(6);504-8	2013	Monitoring of sport participation and injury risk in young athletes	Compare the characteristics of sporting participation in the different categories of sports for young people and establish their relationship with injuries incurred
(81)	Scott, Tannath J.; Black, Cameron R.; Quinn, John. *Journal of strength and conditioning research* 27(1):270-6	2013	Validity and reliability of the session-rpe method for quantifying training In australian football: a comparison of the cr10 and cr100 scales	Validate the CR10 and CR100 perceived exertion scale in team sports that require highly intense intermittent exertion
(82)	Miloski, Bernardo.; Freitas, Victor Hugo.; Bara Filho, Maurício Gattás *Revista brasileira de cineantropometria & desempenho humano* 14(6):671-9	2012	Monitoring of the internal training load in futsal players over a season	Analyse the internal training load in a macro-cycle, using the qualification method of perceived exertion of the session (Indoor football)
(83)	Boullosa, Daniel Alexandre.; Abreu, Laurinda.; Luis Tuimil, Jose. *European journal of applied physiology* 112(6):2233-42	2012	Impact of a soccer match on the cardiac autonomic control of referees	Assess the heart-rate of adult referees during competition (Football)
(84)	Gabbett, Tim J.; Ullah, Shahid. *Journal of strength and conditioning research* 26(4):953-60	2012	Relationship between running loads and soft-tissue injury in elite teamsport athletes	Relate low and high intensity activities and high, and the risk of incurring soft-tissue injuries (Team sports)
(85)	Lovell, G. P.; Townrow, J.; Thatcher, R. *Biology of sport* 27(2):83-8	2010	Mood states of soccer players in the english leagues: reflections of an increasing workload	Evaluate the mood of players in relation with the demands of competition and relate it with their health and performance (Football)
(86)	Pyne, David B.; Mujika, Inigo; Reilly, Thomas. *Journal of sports sciences* 27(3):195-202	2009	Peaking for optimal performance: research limitations and future directions	REVIEW Establish the research constraints that aim to obtain peak performance in team sports

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(87)	Merati, G.; Ce, E.; Maggioni, M. A. *Medicina dello sport* 59(3):325-33	2006	Cardio-pulmonary evaluation of mentally disabled soccer players	Assess the heart-rate and pulmonary response of people with mental disabilities (Football)
(88)	Impellizzeri, F.M.; Rampinini, E.; Coutts, AJ. *Medicine and science in sports and exercise* 36 (6):1042-7	2004	Use of RPE based training load in soccer	Apply the method based on RPE to quantify the internal training load (RPE of the session) and evaluate the correlations with other physiological methods (Football)
	Prevention injuries & training load (n=2)			
(80)	Malisoux, Laurent.; Frisch, Anne; Urhausen, Axel. *Journal of science and medicine in sport* 16(6):504-8	2013	Monitoring of sport participation and injury risk in young athletes	Compare the characteristics of sports participation among the different categories of sports for young people and determine their relationship with injuries obtained.
(89)	Kellmann, M. *Scand J Med Sci Sports* 20(2):95–102	2010	Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring	REVIEW Review the methods used to prevent over-training among high-intensity athletes

Table 3. Prevention of injuries. Training measures.

	Authors, Journal & Reference	Year	Article	Objective / Hypothesis
	Training load & control & team sports (n=5)			
	Physical control. Core			
(91)	Ezechieli, M.; Siebert, C. H.; Ettinger, M. *Technology and health care* 21(4):379-86	2013	Muscle strength of the lumbar spine in different sports	Assess the capacity of stabilising the core in dynamic movements and the ability to absorb strength during repetitive training loads (Sports)
(92)	Jamison, Steve T.; Mcneilan, Ryan J.; Young, Gregory S. *Medicine and science in sports and exercise* 44(10);1924-34	2012	Randomized controlled trial of the effects of a trunk stabilization program on trunk control and knee loading	Determine the extent to which a quasi-static trunk stabilising training programme improves the core performance measures, leg strength, agility and the dynamic knee loading when compared to a resistance training programme.
(93)	Myer, G. D.; Brent, J. L.; Ford, K. R. *British journal of sports medicine* 42(7):614-9	2008	A pilot study to determine the effect of trunk and hip focused neuromuscular training on hip and knee isokinetic strength	Assess the neuromuscular training effect of the core in hip and knee strength
	Balance. Proprioception. Neuromuscular			
(94)	Renkawitz, T.; Boluki, D.; Linhardt, O.; Grifka, *J. Sportverletzung-sportschaden* 21(1):23-8	2007	Neuromuscular imbalances of the lower back in tennis players - the effects of a back exercise program	Establish the risk of injury in athletes with neuromuscular imbalances of the back and set up a corrective programme (Tennis players)
(95)	Grindstaff, T.L; Hammill, R.R.; Tuzson, A.E; Hertel, J. *Journal of athletic training* 41(4):450-6	2006	Neuromuscular control training programs and noncontact anterior cruciate ligament injury rates in female athletes: a numbers-needed-to-treat analysis	META ANALYSIS Assess the related risk reduction associated with neuromuscular training programmes aimed at preventing non-contact anterior cruciate ligament injuries among female athletes
	Prevention injuries & training load (n=34)			
	General strength			
(96)	Herman, D.C.; Oñate, J.A.; Weinhold, P.S.; Guskiewicz, K.M.; Garrett, W.W.; Yu, B.; Padua, D.A. *American Journal of Sports Medicine* 37(7);1301-8	2009	The Effects of Feedback With and Without Strength Training on Lower Extremity Biomechanics	Hypothesis: By using the strength training of the lower extremities, there is a low capacity of altering the biomechanics of the knees and hips when landing after a jump
(97)	Herman, D.C.; Weinhold, P.S.; Guskiewicz, K.M.; Garrett, W.E.; Yu, B.; Padua, D.A. *American Journal of Sports Medicine* 36(4):734-40	2008	The Effects of Strength Training on the Lower Extremity Biomechanics of Female Recreational Athletes During a Stop-Jump Task	Hypothesis: By using the strength training of the lower extremities, there is an alteration to the biomechanics of the knees and hips when jumping, increasing the risk of injury

(keep going)

(98)	Brushoj, C.; Larsen, K.; Nielsen, M.B.; Loye, F.; Holmich, P. *American Journal of sports medicine* 36(4):663-70	2008	Prevention of overuse injuries by a concurrent exercise program in subjects exposed to an increase in training load - A randomized controlled trial of 1020 army recruits	Hypothesis: A preventive training programme based on the literary review of the intrinsic risk factors, and undertaken alongside an increase in physical activity, may reduce the occurrence of knee injuries through overuse and medial tibia stress syndrome
(99)	Brooks, M.A.; Schiff, M.A.; Koepsell, T.D.; Rivara, F.P. *Medicine & science in sports & exercise*	2007	Prevalence of Preseason Conditioning among High School Athletes in Two Spring Sports	Establish the prevalence and indicators of training during the preseason among high school athletes.
(69)	Bahr, R.; Krosshaug, T. *Br J Sports Med* 39:324–9	2005	Understanding injury mechanisms: a key component of preventing injuries in sport	REVIEW Examine the current models being used to describe the etiology of sports injuries and develop a more comprehensive focus to understand the causes of injuries
(68)	Parkkari, J.; Kujala, U.M.; Kannus, P. *Sports Med* 31(14):985-95	2001	Is it Possible to Prevent Sports Injuries? Review of Controlled Clinical Trials and Recommendations for Future Work	REVIEW Review the trials on preventing injuries and describe their most important aspects relating to injury, monitoring and successful injury prevention
			Physical control. Core	
(100)	Wilkerson, J.B.; Giles, J.L.; Seibel, D.K. *Journal of athletic training* 47(3):264–72	2012	Prediction of core and lower extremity strains and sprains in collegiate football players: a preliminary study	Assess the value of strength and core stability measurements as injury indicators in lower extremities and strains in adolescent players (Football)
(101)	Childs, J.D.; Teyhen, D.S.; Benedict, T.M.; Morris, J.B.; Fortenberry, A.D.; Mcqueen, R.M.; Preston, J.B.; Wright, J.C.; Dugan, J.I.; George, S.Z. *Medicine & science in sports & exercise*	2009	Effects of sit-up training versus core stabilization exercises on sit-up performance	Establish if undertaking core stability exercises instead of sit-ups during training has damaging effects on "sit-up" exercise performance
			Balance. Proprioception. Neuromuscular	
(102)	Lindblon, H.; Waldén, M.; Carlfjord, S.; Hägglund, M. *British journal of sports medicine* 19(48):1425-30	2014	Implementation of a neuromuscular training programme in female adolescent football: 3- year follow-up study after a randomized controlled trial	Assess the implementation of a neuromuscular programme among female adolescent players after 3 years using a random controlled trial (Football)
(103)	Blackburn, J.T.; Norcross, M.F. *Journal of electromyography and kinesiology* 24:98–103	2014	The effects of isometric and isotonic training on hamstring stiffness And anterior cruciate ligament loading mechanisms	REVIEW Assess the effects of isometric and isotonic training on hamstring stiffness and anterior cruciate ligament injury mechanisms
(104)	Ostojic, M.; Vujkov, S.; Purkovic, S.; Trivic, T.; Stojanovic, M. *Archives of budo-science of martial arts* 7(2):61-4	2011	Physiological adaptations of a specific muscle-imbalance reduction training programme in the elite female judokas	Determine if isokinetic exercise can provide useful information about the strength of specific muscle groups and detect the imbalance among the muscle groups in Judo
(105)	González, G.; Oyarzo, C.; Fischer, M.; De la Fuente, M.J.; Diaz, V. y Berral, F.J. *Rev int med cienc act fís deporte* 11(41):95-114	2011	Specific postural balance training among young football players	Assess the training response of postural control among athletes without pathologies, using specific training.
(106)	Filipa, A.; Byrnes, R.; Paterno, M.V.; Myer, G.D.; Hewett, T.E. *Orthop sports phys ther* 40(9):551–8	2010	Neuromuscular training improves performance on the star excursion balance test in young female athletes	Establish if a neuromuscular training programme focusing on the core, stability and strength in the lower extremities can affect performance in the "Star Excursion Balance Test" (SEBT)
(107)	Roopchand-Martin, S.; Lue-Chin, S. *West indian med j* 59(2):182	2010	Plyometric training improves power and agility in jamaica's national netball team	Investigate the effects of a plyometric training programme over three weeks in improving jumping and agility and in reducing the number of injuries (Netball)
(108)	Barber-Westin, S.E.; Hermeto, A.A.; Noyes, F.R. *Journal of strength and conditioning research* 24(9):2372–82	2010	A six-week neuromuscular training program for competitive junior tennis players	Assess the efficiency of a specific training programme in improving neuromuscular rates during competition (Tennis)

(keep going)

(109)	*Emery, C.A.; Meeuwisse, W.H.* *British journal of sports medicine* *44(8):555-62*	2010	The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer: a cluster-randomised controlled trial	Examine the effectiveness of a neuromuscular prevention strategy in reducing the number of injuries in young players (Football)
(110)	Distefano, L.; Padua, D.; Blackburn, T.; Garrett, W.; Guskiewicz, K.; Marshall, S. *Journal of strength and conditioning research* 4(2):332-42	2010	Integrated injury prevention program improves balance and vertical jump height in children	Establish the extent to which improvements to balance and strength in jumping can prevent injuries in children
(111)	Pasanen, K.; Parkkari, J.; Pasanen, M.; Hiilloskorpi, H.; Makinen, T.; Jarvinen, M.; Kannus, P. *BMJ*	2008	Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study	Investigate if a neuromuscular training programme is effective in preventing non-contact injuries in women (Floorball)
(112)	Zebis, M.K.; Bencke, J.; Andersen, L.L.; Døssing, S.; Alkjær, T.; Magnusson, P.; Kjær, M.; Aagaard, P. *Clin J Sport Med* 18(4):329–37	2008	The effects of neuromuscular training on knee joint motor control during sidecutting in female elite soccer and handball players	Develop a neuromuscular training programme over a season and experimentally analyse the neuromuscular adaptation mechanisms caused during a standard side-cutting move to the non-contact anterior cruciate ligament injury (Football and Handball)
(94)	Renkawitz, T.; Boluki, D.; Linhardt, O.; Grifka, *J. Sportverletzung-sportschaden* 21(1):23-8	2007	Neuromuscular imbalances of the lower back in tennis players - the effects of a back exercise program	Establish the risk of injury in athletes with neuromuscular imbalances of the back and implement a corrective programme (Tennis players)
(95)	Grindstaff, T.L; Hammill, R.R.; Tuzson, A.E; Hertel, J. *Journal of athletic training* 41(4):450–6	2006	Neuromuscular control training programs and noncontact anterior cruciate ligament injury rates in female athletes: a numbers-needed-to-treat analysis	META ANALYSIS Determine the risk reduction associated with neuromuscular training programmes aimed at preventing non-contact anterior cruciate ligament injury rates in female athletes
(113)	Herring, K.M. *Current sports medicine reports* 5(3):147-54	2006	A plyometric training model used to augment rehabilitation from tibial fascitis.	Determine the effectiveness of a progressive plyometric training programme with an emphasis on the gradual development of the eccentric load to improve tibial fascitis
(114)	McGuine, T. A.; Keene, J.S. *American journal of sports medicine* 34(7):1103-11	2005	The effect of a balance training program on the risk of ankle sprains in high school athletes	Assess the effectiveness of a balance training programme in reducing the risk of ankle sprains (High School)
(115)	Verhagen, E.; Van der Beek, A.; Twisk, J.; Bouter, B.; Bahr, R.; Van Mechelen, W. *The american journal of sports medicine* 32(6):1385-93	2004	The effect of a proprioceptive balance board training program for the prevention of ankle sprains	Assess the effectiveness of a proprioceptive balance programme in preventing ankle sprains (Volleyball)
			Eccentric training work	
(116)	De Hoyo, M.; Pozzo, M.; Sanudo, B.; Carrasco, L.; Gonzalo-Skok, O.; Dominguez-Cob, S.; Moran-Camacho, E. *International journal of sports physiology and performance* 10(1):46-52	2015	Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players	Analyse the effect of an eccentric-overload training programme on muscle injury and the severity and performance among junior players (Football)
(117)	Petersen, J.; Thorborg, K.; Bachmann, M.; Budtz-Jørgensen, E.; Holmich, P. *The american journal of sports medicine* 39(11):2296-303	2011	Preventive effect of eccentric training on acute hamstring injuries in men's soccer	Investigate the preventive effect of eccentric hamstring muscle strengthening using the "Nordic Hamstring" exercise in comparison to other programmes with no additional hamstring exercises, on the acute hamstring injury rate (Football)
(118)	Andrew, P.; Lavendera, B.; Kazunori, N. *Journal of science and medicine in sport* 11:291-8	2008	A light load eccentric exercise confers protection against a subsequent bout of more demanding eccentric exercise	Hypothesis: A gentle eccentric exercise does not induce a loss in muscular function and has a protective effect during more strenuous eccentric activities.
(119)	Visnes, H.; Hoksrud, A.; Cook, J. *Clinical journal of sport medicine* 15(4):225-32	2005	No effect of eccentric training on jumper's knee in volleyball players during the competitive season - a randomized clinical trial	Explore the effect of an eccentric training programme on improving the patellar tendinopathy during a season (Volleyball)

(keep going)

Warming up (FIFA programmes)				
(120)	McKay, C.D.; Steffen, K.; Romiti, M.; Finch, C.F.; Emery, C.A. *Br J Sports Med* 0:1–7	2014	The effect of coach and player injury knowledge, attitudes and beliefs on adherence to the FIFA 11+ programme in female youth soccer	Describe knowledge about injuries among young female football players and identify the relationship between the training load and injury through the "FIFA 11+" programme
(121)	Owoeye, O.; Akinbo, S.; Tella, B.; Olawale, O. *Journal of Sports Science and Medicine* 13:321-8	2014	Efficacy of the FIFA 11+ Warm-Up Programme in Male Youth Football: A Cluster Randomised Controlled Trial	Assess the efficacy of the "FIFA 11+" programme in the risk of injury among young male football players from the Lagos Junior League
(122)	Steffen, K.; Emery, C.A.; Romiti, M.; Kang, J.; Bizzini, M.; Dvorak, J.; Finch, C.F.; Meeuwisse, W.H. *British Journal of Sports Medicine* 47:794-802	2013	High adherence to a neuromuscular injury prevention program (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players : a cluster randomized trial	Evaluate if the different training methods of the "FIFA 11+" programme can improve player performance and prevent injuries
(123)	Steffen, K.; Meeuwisse, W.H.; Romiti, M.; Kang, J.; MCkay, C.; Bizzini, M.; Emery, C.A. *British Journal of Sports Medicine* 47:480-7	2013	Evaluation of how different implementación strategies of an injury prevention programme (FIFA 11+) impact team adherence and injury risk in Canadian female youth football players: a cluster randomized trial	Assess the different training methods of an injury prevention programme (FIFA 11+") on adherence and injury risk among core female football teams
(124)	Longo, U.G.; Loppini, M.; Berton, A.; Marinozzi, A.; Maffulli, N.; Denaro, V. *The American Journal of Sports Medicine* 40(5)	2012	The FIFA 11+ Program Is Effective in Preventing Injuries in Elite Male Basketball Players	Examine the effects of the "FIFA 11+" programme in injury rates among elite male basketball players
(125)	Steffen, K.; Bakka, H.B.; Myklebust, G.; Bahr, R. *Scand J Med Sci Sports*	2008	Performance aspects of an injury prevention program: a ten-week intervention in adolescent female football players	Assess if the "FIFA 11+" programme can improve the performance of a group of female football players aged between 16 and 18 years

Physical control-Core-Core stability

Roetert[126] establishes that core stability is essential for good performance in almost all sports and activities. This is due to the tri-dimensional nature of many sporting movements, which require athletes to have good resistance in the hips and in the core muscles to provide an effective base stability.

Some sports require good balance, others strength, others physical symmetry, but all require good core stability in the three planes of movement[126]. A lack of strength and core stability leads to ineffective technique, which leaves the athlete prone to injury[127]. For example, lumbar pain is a common problem in any sport that requires twisting or extensive rotating movements and continuous bending and stretching movements[128-130]. Leetun *et al*.[131] found that 41 basketball players (28 women, 13 men) out of 139 (35% of the women, 22% of the men), suffered 48 back or lower extremity injuries over the season. They revealed that the players that suffered an injury, generally did not have good core stability, due to a weak abduction and external rotation of the hip, which reduced their ability to maintain stability. The conclusion was drawn that lumber-pelvic muscular requirements among women were greater, which led to them having a higher risk of suffering from lower back injuries. The conclusion was that core training could play an important role in preventing injuries, especially among women.

Physiologically, strength and core stability offer greater potential and more efficient use of shoulder, arm and leg muscles[132], which entails a lower risk of injury and positive effects on sporting performance, in terms of speed, agility, power and aerobic resistance[133].

The preventive programmes that aimed to correct weak links in core ability are designed to[134]:

- Increase joint mobility and muscle extensibility;
- Improve joint stability;
- Improve muscular performance;
- Optimise the function of movement.

Despite lower body strength being more important towards improving performance in certain sports that involve jumping, speed and agility, core resistance seems to be more important in preventing injury and recovery[135,136]. McGill[135] upheld that developing core resistance should predominate over the development of strength in the lower body in order to prevent and recover from injury in the lower body.

Poor core stability can lead to muscular imbalances that predispose the appearance of painful syndromes[91] and increase the possibility of injury to the lower body, in particular to the knee and the anterior cruciate ligament, due to poor alignment that causes overloading to the joints[92,93] and the ankles[100,101].

When prescribing core stability exercises, the concept of specificity should take greater importance. Not all exercises are specific or beneficial, as various studies have suggested[137–141]. Research must continue on the effect of core stability in sporting performance. Some studies have implied that improving core stability and strength does not have an advantageous effect on sporting performance, based on conclusions drawn largely from basic tests[142,143].

Balance. Proprioception. Neuromuscular

The term proprioception was first introduced by Sherington in 1906, who described it as a type of feedback from the limbs in the Central Nervous System. Since then, numerous authors have researched various aspects of proprioception and neuromuscular control. In modern day terms, a combination of posture, kinaesthesia and feelings of tension or strength are considered to be sub-forms of proprioception.

Limited balance ability is associated with a greater risk of falling and therefore a greater risk of injury[144]. Improving balance with training exercises reduces the rate of sprained ankles[145] and the overall rate of injuries to the lower body[95,105,108,111-113,115,146].

The effects of proprioceptive training are: an increase in muscular activation, a reduction in reaction reflex times in stretching, improved inter-muscular coordination, balance and body awareness, and therefore a reduction in proneness to injury[144].

Exercises on unstable surfaces may increase the sensitivity of muscle spindles, improving their ability to respond more effectively to disrupting forces applied to a joint. Exposure to a combination of potentially destabilising forces during training may be a necessary stimulus in promoting the development of neuromuscular effective compensatory models[147]. Paterno *et al.*[148] revealed improvements to the postural control of female athletes following a 6-week training programme that included balancing exercises performed on a Bossu ball, plyometric work, dynamic movement exercises and resistance exercises. Wedderkopp *et al.*[149] revealed that a dynamic warm up followed by ankle balance exercises reduced the chance of injury in the lower extremities in a team of female handball players. The control group was 6 times more likely to sustain an injury than the test group.

The programmes based on neuromuscular work are effective in reducing injuries and improving muscular imbalances[94,104,106,109,110].

Within neuromuscular work, tasks performed with a method based on plyometry (PLY) are noteworthy. Evidence available suggests that PLY, whether alone or in combination with others, causes numerous positive changes in the neural and muscular-skeletal system, in muscle function and sporting performance among healthy individuals.

Specifically, the studies have shown that over the long-term (3-5 sessions a week for 5-12 months), PLY constitutes an effective training method for improving bone mass in pre-pubescent and early pubescent individuals, young and pre-menopausal women. Furthermore, in the short-term (2-3 sessions a week for 6-15 weeks), PLY can alter the stiffness of various elastic components of muscular-tendon of plantar flexors among athletes and non-athletes[150]. PLY over the short-term also improves lower body strength, the power of the stretching-shortening cycle of muscles (SSC) in healthy individuals. These adaptive changes to the neuromuscular functioning are probably the result of[150]:

- Improvements to inter-muscular coordination;
- Changes to the mechanical characteristics of the muscle-tendon complex of plantar flexors;
- Changes to muscle size and/or architecture;
- Changes in the mechanics of a single fibre.

The results also show that PLY, whether used alone or in combination with other methods, has the potential of improving a wide range of sporting performances (jumping, speed races, agility, performance resistance) in children and young adults of both sexes, and reduce the risk of injury to the lower extremities in female athletes.

Although there are still many issues related to PLY still to address, the results allow for PLY to be recommended as a safe and effective training method to improve muscular function in the lower extremities, as well as acting as a functional training method for improving performance among healthy individuals[102,103,114].

Eccentric

Eccentric exercise (ECC) has been classically used to improve muscle strength and power in healthy individuals and athletes, and thanks to its physiological and specific mechanical properties, there is a growing interest in its use for clinical and rehabilitation purposes.

The majority of muscular injuries acquired in team sports are produced through explosive and eccentric type movements, which constitute one of the reasons why this type of work is advocated as a preventive method as well as a treatment for chronic injuries[119].

Eccentric work may reduce the OI, the number of injury days and should be worked into sports injury prevention programmes for team sports[118].

Petersen *et al.* carried out a study with 50 amateur and elite Australian football teams (n=942), implementing a 10-week eccentric hamstring strengthening programme using the Nordic Hamstring exercise. The control group had 52 injuries compared to the 15 injuries sustained by the intervention group[117].

Hoyo *et al.* propose a 10-week programme, 3 sessions per week with 2 open stable kinetic hip exercises (Nordic curls) and one closed unstable exercise (2 lunges Bossu), emphasising the hamstring action and stabilising the knee in the eccentric work (1 eccentric leg dead lifts)[116].

Another study based on a preventive programme for hamstring musculature that entails stretching, exercises for specific sports performed in fatigue, increase in the amount of time working at high intensities and anaerobic interval training as well as increasing the times worked at high intensity, were carried out among elite Australian football players (n=70) over 4 seasons, with the outcome of reducing lost match days from 31 and 38, to 5 and 16 and an OI of 4.7 to 1.3[151].

Interest in eccentric work is based on:

Optimal length movement

It has been suggested that optimum muscle tension in each action can reduce the number of injuries[152]. The only training method that has been proven to consistently increase the optimum length of developing tension has been eccentric exercise[152,153]. This fact has been proven in elbow flexes, plantar flexes and in flexes and extensors of the knee[154-156]. The extent of change depends on 3 variables: eccentric exercise load, eccentric exercise volume and the length of the muscle during the eccentric muscular action.

Accentuated and supra-maximal load eccentric training

It has been shown that human beings are capable of recruiting a lower number of motor units (with the same development of strength) during an eccentric muscular action than during a concentric action. The neural efficiency of eccentric muscular actions is greater, which is why they have been suggested to maximise neural activation and the adaptation of subsequent strength. To perform these actions, greater loads are required[157]. Some research has suggested that subjects may gain 20-60% more concentric and eccentric strength through eccentric training as opposed to concentric training[158].

Eccentric work to improve the S-S cycle (stretching-shortening)

Research has shown that when producing concentric strength, isolation is relatively low in comparison to concentric contractions that are preceded by an eccentric muscular action[159]. This link is called SSC. The SSC may have large or small amounts of angular related movement of the joints and is composed of both voluntary and involuntary reflex actions[160]. To get the optimum potential from SSC (a higher concentric contraction), various factors are essential:

- Pre-activation of muscle before the contact;
- No short coupling times (i.e. time between the end of the eccentric phase and the appearance of the concentric phase);
- Short-lasting contraction;
- High-speed eccentric muscle action;
- Small increase in movements.

Rehabilitation of specific injuries (tendinopathy of the Achilles tendon)

This work is based on the idea that injuries to the Achilles tendon may emerge from supporting traction loads that are higher than the tendon's mechanical resistance[161]. When these loads are repeated, as in many activities and sports, they may result in a symptomatic condition.

The theory of eccentric training, promoted for its importance in the structural adaptation of the symptomatic tendon establishes that it could be used when facing increasing repetitive loads and prevent injury[161]. The rehabilitation programmes that involve eccentric training using loads greater than the weight of the body have provided positive results in treating Achilles tendinopathy, with reduced pain and a greater number of patients returning to the pre-injury physical activity levels[162].

Not all the studies give positive results, such as Visnes et al. who did not find improvements following the implementation of eccentric work to improve patellar tendinitis over 12 weeks among volleyball players that continued to compete whilst the programme was underway[119].

Isokinetic tests[107]

Whenever the opportunity arises, it is recommendable to perform isokinetic tests to establish the agonistic-antagonistic relationship and the possible strength deficits that leave the player prone to injury.

Specific warm ups

Different studies show that by including a specific, dynamic warm up, of between 15-20 minutes, where coordination, balance and strength are all worked, there is an improvement to the postural balance and the risk of injury is reduced. Of particular interest are the studies based on the programme developed by FIFA, called FIFA 11+, which consisted in 10 exercises that worked on core stability, lower extremity strength, balance and agility[120-125], in which all revealed a reduction in the risk of injury.

Table 4 studies found on Injury Prevention analyzed. Other preventive measures.

Blood tests. Supplementing

Blood testing among sportspeople is a long-recognised method for establishing the health of the individual, if training is being assimilated properly, and if some kind of supplementing is necessary, with the most common being iron due to anaemia induced through practicing sports[163, 64].

Biometric analysis

Biomechanical studies and/or video analysis may reveal new ways of reducing the OI and should be part of a preventive work in which they are observed, analysed and then a series of measures are applied to them with the aim of re-training movements and reducing the possibility of injury. In basketball, and more so in women, due to their predisposition to valgus knee, it is important to study landing after a jump. Biomechanical studies can allow us to analyse the movement phases with precision, establishing the loads that are supported upon landing and allowing for the prediction of sportspeople that are at greater risk of having certain types of injury[165,166].

Material and regulations

Many sporting injuries are the result of unavoidable accidents, but there are also many that could be prevented. Taking measures such as altering the rules of play, especially in team and contact sports, should be considered with the objective of reducing the number of violent contacts between participants. There are interventions that have included changes to the rules, involving large groups of participants, and proving to be effective in reducing injuries[173,174]. This is the case of concussions[175]. These measures include changes to the rules to avoid impact to the head, conditioning of the neck muscles, the use of mouth-guards and the use of helmets and head protectors.

The use of protective devices may also result in unexpected conequences, for example, skiers that use helmets can ski harder, closer to their limits, and under worse conditions, supposing that the helmet protects the head, whereas in reality this change in behaviour leads to an even greater risk of injury. The sporting material used can undoubtedly prevent injury, or on the contrary, increase them.

Facial injuries are common in a significant number of sports; thanks to the more systematic use of helmets and face-guards, injury rates have fallen[176]. In the USA alone, it was estimated that over 1,600 eye injuries were sustained in different forms of hockey in 1997[177]. However, since 1997, no major eye injuries have been registered among the over 1 million players that wore fully-certified hockey masks[178].

In the case of sports footwear (trainers, boots, skates, etc.), it is of equal importance to ensure they have the correct properties, i.e. of stiffness, absorption, etc. required for each sport[167-169]. Based on the literature available, Robbins and Waked[178] reached the conclusion that in terms of the feeling the foot position in human beings, being barefoot is necessary but sporting footwear distorts feet, increasing the

Table 4. Prevention of injuries. Other preventive measures.

	Authors, Journal & Reference	Year	Article	Objective / Hypothesis
			Training load & control & team sports (n=3)	
			Blood test-Supplementing	
(163)	Claudino, Joao G.; Mezencio, Bruno; Amaral, Sergio. *Journal of the international society of sports nutrition* 11(32)	2014	Creatine monohydrate supplementation on lower-limb muscle power in Brazilian elite soccer players	Examine the effects of creatine-monohydrate supplementation on lower-limb muscle power in Brazilian elite football players
(164)	Bizzaro, N. *Recenti progressi in medicina* 80(5):237-40	1989	Study of variations in hematologic parameters in rugby players undergoing physical training at a high altitude	Prove that well-trained rugby players can develop mild anaemia due to the increase in plasma volume with a relative reduction of red blood cells
			Biomechanical Analysis	
(165)	Pietraszewski, B.; Struzik, A. *Acta of bioengineering and biomechanics* 15(4):103-8	2013	Evaluation of selected biomechanical parameters in female team sports players	Assess the biomechanical parameters of lower limbs and their influence in the height of vertical jumps
			Prevention injuries & training load (n=7)	
			Biomechanical Analysis	
(166)	Myer, G.D.; Ford, K.R.; Barber, K.D.; Rauh, M.J.; Paterno, M.V.; Hewett, T.E. *Journal of Athletic Training* 49(3):389-98	2014	A Predictive Model to Estimate Knee-Abduction Moment: Implications for Development of a Clinically Applicable Patellofemoral Pain Screening Tool in Female Athletes	Identify biomechanical laboratory measures to precisely measure the loads supported during landing and predict a greater risk of injury among female athletes
			Material	
(167)	Fourchet, F.; Kuitunen, S.; Girard, O.; Beard, A.J.; Millet, J.P. *Journal of Sports Science and Medicine* 10:292-300	2011	Effects of combined foot/ankle electromyostimulation and resistance training on the in-shoe plantar pressure patterns during sprint in young athletes	Investigate the influence of a five-week ankle and knee strengthening training programme on the in-shoe plantar pressure patterns during sprint in young male athletes
(168)	Lohrer, H.; Turbanski, S.; Nauck, T.; Schmidtbleicher, D. *Sportverletzung-sportschaden* 22(4):191-5	2008	Balance Therapy Shoes - a Comparative Analysis with Respect to Immediate Training Effects	Hypothesis: Using a different shoe to that normally used entails a different load supported by the neuromuscular system that affects postural control
(169)	Eils, E.; Streyl, M. *Sportverletzung Sportschaden* 19(3):140-5	2005	A one year aging process of a soccer shoe does not increase plantar loading of the foot during soccer specific movements	Assess the influence of a controlled ageing process on a foot load model inside a football shoe
			Public Health	
(170)	Finch, C.F. *British journal of sports medicine* 46(1):70-4	2012	Getting sports injury prevention on to public health agendas - addressing the shortfalls in current information sources	Hypothesis: The main reason behind a lack of sports injuries policies in Government Departments for health or sport till now is a lack of relevant information made available to the politicians in charge for decision-making
			Educational Intervention	
(171)	Myer, G.D.; Faigenbaum, A.D.; Chu, D.A.; Falkel, J.; Ford, K R.; Best, T.M.; Hewett, T.E. *Physician and sportsmedicine* 39(1):74-84	2011	Integrative Training for Children and Adolescents: Techniques and Practices for Reducing Sports-Related Injuries and Enhancing Athletic Performance	REVIEW Review the scientific evidence available on youth and conditioned strength training and offer recommendations that are appropriate for each age to integrate them into the different strength and conditioning activities in a well-designed programme that is safe, effective and enjoyable
(172)	Cook, M.; Cusimano, C.H.; Chipman, M.L. *Injury Prevention* 9:361-6	2003	Evaluation of the ThinkFirst Canada, Smart Hockey, brain and spinal cord injury prevention video	Assess the knowledge and adherence to the "ThinkFirst Canada" programme about preventing injuries that shows the mechanisms and onsequences of brain and spinal injuries acquired whilst playing ice-hockey among 11-12 year old children practicing this sport.

frequency of ankle sprains while using sporting footwear. They suggest that the best solution for reducing ankle sprains while using sport shoes is to use footwear that offers a maximum level of sensitivity, thus being aware of the foot's position.

The positive preventive effect of ankle stabilisers has been revealed in different studies[179-181]. The use of shock-absorbing soles in footwear reduces the incidence of fractures due to overloading among athletes[182-186]. Gillespie and Grant[187] calculated, using their systematic Cochrane review, that in accordance with these trials, the use of shock-absorbing soles reduces the risk of stress fractures by 53%. However, these authors expressed their concern regarding the relatively low quality of these 5 trials.

Despite prophylactic ankle stabilisers appearing to prevent some ankle injuries, once again, more research is required with other prophylactic interventions and their general applicability[188,189].

***Public Health*[170]**

Injuries have moved through the sporting sphere, reaching all sectors of the population to the point that they have been considered as public health concerns with the subsequent intervention of governmental departments.

Until research in sports medicine produces information about the population and cost-benefit estimations, the prevention of sporting injuries will continue to be undervalued within the public health sphere, due to the lack of relevant information available that would allow political leaders to make decisions and implement measures.

Educational intervention

Education-Training from childhood

It is important to establish age-appropriate training guidelines that may reduce the risk of sport-related injuries and improve sporting performance. Integrative Training is defined as a programme or plan that incorporates strength and conditioning into general and specific activities that improve both components, such as health and physical condition[171].

The keystone of integral training is age-appropriate education and teaching by qualified professionals that understand the physical and psychosocial uniqueness of children and adolescents.

Educational intervention programme

To date, existing data about OI, injury factors and mechanisms in different sports and the preventive measures that have proven effective, may be used to educate young athletes, despite them facing a low risk of injury, given that a good understanding of the risks is likely to generate a preventive effect[190].

In team sports, it is generally necessary to have a larger focus on reducing rough and violent contact between athletes.

Ice hockey is a good example of preventive measures of this type. To avert spinal injuries aggressive behaviour should be avoided, especially if sustained from behind or next to the rink barriers, and should be penalised by the rules of play. The use of contact with the stick in this sport partly explains the high number of hand injuries and wrist fractures sustained, and should be controlled[191]. With the aim of reducing OI in ice hockey, a Canadian programme was implemented called "Think first" [172], with the objective of assessing the transfer of knowledge and results to 11 and 12-year old players via a video, explaining how to avoid injuries, injury mechanisms and their consequences, with particular emphasis on brain and spinal injuries. The results indicated that after just one viewing their knowledge improved, as did their behaviour on the rink, and stayed that way for three months, though they indicate that a greater number of samples would be necessary.

In Table 5 the studies found on Injury Prevention anterior cruciate ligament (ACL) are analyzed.

Anterior cruciate ligament injuries (ACL) are among the most worrying in team sports, as these injuries may have serious consequences for the sportsperson with a high risk of early-onset osteoarthritis and are considered one of the most serious frequently occurring injuries[193,199,200].

The capacity to design specific prevention programmes is currently limited by an incomplete understanding of the causes of injury. A multifactorial approach should be used to appreciate all the factors involved, internal and external, as well as the causes of the injury and a description of the entire body and biomechanics together at the time of the injury.

Again, the previously seen aspects (general and mode-specific strength work, physical control, balance, propioception, neuromuscular, eccentric) seem to be the bases of ACL injury prevention.

Physical control-Core-Core stability

Core stability exercises have been defended in the prevention and rehabilitation of lower extremity injuries[211,212].

Power and stability training of the core, along with the correct alignment of the lower extremities, result in a lower loading of the knee and reduce knee injury risk factors[91,93,194,195,197,203,208,209].

The body's core forms a base upon which the lower extremity muscles produce or resist strength. Several of the muscles that act on the knee joint originate from the pelvic lumbar region.

McGill[135] establishes that developing core resistance should take priority over developing lower body strength in order to prevent and recover from lower body injuries. For example, a lack of core muscle conditioning may result in a defective landing mechanism with the increase of valgus type exertions acting on the knee joint, which could lead to an anterior cruciate ligament injury (ACL).

Movement re-training techniques

The studies that implemented intervention programmes to re-train both the stride technique while running and the most basic and common movement action in team sports, such as in basketball, handball, football, indoor football, where running stops followed by a jump and subsequent landing, called the "stop and jump task" in some articles, are of particular interest.

These programmes seek to avoid poor alignment of the hip, knee and ankle, such as the valgus position, insufficient flex of the knee and hip flexion[97,99,107,166,192,196-198,201,202,205-207,210].

Balance. Proprioception

Research has revealed the effectiveness of exercises performed on unstable surfaces in reducing the possibility of injuring the ACL[211,212].

Myklehust *et al.*[213] establish that plyometric and balance exercises significantly reduce the risk of ACL injuries in elite handball players.

Table 5. Prevention of injury to the anterior cruciate ligament (ACL).

	Authors, Journal & Reference	Year	Article	Objective/Hypothesis
			Training load & control & team sports (n=9)	
(192)	Dempsey, Alasdair R.; Elliott, Bruce C.; Munro, Bridget J. *Journal of applied biomechanics* 30(2):231-6	2014	Can technique modification training reduce knee moments in a landing task?	Assess if the landing technique is involved in the injury of the ACL
(193)	Donnelly, C. J.; Elliott, B. C.; Ackland, T. R. *Research in sports medicine* 20(3):239-62	2012	An anterior cruciate ligament injury prevention framework: incorporating the recent evidence	REVIEW Review the scientific evidence on ACL injury mechanisms
(194)	Hewett, Timothy E.; Myer, Gregory D. *Exercise and sport sciences reviews* 39(4):161-6	2011	The mechanistic connection between the trunk, hip, knee, and anterior cruciate ligament injury	Hypothesis: The lateral movement of the core increases the load and neuromuscular training improves core control, reducing the load borne by the knees.
(195)	Cochrane, Jodie L.; Lloyd, David G.; Besier, Thor F. *Medicine and science in sports and exercise* 166(42):1535-44	2010	Training affects knee kinematics and kinetics in cutting maneuvers in sport	Examine how different training forms affect the kinematics of the knee during different actions and the potential of these forms in reducing the ACL loading
(196)	Dworak, Lechoslaw B.; Rzepnicka, Agata.; Wilkosz, Piotr. *Chirurgia narzadow ruchu i ortopedia polska* 75(1):35-41	2010	Analysis of knee joint injuries of competitive volleyball players in selected sports clubs of poznan city-biomechanical context. Synthesis-proposal for the usage of physiotherapy methods in the prevention of the discussed injuries.	Analyse the frequency and type of injury in knee joints that occur in elite volleyball players, as well as how to propose the use of modern physiotherapy with the aim of preventing these injuries (Volleyball)
(197)	Dempsey, Alasdair R.; Lloyd, David G.; Elliott, Bruce C. *American journal of sports medicine* 37(11):2194-200	2009	Changing sidestep cutting technique reduces knee valgus loading	Hypothesis: Modifying the sidestep cutting technique could reduce knee loading
(198)	Imwalle, Lauren E.; Myer, Gregory D.; Ford, Kevin R. *Journal of strength and conditioning research* 23(8):2223-30	2009	Relationship between hip and knee kinematics in athletic women during cutting maneuvers: a possible link to noncontact anterior cruciate ligament injury and prevention	Compare the kinematics of the lower extremities to 45º and 90º during the sidestep cutting action and examine the rotations of the lower extremities during these actions
(199)	Renstrom, P.; Ljungqvist, A.; Arendt, E. *British journal of sports medicine* 42(6):394-412	2008	Non-contact acl injuries in female athletes: an international olympic committee current concepts statement	REVIEW Review the ACL injury mechanisms in female athletes
(200)	Petersen, W.; Rosenbaum, D.; Raschke, M. *Deutsche zeitschrift fur sportmedizin* 56(6):150-6	2005	Anterior cruciate ligament ruptures in female athletes. Part 1: epidemiology, injury mechanisms, and causes	REVIEW Review the epidemiology, the injury mechanisms and the causes of injury of the ACL in female athletes
			Prevention injuries & training load (n=10)	
(201)	Aerts, I.; Cumps, E.; Verhagen, E.; Wuyts, B.; De Gucht, S.V.; Meeusen, R. *Journal of sport rehabilitation* 24(1):21-30	2015	The Effect of a 3-Month Prevention Program on the Jump-Landing technique in Basketball: A Randomized Controlled Trial	Assess the influence of an anterior cruciate ligament injury prevention programme by teaching jumping and landing techniques
(202)	Dai, B.Y.; Garrett, W.E.; Gross, M.T.; Padua, D.A.; Queen, R.M.; Yu, B. *American journal of sports medicine* 43(2):466-74	2015	The Effects of 2 Landing Techniques on Knee Kinematics, Kinetics, and Performance During Stop-Jump and Side-Cutting Tasks	Assess the effect of an intervention programme aimed at improving the jumping and landing technique, on the anterior cruciate ligament injury rate
(203)	Myer, Gregory D.; Ford, Kevin R.; Brent, Jensen L.; Hewett, Timothy E. *Strength cond res.* 26(8):2272–92	2012	An integrated approach to change the outcome part ii: targeted neuromuscular training techniques to reduce identified acl injury risk factors	Propose an integrated approach to identify and select mechanical bases that explain the increase in ACL injuries among female sportswomen
(204)	Greska, Eric K.; Cortes, N.; Van Lunen, Bonnie L.; Oñate, James A. *J strength cond res.* 26(6):1609–19	2012	A feedback inclusive neuromuscular training program alters frontal plane kinematics	REVIEW

(keep going)

(205)	White P.E.; Ullah, S.; Donaldson, A.; Otago, L.; Saunders, N.; Romiti, M.; Caroline, A.; Finch, F. *Journal of Science and Medicine in Sport* 15:19–24	2012	Encouraging junior community netball players to learn correct safe landing technique	Understand the behavioural factors associated with the correct landing technique during training sessions with junior netball players to reduce the risk of anterior cruciate ligament injury
(206)	Aerts, I.; Cumps, E.; Verhagen, E.; Meeusen, R. BMC Musculoskeletal Disorders 11, 281	2010	Efficacy of a 3 month training program on the jump-landing technique in jump-landing sports. Design of a cluster randomized controlled trial	Assess the effect of an intervention programme aimed at improving the jumping and landing technique, on the anterior cruciate ligament injury rate (ACL)
(207)	Herrington, L. *Journal of strength and conditioning research* 24(12):3427-32	2010	The effects of 4 weeks of jump training on landing knee valgus and crossover hop performance in female basketball players	Assess whether a reduced jumping programme could have similar effects to previously reported longer-lasting programmes in preventing anterior cruciate ligament injuries
(208)	Myers, C.A.; Hawkins, D. *Journal of biomechanics* 43(14):2657-64	2010	Alterations to movement mechanics can greatly reduce anterior cruciate ligament loading without reducing performance	Identify biomechanical changes that sportspeople can perform to reduce anterior cruciate ligament loading
(209)	Myer, Gregory D.; Ford, Kevin R.; Brent, Jensen L.; Hewett1, Timothy E. BMC musculoskeletal disorders 39(8)	2007	Differential neuromuscular training effects onacl injury risk factors in"high-risk" versus "low-risk" athletes	Establish the effect of neuromuscular training among athletes classed as "high-risk" of suffering ACL injuries in comparison with those classed as "low-risk" Hypothesis: high-risk athletes will reduce abduction stages whilst low-risk athletes will not show any measurable changes
(210)	Dempsey, A.R.; Lloyd, D.G.; Elliott, B.C.; Steele, J.R.; Munro, B.J.; Russo, K.A. *Medicine & Science in Sports & Exercise* 39(10):1765-73	2007	The effect of technique change on knee loads during sidestep cutting	Identify the effect of modifying the sidestepping technique on the knee and predict what impact the change will have on the risk of injuring the anterior cruciate ligament

Caraffa *et al.*[214] reported significantly fewer ACL injuries among semi-professional and amateur football players after performing a balance exercise programme in training.

Padua[215] revealed that performing balance and plyometric exercises in training influences the capacity to change the biomechanics of the use of the lower extremities in more damaging movements, thus reducing the risk of injury to the knee and rupture of the ACL.

Despite this evidence and the frequent incorporation of balance exercises into injury prevention programmes, only a few studies have actually assessed and proven the influence of balance work on preventing ACL rupture[216].

Neuromuscular and proprioceptive work is very important in both preventing[94,106,110,204,209] and avoiding recurrences. Fitzgerald, Hacha and Snyder-Mackler[217] assessed the effectiveness of a training programme with imbalances as a complement to rehabilitation exercises. The intervention group that worked within this programme were 5 times more likely to successfully return to vigorous sporting activities.

Neuromuscular work should be included within weekly training loads, as it is appropriate for compensating muscular imbalances, increasing strength and protecting the body from all kinds of injury, including non-contact anterior cruciate ligament rupture, reducing, among other aspects, valgus knee.

A successful return to previous activity levels following the reconstruction of the anterior cruciate ligament (ACL) is not guaranteed, and the likelihood of sustaining a second ACL injury may reach 30%. In particular, young athletes that return to sporting activities in the first months following a first ACL reconstruction may have a significantly greater risk than after a second.

Significant neuromuscular deficits and functional limitations are commonly identified among athletes with ACL reconstruction. Unusual movements and a lack of neuromuscular control may be both residual, from deficits that were already present before the initial injury, and exacerbated through the injury and the subsequent ACL reconstruction surgery. Following ACL reconstruction surgery, neuromuscular deficits are present in both surgical and non surgical extremities, and may precisely predict the risk of a second ACL injury in adolescent athletes.

All the work reviewed revealed a reduction in the risk on injury and a lower OI in the intervention group after implementing work of this type.

Conclusions and personal opinion

- Preventing injury has become one of the technical team's most important objectives, if not the most important, and is a component within the training programme with its very own fundamental organisation.
- Work should continue to develop on consensus regarding the work methodology to be followed, allowing for enhanced study comparisons.
- Load monitoring should involve the collecting of quantitative and qualitative data, both within and outside training (recovery

capacity) and should consider the sensations of the athlete and the possible deviations between the technical team plan and that carried out by the athlete.

- General and specific strength work, with particular emphasis on eccentric work, along with proprioceptive control and neuromuscular coordination, shape the basic pillars upon which an injury prevention plan is based. This type of work is based around enhancing all the active protection mechanisms through systematised stimulation which obliges athletes to control, think about and internalise their movements, giving them greater control over them.
- An on-going review of the rules of play and protection materials should be considered, as they lead to a reduction in incidents incurring injury.
- Biomechanical and video studies should continue, both laboratory and field based, which allow for on-going progress in the knowledge of the causes and factors of injuries.
- Injuries have expanded out of the sporting world and have reached the general population. Epidemiological studies are needed regarding injury incidents in the general public, which would allow us to assess the magnitude of the situation.
- Prevention has been shown to be cheap and effective when compared to the economic, sporting and labour costs caused by injuries, even if it is difficult to assess how many injuries are produced through inadequate sports training and how many are averted through adequate sports training.
- Efforts should be continued to promote injury prevention from the global perspective of the athlete from childhood, where perhaps the real prevention can be found, through:
  - Medical checks adapted to each life stage
  - Developing complete physical activity programmes that entail a domain over basic movement models and abilities in different situations and across all fields and planes.
  - Develop general and specific educational intervention programmes that explain the occurrence of injuries, their causes, factors and consequences.

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