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 training, 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 allow 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:

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.

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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) 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) 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) 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); oxygen consumption (VO2); and blood lactate (LA), as objective and quantitative measures.

In recent years, some authors 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. Some of these control methods are training logs, questionnaires, direct observation 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.
Borg's RPE Scales from 1962⁴⁰ and 1982⁴² have been used in numerous studies to control and evaluate exertion made, both in team sports⁴¹-⁴⁸ as well as individual sports⁴⁹.

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 athletics⁴⁹, swimming⁵⁰, basketball⁵¹ and handball⁵² 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 HR⁵⁴-⁵⁸, RPE and VO2⁵⁹-⁶¹ and RPE and LA⁶²-⁶³.

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 conditions⁶⁶.

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 reasons⁶⁶. 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 seasons⁶⁷.

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 process⁶⁸-⁶⁹. 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 methodology⁷¹-⁷². In the review carried out by Parkkari et al. (2001)⁷³ a sequence is suggested for collecting injury data, establishing the most important points to consider:

- Clearly define what constitutes an injury and standardise it.
- The use of protective equipment.
- Part(s) of the body injured.
- The characteristics of the injured person.
- Nature of the injury (severe sprain, fracture, etc.).
- Type of sporting event and the activity being undertaken at the time of injury.
- The seriousness of the injury (affected activity, working time lost, treatment needs, treatment costs, permanent damage, deterioration or disability).
- The mechanism of the injury, acute or through overuse.
- Level of supervision.
- Location where the injury took place.
- 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 sequence⁷⁸,⁷⁹.**

1. Establish the scope of injuries:
   - Incidence
   - Seriousness

2. Establish the etiology and mechanisms of sporting injuries

3. Introduce preventive measures

4. Assess their efficiency to repeat step 1
− 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.
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- 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.

<table>
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<tr>
<th>Training load &amp; control &amp; team sports</th>
<th>Prevention injuries &amp; training load</th>
<th>Total</th>
<th>%</th>
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<td><strong>Control, training monitoring</strong></td>
<td>15</td>
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<td>17</td>
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<td><strong>Prevention of injuries</strong></td>
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<td><strong>Measures in the training</strong></td>
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<td>Physical control. Core.</td>
<td>3</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Balance. Proprioception. Neuromuscular</td>
<td>2</td>
<td>16</td>
<td>18</td>
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<tr>
<td>Eccentric work</td>
<td>0</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Warming up (FIFA programmes)</td>
<td>0</td>
<td>6</td>
<td>6</td>
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<tr>
<td><strong>Other measures</strong></td>
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<tr>
<td>Blood test- Supplementing</td>
<td>2</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Biomechanical analysis</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Rules and subject matter</td>
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<td>Public Health</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>Educational Intervention</td>
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<td>2</td>
<td>2</td>
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<tr>
<td><strong>Prevention of ACL</strong></td>
<td>9</td>
<td>10</td>
<td>19</td>
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<tr>
<td><strong>Injury frequency. Epidemiology</strong></td>
<td>13</td>
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<tr>
<td>Others</td>
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<td><strong>N</strong></td>
<td>49</td>
<td>76</td>
<td>125</td>
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**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, 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, 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, and other applications to standardise data collection from training loads and injuries such as the “Training and Injury Prevention Platform for Sports” (TIPPS).

The holistic approach 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. 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 and stress using questionnaires such as RESTQ-Sport or “Profile of mood states” (POMS) 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, 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, even if some suggest that a general strength programme alone is not enough to reduce the OI, requiring the application of other measures such as retraining movement and giving suitable feedback.

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<table>
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<th>Authors, Journal &amp; Reference</th>
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<th>Article</th>
<th>Objective / Hypothesis</th>
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<td><strong>Training load &amp; control &amp; team sports (n=15)</strong></td>
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<tr>
<td>(74) Henderson, Brendan.; Cook, Jill.; Kidgell, Dawson J.</td>
<td>2015</td>
<td>Game and training load differences in elite junior Australian football</td>
<td>Assess the differences in the measurements of external and internal physical training loads during competition and training (Australian football)</td>
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<td><em>Journal of sports science and medicine</em> 14(3):494-500</td>
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<tr>
<td>(75) Gallo, Tania.; Cormack, Stuart.; Gabbett, Tim.</td>
<td>2015</td>
<td>Characteristics impacting on session rating of perceived exertion training load in Australian footballers</td>
<td>Establish the relationship between the training load and external qualification session of perceived exertion (Australian football)</td>
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<td><em>Journal of sports sciences</em> 33(5):467-75</td>
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<tr>
<td>(76) Matos, Felipe de Oliveira.; Samulski, Dietmar Martin.; Perrout de Lima, Jorge Roberto.</td>
<td>2014</td>
<td>High loads of training affect cognitive functions in soccer players</td>
<td>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)</td>
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<td><em>Revista brasileira de medicina do esporte</em> 20(5):388-93</td>
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<tr>
<td>(77) Rodriguez-Marroyo, Jose A.; Medina, Javier; Garcia-Lopez, Juan.</td>
<td>2014</td>
<td>Correspondence between training load executed by volleyball players and the one observed by coaches</td>
<td>Compare the training load executed by players with that observed by trainers (Volleyball)</td>
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<td><em>Journal of strength and conditioning research</em> 28(6):1588-94</td>
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<tr>
<td>(78) Lion, Alexis.; Theisen, Daniel; Windal, Thierry.</td>
<td>2014</td>
<td>Moderate to severe injuries in football: a one-year prospective study of twenty-four female and male amateur teams</td>
<td>Assess the seriousness of injuries produced during a season among amateur teams (Football)</td>
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<tr>
<td>(79) Binnie, Martyn John.; Dawson, Brian.; Arnot, Mark Alexander.</td>
<td>2014</td>
<td>Effect of sand versus grass training surfaces during an 8-week pre-season conditioning programme in team sport athletes</td>
<td>Compare the intensity of training on two different surfaces: grass and sand</td>
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<td><em>Journal of sports sciences</em> 32(11):1001-12</td>
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<tr>
<td>(80) Malisoux, Laurent.; Frisch, Anne.; Urhausen, Axel.</td>
<td>2013</td>
<td>Monitoring of sport participation and injury risk in young athletes</td>
<td>Compare the characteristics of sporting participation in the different categories of sports for young people and establish their relationship with injuries incurred</td>
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<td><em>Journal of science and medicine in sport</em> 16(6):504-8</td>
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<td>(81) Scott, Tannath J.; Black, Cameron R.; Quinn, John.</td>
<td>2013</td>
<td>Validity and reliability of the session-rpe method for quantifying training in Australian football: a comparison of the cr10 and cr100 scales</td>
<td>Validate the CR10 and CR100 perceived exertion scale in team sports that require highly intense intermittent exertion</td>
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<td><em>Journal of strength and conditioning research</em> 27(1):270-6</td>
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<td>(82) Miloski, Bernardo.; Freitas, Victor Hugo.; Bara Filho, Mauricio Gattas</td>
<td>2012</td>
<td>Monitoring of the internal training load in futsal players over a season</td>
<td>Analyse the internal training load in a macro-cycle, using the qualification method of perceived exertion of the session (Indoor football)</td>
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<td><em>Revista brasileira de cineantropometria &amp; desempenho humano</em> 14(6):671-9</td>
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<td>(83) Boullosa, Daniel Alexandre.; Abreu, Laurinda.; Luis Tuimil, Jose.</td>
<td>2012</td>
<td>Impact of a soccer match on the cardiac autonomic control of referees</td>
<td>Assess the heart-rate of adult referees during competition (Football)</td>
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<td><em>European journal of applied physiology</em> 112(6):2233-42</td>
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<td>(84) Gabbett, Tim J.; Ullah, Shahid.</td>
<td>2012</td>
<td>Relationship between running loads and soft-tissue injury in elite team sport athletes</td>
<td>Relate low and high intensity activities and high, and the risk of incurring soft-tissue injuries (Team sports)</td>
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<td><em>Journal of strength and conditioning research</em> 26(4):953-60</td>
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<td>(85) Lovell, G. P.; Townrow, J.; Thatcher, R.</td>
<td>2010</td>
<td>Mood states of soccer players in the English leagues: reflections of an increasing workload</td>
<td>Evaluate the mood of players in relation with the demands of competition and relate it with their health and performance (Football)</td>
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<td><em>Biology of sport</em> 27(2):83-8</td>
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<td>(86) Pyne, David B.; Mujika, Inigo; Reilly, Thomas.</td>
<td>2009</td>
<td>Peaking for optimal performance: research limitations and future directions</td>
<td>REVIEW Establish the research constraints that aim to obtain peak performance in team sports</td>
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<td><em>Journal of sports sciences</em> 27(3):195-202</td>
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<td><strong>Physical control. Core</strong></td>
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<tr>
<td>(91) Ezechieli, M.; Siebert, C. H.; Ettinger, M. Technology and health care 21(4):379-86</td>
<td>2013</td>
<td>Muscle strength of the lumbar spine in different sports</td>
<td>Assess the capacity of stabilising the core in dynamic movements and the ability to absorb strength during repetitive training loads (Sports)</td>
</tr>
<tr>
<td>(92) Jamison, Steve T.; Mcneilan, Ryan J.; Young, Gregory S. Medicine and science in sports and exercise 44(10);1924-34</td>
<td>2012</td>
<td>Randomized controlled trial of the effects of a trunk stabilization program on trunk control and knee loading</td>
<td>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.</td>
</tr>
<tr>
<td>(93) Myer, G. D.; Brent, J. L.; Ford, K. R. British journal of sports medicine 42(7):614-9</td>
<td>2008</td>
<td>A pilot study to determine the effect of trunk and hip focused neuromuscular training on hip and knee isokinetic strength</td>
<td>Assess the neuromuscular training effect of the core in hip and knee strength</td>
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**Balance. Proprioception. Neuromuscular**

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<tr>
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<th>Article</th>
<th>Objective / Hypothesis</th>
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<tbody>
<tr>
<td>(94) Renkawitz, T.; Boluki, D.; Linhardt, O.; Griffa, J. Sportverletzung-sportschaden 21(1):23-8</td>
<td>2007</td>
<td>Neuromuscular imbalances of the lower back in tennis players - the effects of a back exercise program</td>
<td>Establish the risk of injury in athletes with neuromuscular imbalances of the back and set up a corrective programme (Tennis players)</td>
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**Prevention injuries & training load (n=34)**

**General strength**

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<td>(96) Herman, D.C.; Oñate, J.A.; Weinhold, P.S.; Guszkiewicz, K.M.; Garrett, W.W.; Yu, B.; Padua, D.A. American Journal of Sports Medicine 37(7):1301-8</td>
<td>2009</td>
<td>The Effects of Feedback With and Without Strength Training on Lower Extremity Biomechanics</td>
<td>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</td>
</tr>
<tr>
<td>(97) Herman, D.C.; Weinhold, P.S.; Guszkiewicz, K.M.; Garrett, W.E.; Yu, B.; Padua, D.A. American Journal of Sports Medicine 36(4):734-40</td>
<td>2008</td>
<td>The Effects of Strength Training on the Lower Extremity Biomechanics of Female Recreational Athletes During a Stop-Jump Task</td>
<td>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</td>
</tr>
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Note: The table continues with more entries that are not fully displayed in the image.
Evolution of injury prevention training monitoring

| (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 |

Physical control. Core

| (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.J.; George, S.Z. | *Medicine & science in sports & exercise* 33(6):985-95 | 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) | Lindblom, H.; Waldén, M.; Carliford, S.; Häggliund, M. | *British journal of sports medicine* 49(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 |
| (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) |
(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)


(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)


(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)


(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 program 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)


### Eccentric training work


(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)
Physical control-Core-Core stability

Roetert\(^{16}\) 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\(^{16}\). A lack of strength and core stability leads to ineffective technique, which leaves the athlete prone to injury\(^{17}\). For example, lumbar pain is a common problem in any sport that requires twisting or extensive rotating movements and continuous bending and stretching movements\(^{18-19}\). Leetun et al.\(^{20}\) 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 lumbar-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\(^{12,13}\), which entails a lower risk of injury and positive effects on sporting performance, in terms of speed, agility, power and aerobic resistance\(^{13,31}\).

The preventive programmes that aimed to correct weak links in core ability are designed to\(^{13,4}\):
- 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\(^{31}\) 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\(^{6,20}\) and the ankles\(^{16,10}\).

When prescribing core stability exercises, the concept of specificity should take greater importance. Not all exercises are specific or bene-
ficial, as various studies have suggested. 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.

Balance. Proprioception. Neuromuscular

The term proprioception was first introduced by Sherrington 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. Improving balance with training exercises reduces the rate of sprained ankles and the overall rate of injuries to the lower body.

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

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. Paterno et al. 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. 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.

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. 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.

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.

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.

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

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.

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).

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.

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. The only training method that has been proven to consistently increase the optimum length of developing tension has been eccentric exercise. This fact has been proven in elbow flexes, plantar flexes and in flexes and extensors of the knee. The extent of change depends on 3 variables: eccentric exercise load,
Evolution of injury prevention training monitoring

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\(^{162}\). 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\(^{163}\).

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\(^{179}\).

**Isokinetic tests**\(^{170}\)

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\(^{170-172}\), 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 sportspersons 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\(^{165,166}\).

**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 sportspersons 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 consequences, 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\(^{167,168}\). Based on the literature available, Robbins and Waked\(^{179}\) 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.

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<tr>
<td><strong>Blood test-Supplementing</strong></td>
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<tr>
<td>(163) Claudino, João G.; Mezencio, Bruno; Amaral, Sergio. <em>Journal of the international society of sports nutrition</em> 11(32)</td>
<td>2014</td>
<td>Creatine monohydrate supplementation on lower-limb muscle power in Brazilian elite soccer players</td>
<td>Examine the effects of creatine-monohydrate supplementation on lower-limb muscle power in Brazilian elite football players</td>
</tr>
<tr>
<td>(164) Bizzaro, N. <em>Recenti progetti in medicina</em> 80(5):237-40</td>
<td>1989</td>
<td>Study of variations in hematologic parameters in rugby players undergoing physical training at a high altitude</td>
<td>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</td>
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<tr>
<td><strong>Biomechanical Analysis</strong></td>
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<td>(167) Fourchet, F.; Kuitunen, S.; Girard, O.; Beard, A.J.; Millet, J.P. <em>Journal of Sports Science and Medicine</em> 10:292-300</td>
<td>2011</td>
<td>Effects of combined foot/ankle electromyostimulation and resistance training on the in-shoe plantar pressure patterns during sprint in young athletes</td>
<td>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</td>
</tr>
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<td>(168) Lohrer, H.; Turbanski, S.; Nauck, T.; Schmidtbleicher, D. <em>Sportverletzung-sportschaden</em> 22(4):191-5</td>
<td>2008</td>
<td>Balance Therapy Shoes - a Comparative Analysis with Respect to Immediate Training Effects</td>
<td>Hypothesis: Using a different shoe to that normally used entails a different load supported by the neuromuscular system that affects postural control</td>
</tr>
<tr>
<td>(169) Eils, E.; Streyl, M. <em>Sportverletzung Sportschaden</em> 19(3):140-5</td>
<td>2005</td>
<td>A one year aging process of a soccer shoe does not increase plantar loading of the foot during soccer specific movements</td>
<td>Assess the influence of a controlled ageing process on a foot load model inside a football shoe</td>
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<td><strong>Public Health</strong></td>
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<td>(170) Finch, C.F. <em>British journal of sports medicine</em> 46(1):70-4</td>
<td>2012</td>
<td>Getting sports injury prevention on to public health agendas - addressing the shortfalls in current information sources</td>
<td>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</td>
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<td><strong>Educational Intervention</strong></td>
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<tr>
<td>(171) Myer, G.D.; Faigenbaum, A.D.; Chu, D.A.; Falkel, J.; Ford, K.R.; Best, T.M.; Hewett, T.E. <em>Physician and sportsmedicine</em> 39(1):74-84</td>
<td>2011</td>
<td>Integrative Training for Children and Adolescents: Techniques and Practices for Reducing Sports-Related Injuries and Enhancing Athletic Performance</td>
<td>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</td>
</tr>
<tr>
<td>(172) Cook, M.; Cusimano, C.H.; Chipman, M.L. <em>Injury Prevention</em> 9:361-6</td>
<td>2003</td>
<td>Evaluation of the ThinkFirst Canada, Smart Hockey, brain and spinal cord injury prevention video</td>
<td>Assess the knowledge and adherence to the &quot;ThinkFirst Canada&quot; programme about preventing injuries that shows the mechanisms and consequences of brain and spinal injuries acquired whilst playing ice-hockey among 11-12 year old children practicing this sport.</td>
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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. The use of shock-absorbing soles in footwear reduces the incidence of fractures due to overloading among athletes. Gillespie and Grant 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.

Public Health

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.

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 OL, 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.

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. With the aim of reducing OL in ice hockey, a Canadian programme was implemented called “Think first” , 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.

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, proprioception, 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.

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.

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 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. Myklehust et al. 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).

<table>
<thead>
<tr>
<th>Authors, Journal &amp; Reference</th>
<th>Year</th>
<th>Article</th>
<th>Objective/Hypothesis</th>
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<tbody>
<tr>
<td><strong>Training load &amp; control &amp; team sports (n=9)</strong></td>
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<tr>
<td>(192) Dempsey, Alasdair R.; Elliott, Bruce C.; Munro, Bridget J. <em>Journal of applied biomechanics</em> 30(2):231-6</td>
<td>2014</td>
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<tr>
<td>(194) Hewett, Timothy E.; Myer, Gregory D. <em>Exercise and sport sciences reviews</em> 39(4):161-6</td>
<td>2011</td>
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<td>Hypothesis: The lateral movement of the core increases the load and neuromuscular training improves core control, reducing the load borne by the knees.</td>
</tr>
<tr>
<td>(195) Cochrane, Jodie L.; Lloyd, David G.; Besier, Thor F. <em>Medicine and science in sports and exercise</em> 166(42):1535-44</td>
<td>2010</td>
<td>Training affects knee kinematics and kinetics in cutting maneuvers in sport</td>
<td>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</td>
</tr>
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<td>(196) Dvorak, Lechoslaw B.; Rzepnicka, Agata.; Wilkosz, Piotr. <em>Chirurgia narzadow ruchu i ortopedia polska</em> 75(1):35-41</td>
<td>2010</td>
<td>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.</td>
<td>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)</td>
</tr>
<tr>
<td>(197) Dempsey, Alasdair R.; Lloyd, David G.; Elliott, Bruce C. <em>American journal of sports medicine</em> 37(1):2194-200</td>
<td>2009</td>
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<td>Hypothesis: Modifying the sidestep cutting technique could reduce knee loading</td>
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<tr>
<td>(198) Imwalle, Lauren E.; Myer, Gregory D.; Ford, Kevin R. <em>Journal of strength and conditioning research</em> 23(8):2272–92</td>
<td>2009</td>
<td>Relationship between hip and knee kinematics in athletic women during cutting maneuvers: a possible link to noncontact anterior cruciate ligament injury and prevention</td>
<td>Compare the kinematics of the lower extremities to 45° and 90° during the sidestep cutting action and examine the rotations of the lower extremities during these actions</td>
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</table>

**Prevention injuries & training load (n=10)**

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<tbody>
<tr>
<td>(203) Myer, Gregory D.; Ford, Kevin R.; Brent, Jensen L.; Hewett, Timothy E. <em>Strength cond res.</em> 26(8):2272–92</td>
<td>2012</td>
<td>An integrated approach to change the outcome part ii: targeted neuromuscular training techniques to reduce identified acl injury risk factors</td>
<td>Propose an integrated approach to identify and select mechanical bases that explain the increase in ACL injuries among female sportswomen</td>
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(keep going)
Caraffa et al.\textsuperscript{214} reported significantly fewer ACL injuries among semi-professional and amateur football players after performing a balance exercise programme in training.

Padua\textsuperscript{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\textsuperscript{216}. Neuromuscular and proprioceptive work is very important in both preventing\textsuperscript{217,218,219,220} and avoiding recurrences. Fitzgerald, Hacha and Snyder-Mackler\textsuperscript{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

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<td>(206)</td>
<td>Aerts, I.; Cumps, E.; Verhagen, E.; Meesuwen, R.</td>
<td>2010</td>
<td>Efficacy of a 3 month training program on the jump-landing technique in jump-landing sports. Design of a cluster randomized controlled trial</td>
<td><em>BMC Musculoskeletal Disorders</em> 11, 281</td>
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<tr>
<td>(208)</td>
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<td><em>Journal of Biomechanics</em> 43(14):2657-64</td>
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<td>(210)</td>
<td>Dempsey, A.R.; Lloyd, D.G.; Elliott, B.C.; Steele, J.R.; Munro, B.J.; Russo, K.A.</td>
<td>2007</td>
<td>The effect of technique change on knee loads during sidestep cutting</td>
<td><em>Journal of Science and Medicine in Sport</em> 11, 281</td>
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Arch Med Deporte 2016;33(1):37-58
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 occurring 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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