PREVENTION OF SPORTS INJURIES

Systematic review and meta-analysis of randomized controlled trials

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TIIVISTELMÄ

Urheiluvammojen ennaltaehkäisy: Systemaattinen kirjallisuuskatsaus ja meta-analyysi satunnaistetuista, kontrolloiduista tutkimuksista
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Urheilu sisältää aina riskin vammautumisesta. Urheiluvamma vaikuttaa negatiivisesti urheilijan terveyteen ja vammojen hoito on kallista. Tutkimukset urheiluvammojen ennaltaehkäisystä ovat lisääntyneet huomattavasti viime vuosien aikana.

Tämä pro gradu –tutkielma on systemaattinen kirjallisuuskatsaus ja meta-analyysi satunnaistetuista, kontrolloiduista tutkimuksista. Tutkimuksen tarkoituksena on tehdä yhteenveto urheiluvammojen ennaltaehkäisyyn tähtäävistä interventioista. Systemaattinen kirjallisuushaku tehtiin käyttämällä seuraavia hakusanoja: sports injuri/es, athletic injuri/es, prevention, preventive, randomized, controlled trial ja randomized controlled trial. Käytetyt tietokannat olivat: PubMed, MEDLINE, SPORTDiscus, the Cochrane Central Register of Controlled Trials, CINAHL, PEDro ja Web of Science. Löydettyjen artikkelien sekä olennaisten katsausartikkelien lähdeviitteet tarkastettiin käsihaulla. Tutkimuksille suoritettiin laadun arviointi. Laskelmat tehtiin the Cochrane Collaboration Review Manager –ohjelmistolla. Laskelmissa käytettiin vetosuhdetta (OR).

Meta-analyysiin otettiin mukaan 59 tutkimusta, yhteensä 65 vertailua. Tukipohjalliset/iskua vaimentavat pohjalliset (OR 0.51, 95%CI 0.32–0.81), ulkoiset niveltuet (OR 0.40, 95%CI 0.30–0.53) ja harjoitusohjelmat (OR 0.55, 95%CI 0.46–0.66) olivat tehokkaita ennaltaehkäisemään urheiluvammoja. Venyttely (OR 0.92, 95%CI 0.80–1.06), modifioidut jalkineet (OR 1.23, 95%CI 0.81–1.87) ja ennaltaehkäisevät videot (OR 0.94, 95%CI 0.43–2.04) eivät vaikuttaneet vammariskiin.

Tämä meta-analyysi osoitti, että urheiluvammoja voidaan ennaltaehkäistä erilaisilla pohjallisilla, ulkoisilla niveltuilla ja harjoitusohjelmilla. Hyödyntämällä tutkimuksen tuloksia käytännössä, voidaan saada merkittäviä tuloksia liikuntavammojen vähentämisessä. Meta-analyysin ongelmia olivat yksittäisten tutkimusten metodologiset heikkoudet, tutkimustulosten heikko yleistettävyys ja tutkimusten heterogeeniset tutkimusasetelmat. Tulevissa tutkimuksissa tulisi keskittyä suosittuihin, korkeariskisiin urheilulajeihin. Ennaltaehkäisevien harjoitusohjelmien vaikutusmekanismit ja hyödyllisimmät, vammoja ehkäisevät harjoitusmenetelmät tulisi pyrkiä selvittämään.

Avainsanat: urheiluvammat, liikuntavammat, ennaltaehkäisy, interventio, satunnaistettu, kontrolloitu tutkimus.

ABSTRACT

Prevention of sports injuries: Systematic review and meta-analysis of randomized controlled trials
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Participation in sports includes a risk of injury. Injuries burden athlete's health and health care system. The number of trials investigating prevention of sports injuries has increased over the past decade.

This master's thesis is a systematic review and meta-analysis of RCTs. The purpose of the study is to summarize the effects of sports injury prevention interventions. Systematic literature search was conducted using following keywords: sports injuri/es, athletic injuri/es, prevention, preventive, randomized, controlled trial and randomized controlled trial. Following databases were used: PubMed, MEDLINE, SPORTDiscus, the Cochrane Central Register of Controlled Trials, CINAHL, PEDro and Web of Science. The reference lists of retrieved articles and reviews were hand searched. Calculations were made with the Cochrane Collaboration Review Manager – software.

Meta-analysis included 59 trials with 65 comparisons. Insoles (OR 0.51, 95%CI 0.32–0.81), external joint supports (OR 0.40, 95%CI 0.30–0.53) and training programs (OR 0.55, 95%CI 0.46–0.66) appeared to be effective to reduce the risk of sports injuries. Stretching (OR 0.92, 95%CI 0.80–1.06), modified shoes (OR 1.23, 95%CI 0.81–1.87) and preventive videos (OR 0.94, 95%CI 0.43–2.04) were not effective.

This meta-analysis showed that certain interventions can reduce the risk of sports injuries. By taking preventive actions to practice, major benefits can be accomplished. There were limitations with quality of the trials, generalizability of the results and heterogeneity of the study designs. Future research should focus on commonly practiced, high-risk sports. The mechanisms behind effective methods and the most beneficial elements of preventive intervention need to be clarified.

Keywords: sports injuries, athletic injuries, prevention, intervention, randomized, controlled trial.

CONTENTS

1 INTRODUCTION

Although physical activity has multiple health benefits (Warburton et al. 2006, Kruk 2007), such as reducing risks for chronic diseases (Morris et al. 1980, Paffenbarger et al. 1986, Garber et al. 2011) and mortality (Kujala et al. 1998), participation in sports also includes a risk of injury (Junge et al. 2009, Ristolainen 2012). To a certain extent, there is a dose-response relationship between regular exercise and health benefits. However, vigorous sports-related training can also include disadvantages and even health risks due to increasing risk of getting injured (Vuori 2005). Sport-related injuries affect negatively the injured athlete's health (Darrow et al. 2009) and may cause permanent disability or even terminate an athlete's sports career (Ristolainen 2012). Injuries also burden the health care system (Darrow et al. 2009) as the treatment of sports injuries is often demanding, expensive and time-consuming (Parkkari et al. 2001). Injury prevention research is needed to promote safe exercise participation by identifying risk factors for injuries (McBain et al. 2012b), minimizing sports injury rates and severe injuries, and maximizing the health benefits that stem from sports participation (Darrow et al. 2009).

Over the past decade, interest in sports injury prevention research has increased (Klügl et al. 2010, McBain et al. 2012b). The recent review of all the published injury prevention articles found a substantial increase of these publications over the past 15-20 years (Klügl et al. 2010). In addition, the number of clinical trials and randomized controlled trials (RCTs) investigating prevention of sports injuries has nearly doubled from year 2000 to 2005 (Engebretsen & Bahr 2005).

At present, effects of several interventions targeting prevention of sports injuries have been studied in RCTs. Earlier RCTs have investigated more often protective equipments, such as insoles and external joint supports, but recently, an increased number of training programs and multi-interventions have been studied (Klügl et al. 2010). Thus, because of the increasing amount of the sports injury prevention trials and alterations in study field of sports injuries, there is a need for updating systematically the body of knowledge on sports injury prevention.

This study is a systematic review and meta-analysis of RCTs examining the prevention of sports injuries. The aim of the study is to summarize the effects of preventive interventions and update the data of the prevention of sports injuries.

2 LITERATURE REVIEW

2.1 Sports injury definitions

A theoretical definition of an injury is often difficult because of its dependence on context (Langley & Brenner 2004). Generally, sports injuries are considered as all types of injury occurring during sporting activities (Bahr et al. 2005). An injury occurs when the stress that falls upon a tissue exceeds the tissue's ability to absorb the stress acutely or chronically (McBain et al. 2012a). In research articles, sports injuries are variously defined (Ristolainen 2012). Two broadly acceptable injury definitions are based on medical treatment, which includes injuries requiring any treatment from a physician, and loss-of-time, which includes injuries that result in loss of time from training or competitions (Brooks & Fuller 2006).

Although variations in definitions and methodologies may create significant differences in the results and conclusions obtained from studies of sports injuries, there is still lack of consistency in the definition of sports injuries (Brooks & Fuller 2006, Fuller et al. 2006). There are only few consensus statements on injury definitions in the studies on sports injuries. These consensus statements are concerning team sports such as football (Fuller et al. 2006), rugby (Fuller et al. 2007) and cricket (Orchard et al. 2005). Consensus statements can be used as the basis of definitions for studies in other team sports also (Fuller et al. 2006). The following injury definitions are gathered from the consensus statements and from the review articles available.

2.1.1 Acute injuries

Acute injury, also called traumatic injury, can be defined as any physical complaint, which is caused by transfer of energy that acutely exceeds the body's ability to maintain its structural and/or functional integrity (Fuller et al. 2007). According to Fuller et al. (2006) a traumatic injury is an injury resulting from a specific, identifiable event. Injury is referred to as a 'medical attention' injury if it requires any treatment by a physician. Injury that results in an athlete being unable to take a full part in training or competition is referred to as ‘time-loss’ injury (Fuller et al. 2006, Fuller et al. 2007). Acute injuries occur mostly in sports with high speed, when risk of falling is high, and in team sports when a large number of physical contacts with other players exist (Bahr 2009).

2.1.2 Overuse injuries

In the consensus statements overuse injury is defined as an injury, caused by repeated micro-trauma, without a single, identifiable event responsible for the injury (Fuller et al. 2006). Overuse injuries have also been defined as gradual onset injuries (Bahr 2009) or injuries caused by low-intensity forces of long duration (Knight 2008). Classification of acute injuries and overuse injuries is in most cases simple, but in some cases it may not be that obvious. Sometimes symptoms may have a sudden onset, but actually the injury is a result from a long-term process. Overuse injuries occur mostly in endurance sports that require long training sessions and include monotonous routine (such as long-distance running, bicycling and cross-country skiing), but also in more technical sports, which include a large number of repetitive movements of same kind (i.e. tennis, high jumping and weight lifting) (Bahr 2009).

2.1.3 Recurrent injuries

The definition of recurrent injuries includes both the definition of an injury and the definition of a recurrence (Brooks & Fuller 2006). Recurrent injury can be defined as an injury of the same type and same site as an index injury occurring after athlete has returned to full participation from the index injury (Fuller et al. 2006, Fuller et al. 2007). Furthermore recurrent injury can be referred as an ‘early recurrence’, ‘late recurrence’ or ‘delayed recurrence’ according to the time recurrence occur after the index injury, which is within 2 months, 12 months or more than 12 months respectively (Fuller et al. 2006, Fuller et al. 2007). Recurrent injuries are usually described as acute injuries that occur multiple times; still they sometimes can be mixed up with chronic overuse injuries. Therefore, to be precise these concepts should be separated from each other (Knight 2008), although it may be difficult.

2.2 Occurrence and severity of sports injuries

Increasing participation in physical activity and sports has also increased the incidence of sports injuries (Parkkari 2011). Sports injuries are the biggest injury causing accident category in Finland (Heiskanen et al. 2004, Parkkari 2011). In Finland, in year 2003, there were 338 000 accidents, which occurred during sporting activities, whereas the same number in year 1980 was 210 000 (Heiskanen et al. 2004). Sports injuries concern especially young people's health (Parkkari et al. 2004a, Parkkari et al. 2004b, Tiirikainen et al. 2008). In Finnish population aged 15-25 years, the number of sports injuries increased by 53% between 1988 and 2003 (Tiirikainen et al. 2008). This dramatic increase may be explained by the changes in choosing sports. Injury risk is high in team sports and ball games, which have become more popular in Finland (Tiirikainen et al. 2008). Especially in floorball, where the injury risk is very high (Pasanen 2009), the number of players has increased remarkably (Tiirikainen et al. 2008).

Parkkari et al. (2004b) studied injury risk in various activities and sports in Finland. Injury risk was found to be highest in squash, orienteering, and contact and team sports, such as judo, wrestling, karate, rinkball, floorball, basketball, soccer, ice hockey, volleyball and Finnish baseball. Injury incidence of these sports ranged from 6.6 to 18.3 per 1000 hours of participation. These results are similar to the Finnish Health 2003 -report (Heiskanen et al. 2004), where injuries in team sports (soccer, floorball and ice hockey) were the most common. Moreover, in epidemiologic studies of Yang et al. (2012) and Hootman et al. (2007) football, soccer and wrestling had a high injury risk, which further supports the conception that contact sports and team sports are high-risk sporting activities. Injury risk seems to be high in these sports whether competitive athletes (Hootman et al. 2007, Junge et al. 2009, Yang et al. 2012) or non-professional active people (Parkkari et al. 2004b) are at issue. Acute risk of injury is usually low in endurance sports (Parkkari et al. 2001), although the risk of overuse injury is typically higher in these sports (Clarsen et al. 2012).

Generally speaking, most of the sports injuries are lower extremity injuries (Hootman et al. 2007, Darrow et al. 2009, Junge et al. 2009, Yang et al. 2012). Knee (Hootman et al. 2007, Darrow et al. 2009, Junge et al. 2009), ankle (Hootman et al. 2007, Darrow et al. 2009) and thigh (Junge et al. 2009) are the most common injury sites. The most common injury types are sprains and strains (Junge et al. 2009, Yang et al. 2012). Many of the sports injuries are acute injuries and approximately one-quarter of all injuries are overuse injuries (Junge et al. 2009, Yang et al. 2012). Competition is often predisposing factor for injuries in sports; substantial proportion of sports injuries occur during game or competition (Kujala et al. 1995, Hootman et al. 2007, Darrow et al. 2009, Junge et al. 2009). Influence of competition varies between different sports and different injury types. For example, in the study by Dragoo et al. (2012), football players were 10 times more likely to sustain an anterior cruciate ligament injury in competition when compared with training sessions. A plausible explanation to the phenomenon is that game and competition conditions often involve less predictable environment and greater intensity and speed (Dragoo et al. 2012), but also higher amounts of ambition and risk taking.

The severity of sports injuries can be described on the basis of six criteria: 1. nature of sports injuries, 2. duration and nature of treatment, 3. sporting time lost, 4. working time lost, 5. permanent disability and 6. costs of sports injuries (van Mechelen et al. 1992). *The nature of sports injury* determines what kind of medical treatment or other assistance is needed. The nature of sports injury is usually described in terms of medical diagnosis. *Duration and nature of treatment* determines the severity of an injury more precisely. To an athlete, the length of *sporting time lost* gives the most concrete indication of the consequences of an injury. *Working or school time lost* describes injury consequences at a societal level and this criterion can be used when assessing the cost of sports injuries to society. Severe injuries can *cause permanent disability*, which can reduce or eliminate the athlete’s capability for work or school, or even cause death. *Economic costs of sports injuries* can be divided into direct costs, which is the cost of medical treatment, and indirect costs, which is the loss of productivity due to death or disability (van Mechelen et al. 1992, Bahr et al. 2005).

Based on recent research articles, a severe injury has been defined as any injury that results in a loss of more than 21 days of sports participation (Darrow et al. 2009, Knowles et al. 2009, Yang et al. 2012). Even though most of the sports injuries are not severe, severe injuries are often difficult and expensive to treat and may end an athlete’s career or cause permanent disabilities (Darrow et al. 2009). One of the known examples of permanent disability is premature osteoarthritis (Kujala et al. 1994).

2.3 Risk factors

Although a casual observer may think sports injuries as random accidental events, as a matter of fact, many factors play a role before the actual musculoskeletal injury occurs (Meeuwisse 1994). There is a widespread agreement that sports injuries result from a complex interaction of multiple risk factors and events (Taimela et al. 1990, Bahr & Holme 2003).

In the literature, risk factors of sports injuries are commonly divided into two categories: extrinsic and intrinsic risk factors (Taimela et al. 1990, van Mechelen et al. 1992, Meeuwisse 1994) (Table 1). Intrinsic risk factors are factors that influence the risk of sustaining injuries and predispose the athlete to injury. Extrinsic risk factors are factors that modify the risk by making the athlete even more vulnerable to injury. These risk factors together influence the athlete to become susceptible to injuries. The final link in the chain is an inciting event (such as tackle or fall), which is obviously and often visibly related to the injury (Meeuwisse et al. 1994, Bahr & Krosshaug 2005). In order to understand the whole picture, we have to pay attention to all components of the chain. A multifactorial model of athletic injury etiology, developed by Meeuwisse (1994), is presented in Figure 1.

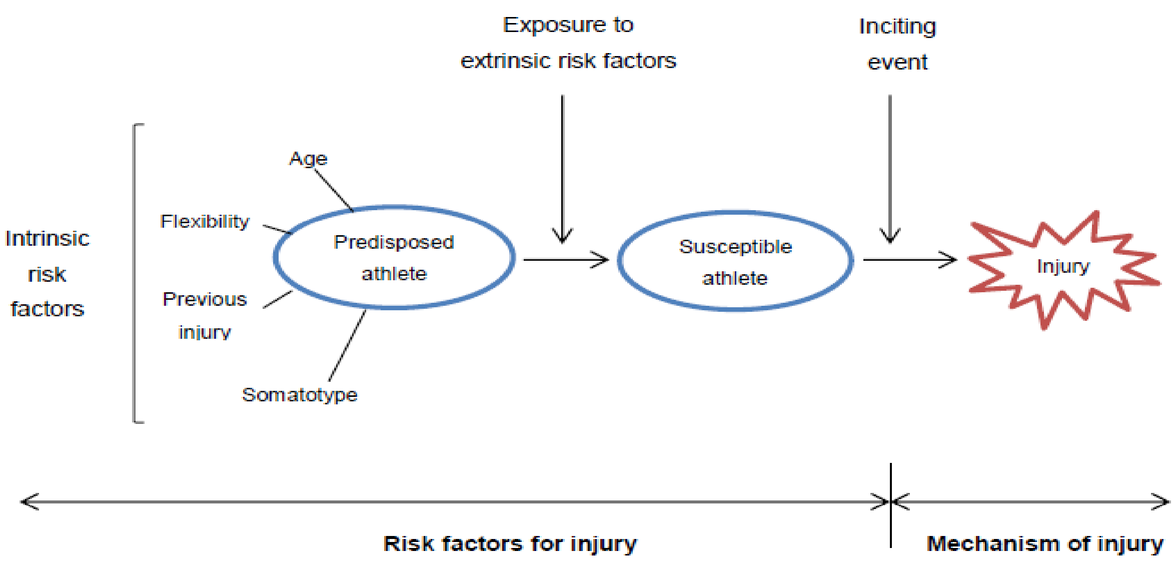

Figure 1. Interaction between intrinsic and extrinsic risk factors and athletic injury (adapted from Meeuwisse 1994).

Table 1. Extrinsic and intrinsic risk factors for sports injuries (adapted from Parkkari et al. 2001, Bahr & Krosshaug 2005).

Extrinsic risk factors	Intrinsic risk factors
Exposure	***Physical characteristics***
Type of sports	Age
Exposure time	Gender
Position in the team	Body composition (e.g. body weight, height, BMI, anthropometry)
Level of competition	Health (e.g. previous injuries)
Training	Physical fitness (e.g. muscle strength, aerobic fitness, joint range of movement)
Type	Anatomy abnormalities
Amount	Motor abilities and sports-specific skills
Frequency	***Psychological profile***
Intensity	Motivation
Environment	Risk taking
Type of playing surface	Stress coping
Indoor vs outdoor	
Weather conditions	
Time of season	
Human factors (coaching, referees, rules, team mates, opponents)	
Equipment	
Protective equipment (e.g. helmet, shin guards)	
Playing equipment (e.g. footwear, clothing, racket, stick)	

2.3.1 Intrinsic risk factors

Intrinsic risk factors are individual physical and psychosocial characteristics that predispose an athlete to the outcome of a musculoskeletal injury (Ristolainen 2012). Intrinsic factors include age, gender, body composition, health, physical fitness, anatomy, previous injuries, sports-specific skills and abilities, and psychological factors (Taimela et al. 1990, Parkkari et al 2001, Bahr & Krooshaug 2005).

According to some studies, sports injury risk seems to increase with age (Taimela et al. 1990). This may partly be explained with increased frequency and intensity within training and competitions in adult athletes compared to adolescents (Taimela et al. 1990, Pasanen 2009). In the prospective cohort study by Mattila et al. (2009), the researchers found that participation in sports clubs was the strongest risk factor for injuries leading to hospitalization especially in adolescence and early adulthood. Furthermore, in the study by Parkkari et al. (2004b), the injury incidence decreased by age in recreational and competitive sports, in the way that in 15–24 -year-old men and women, the injury incidence rates were 4.2 and 3.1 per 1000 hours of participation, while in 65–74 -year-old persons the corresponding numbers were 1.0 and 1.2, respectively.

Studies have shown rather conflicting results of influence of gender on injury risk (Ristolainen 2012). Junge et al. (2009) investigated sports injuries during the summer Olympic Games 2008 and found no difference in injury incidences between men and women. Parkkari and others (2004b) found in their study that in recreational and competitive sports, an overall injury risk was higher in men, but in endurance sports, women had higher injury risk than men. Similar results were found in the study by Yang et al. (2012), where men collegiate athletes had a higher acute injury rate than women, but women had a higher rate of overuse injury than men. Darrow and others (2009) studied high school athletes and found that the injury rates of boys were higher, but girls sustained a higher rate of severe injuries in certain sports like basketball. According to Pasanen (2009), then, several studies have shown that female athletes, who participate in pivoting and cutting sports, have a higher risk for lower extremity injuries (especially ankle sprains and knee injuries) than do males participating in the same sports. The reasons behind this phenomenon of increased ligament injuries in female athletes are not well understood, but thought to be multifactorial. Plausible explanations include anatomical, hormonal (such as increased ligament laxity and joint looseness due to sex-hormones) and neuromuscular factors (such as decreased coordination and muscle activation) (Pasanen 2009).

Anthropometrics, anatomical factors and physical abilities have been suggested to be factors that influence the injury risk. Increased body mass index and increased body weight may predispose to ankle joint injuries (Fousekis et al. 2012). Also certain asymmetries, such as asymmetries in functional leg length (Fousekis et al. 2011) or in eccentric muscle strength of the lower extremity (Fousekis et al. 2011, Fousekis et al. 2012) have in some studies shown to increase the risk of leg injuries. In addition, other neuromuscular deficiencies, such as lack of strength, delayed muscle firing, and defective muscle activation order have in some studies shown to associate with injury risk. Aerobic fitness level is also an important factor, because fatigue reduces coordination and muscle control (Pasanen 2009).

The literature is inconsistent with regard to whether or not previous injury is connected with increased risk of new injury. In some earlier studies among male soccer players (Hägglund et al. 2006, Engebretsen et al. 2008) and among high-school football players (Knowles et al. 2009) a previous injury has been proven to be an important risk factor for reinjury to the same site. Contrary to this, however, the study by Fousekis et al. (2011) indicated that previous thigh muscle injury was protective rather than predisposing to a new injury. The possible influence of previous injury on risk of new injury is probably attributed to type of sports and injury and also to other factors, such as rehabilitation. If treated adequately, previous injuries may not necessarily cause repetition injuries. However, some individuals with other intrinsic risk factors, which make them more prone to injuries, may have a higher risk for the new injury (Taimela et al. 1990).

2.3.2 Extrinsic risk factors

Extrinsic risk factors are factors that are independent of the injured athlete and primarily related to the type of ongoing activity (Taimela et al. 1990). Extrinsic risk factors can be divided into factors related to exposure, training, equipment and environment. Type of sports, exposure time, position in team, and level of competition are exposure factors. Training factors include type, amount, frequency and intensity of training (Parkkari et al. 2001) of which particularly training errors such as initiating training too suddenly play a significant role in the outcome of an injury (Taimela et al. 1990). Equipment factors include sports equipment (e.g. footwear, clothing, skis, racket) and protective equipment (e.g. helmet, shin guards). Risk factors associated with environment are type of a playing surface, weather conditions, time of season, indoor/outdoor conditions as well as human factors (coaching, rules, referees, team mates, opponent and spectators) (Parkkari et al. 2001, Bahr & Krosshaug 2005). Environmental conditions also play a major role in the outcome of injury (Taimela et al. 1990).

2.4 Injury prevention research

Injury prevention research has been described as a model of four step sequence by van Mechelen et al. (1992) (Figure 2). This model has further been utilized by many others (Parkkari et al. 2001, Bahr & Holme 2003, Bahr & Krosshaug 2005, Hägglund et al. 2006). Before initiating any program for preventing sports injuries, the magnitude of the problem must be identified and the extent of the injury defined in terms of the incidence and severity. The second step is to establish the risk factors and mechanisms that play a part in the occurrence of sports injuries. Thirdly, measures that are likely to reduce the future risk of sports injuries should be introduced. These measures should be based on information (aetiology and injury mechanisms) gathered in the second phase. The final step is to assess the effectiveness of the preventive action by repeating step one, which can be achieved by means of a randomized clinical trial (van Mechelen et al 1992, Parkkari et al. 2001, Bahr & Krosshaug 2005).

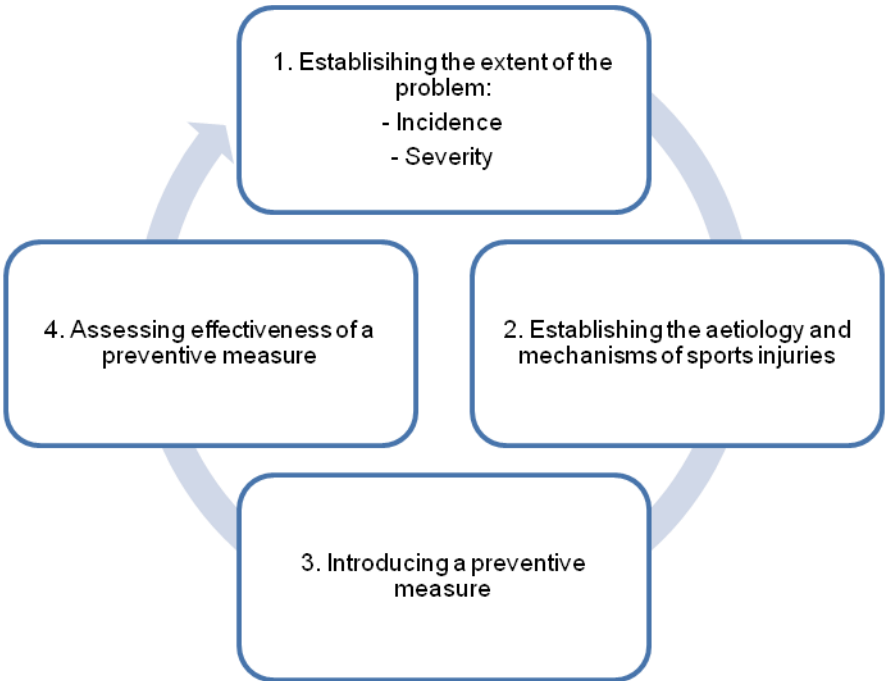

Figure 2. Four step sequence of injury prevention research (adapted from van Mechelen et al. 1992).

Given the importance of information derived from injury prevention research, it is essential that the data is obtained from clearly delineated methodologies in order to reflect the true risks of injury within sport (Brooks & Fuller 2006). In order to make injury prevention research reliable and comparable and to avoid the 'tip-of-the-iceberg' phenomenon, there is a need to uniform agreement on issues related to sports injury research. Firstly, the definition of sports injury must be universally applicable and unambiguous. Secondly, injury incidence must be expressed in a way that it indicates the true extent of the problem and also in a way that incidence rates for different sports can be properly compared (van Mechelen et al. 1992). Common ways of reporting injuries are the absolute number of injuries or injured individuals, relative proportions of injuries and incidence of injuries (Brooks & Fuller 2006). Absolute numbers and proportions of injuries, however, cannot provide information about the exposure (van Mechelen et al. 1992, Brooks & Fuller et al. 2006), which is the number of hours the person actually is in the risk of being injured, despite the fact that this exposure factor certainly influences the risk of injury (van Mechelen et al. 1992). For this purpose injury incidence is often expressed as the number of injuries per 1000 hours of sports participation. In this case researchers have to decide what is included and excluded in the definition of sports participation and also differences between recreational and competitive sports and training and competition have to be taken into account. Finally, the outcome of sports injury research also depends on the applied research design and research methodology, as well as on the representativeness of the sample (van Mechelen et al. 1992).

2.4.1 Preventive measures in randomized controlled trials

The purpose of sports injury prevention research is to establish a preventive measure to "…optimize the balance of applied and absorbed stress" (McBain et al. 2012b). Seemingly the first randomized controlled trial investigating the efficacy of a preventive measure in sports was made by Ekstrand et al. (1983). This study was conducted to study the effects of a prophylactic program on injury incidence among male soccer players (Ekstrand et al. 1983). Since then, various interventions in several sports and study groups have been studied in randomized trials.

Intervention programs of sports injury prevention research can be divided into three categories: equipment, training and regulatory interventions (Klügl et al. 2010). Earlier, equipment interventions were more commonly studied whereas recent studies have been focusing on training interventions (Klügl et al. 2010, McBain et al. 2012a). When taking into account all the published articles that evaluate interventions designed to reduce the risk of sports injuries, McBain and others (2012b) expressed in their review that most of the equipment interventions have been using some stability device, such as orthoses, braces and taping. Other commonly used equipment were head/face protectors and attenuating devices, such as shock absorbing insoles. Of the training interventions, most of them have been studied from the point of view of balance and coordination, but more recently an increasing amount of strength, power and stretching interventions have also been examined. Furthermore, training interventions often combine elements of different categories (McBain et al. 2012b). The third intervention category, studies that examine rules and regulations, constitute only one percent of all the intervention programs studied (Klügl et al. 2010).

In practice, many different methods are used and recommended to prevent injuries even though the evidence behind them can be inconclusive (Aaltonen et al. 2007). It is not always possible to conduct a controlled study design due to ethical reasons (for example to study head injuries in ice hockey players wearing a helmet vs. players without a helmet). On the other hand, several interventions have been studied in randomized controlled trials, but their results have sometimes been controversial (Aaltonen et al. 2007). Warming up (Fradkin et al. 2006) and stretching (Small et al. 2008), for instance, are probably the most widely promoted methods to reduce the risk of injuries and nevertheless, there is still insufficient evidence of what are the actual beneficial components of preventive warm-up strategy (Herman et al. 2012).

2.4.2 Previous systematic reviews

The effects of injury prevention methods have been studied in several systematic reviews earlier. Some of the reviews have included only RCTs, but a few have also included controlled trials. These previous reviews have summarized the effects of specific injury prevention methods or prevention of specific injury types. The study by Aaltonen et al. (2007) is presumably the only systematic review of RCTs summarizing the effects of all interventions targeted at preventing sports injuries. Since then, interest in the prevention of sports injuries has increased and many new trials have been published. Although the number of systematic reviews published is quite large, those reviews seldom included meta-analysis due to a low number of homogeneous studies. The following paragraph summarizes briefly the results from some recent systematic reviews and meta-analyses.

Equipment interventions studied in previous systematic reviews have mainly been external joint supports and foot orthoses. Systematic reviews on the effectiveness of external joint supports have concluded that ankle supports are effective in reducing ankle injuries (Dizon & Reyes 2010), but the data on the effectiveness of knee braces is inconsistent (Pietrosimone et al. 2008). The evidence from one meta-analysis (Collins et al. 2007) and review (Hume et al. 2008) supported the use of foot orthoses in the prevention of lower-limb overuse injuries. Headgears and mouth guards have mainly been studied in other than randomized controlled study designs, but a few of them have been controlled trials. According to Benson et al. (2009), the use of headgear reduces the risk of head injuries in skiing, bicycling and snowboarding, but the effect on concussion risk is inconclusive. In addition, against some supporting statements, there is no strong evidence that the use of mouth guards reduces the risk of concussion. Instead, mouth guards appear to be beneficial for dental protection (Benson et al. 2009).

The effects of various training interventions have been summarized in recent reviews (Hübscher et al. 2010, Herman et al. 2012, Stojanovic & Ostojic 2012) and meta-analysis (Yoo et al. 2010). These studies emphasized that neuromuscular training is effective in reducing the risk of certain types of sports injuries among female athletes (Yoo et al. 2010, Stojanovic & Ostojic 2012) and young athletes during pivoting sports (Hübscher et al. 2010), but also among wider population (Herman et al. 2012). Reviews of warming up (Fradkin et al. 2006) and static stretching as a part of a warm-up (Small et al. 2008) showed inconclusive evidence of effectiveness of these routines. Two systematic reviews on the prevention of hamstring injuries found different results. Hibbert et al. (2008) supported the role of eccentric strength training for the risk of hamstring strains, but when taking into all interventions for prevention of hamstring injuries, there was lack of evidence of their effectiveness (Goldman & Jones 2011).

A Cochrane review studying interventions for preventing stress fractures of the lower limb in young adults (Rome et al. 2009) suggested that although the evidence from randomized trials is insufficient, shock absorbing insoles in the boots of military recruits may reduce the overall incidence of stress fractures. Another Cochrane review examining interventions for preventing lower limb soft tissue running injuries (Yeung et al. 2011) stated that there is no evidence to support stretching, conditioning exercises or modification of training schedules, and very little evidence to support the use of insoles for preventing running-related injuries.

Systematic reviews have also summarized results from strategies to prevent injuries in adolescent sport (MacKay et al. 2004, Abernathy & Bleakley 2007). Although there was a lack of well-designed and controlled studies (MacKay et al. 2004), certain injury prevention strategies, focusing on different training methods, may be effective to reduce the risk of injury among young athletes (Abernathy & Bleakley 2007). These reviews were published a few years ago and since then an increasing amount of trials have been published.

3 METHODS

3.1 The purpose of the thesis

The present study is based on the previous systematic review of sports injury prevention written by Aaltonen et al. (2007) including 32 trials. The purpose of this systematic review and meta-analysis is to update and summarize the results of the randomized controlled trials concerning prevention of sports injuries. The aim of the study is to answer the following research questions: 1. Is it possible to prevent sports injuries? 2. And if it is, how can sports injuries be prevented?

3.2 Search strategy

The literature search of this study was performed by combining two independent, similarly conducted search processes. The first search was conducted by Aaltonen et al. (2007) until December 31, 2005 and is described elsewhere. The second literature search was performed by using the same search strategy as Aaltonen and others (2007) did, with the exception of initiating the search from January 1, 2006.

The systematic literature search was performed in November 2012. Relevant trials were searched by using following databases: PubMed, MEDLINE (Ovid), SPORTDiscus, the Cochrane Central Register of Controlled Trials, CINAHL (Cumulative Index to Nursing and Allied Health Literature), PEDro (the Physiotherapy Evidence Database) and Web of Science. The search was conducted from January 1, 2006, to October 31, 2012. Following key words were used in the search: sports injury/ies, athletic injury/ies, prevention, preventive, randomized, controlled trial and randomized controlled trial. Various combinations of the key words were used. In addition, the reference lists of retrieved articles and relevant reviews were hand searched.

3.3 Trial selection

Both searches combined, electronic search process yielded in total 5490 articles (4803 and 687 articles from the first and second search, respectively). Retrieved articles were first assessed based on the title and the abstract. After first screening, 5373 articles (4755 and 618) were excluded. The rest 117 potential articles (48 and 69) were evaluated more detailed on the basis of the full article. Relevant reviews and reference lists of retrieved articles were hand searched, and two studies were included through hand search. Altogether 67 trials (32 and 35) were included in the present systematic review. Eight trials could not be pooled for meta-analysis due to lack of sufficient data. Thus, 59 trials provided adequate data and were included in meta-analysis. Literature search is seen as a flow chart in Figure 3.

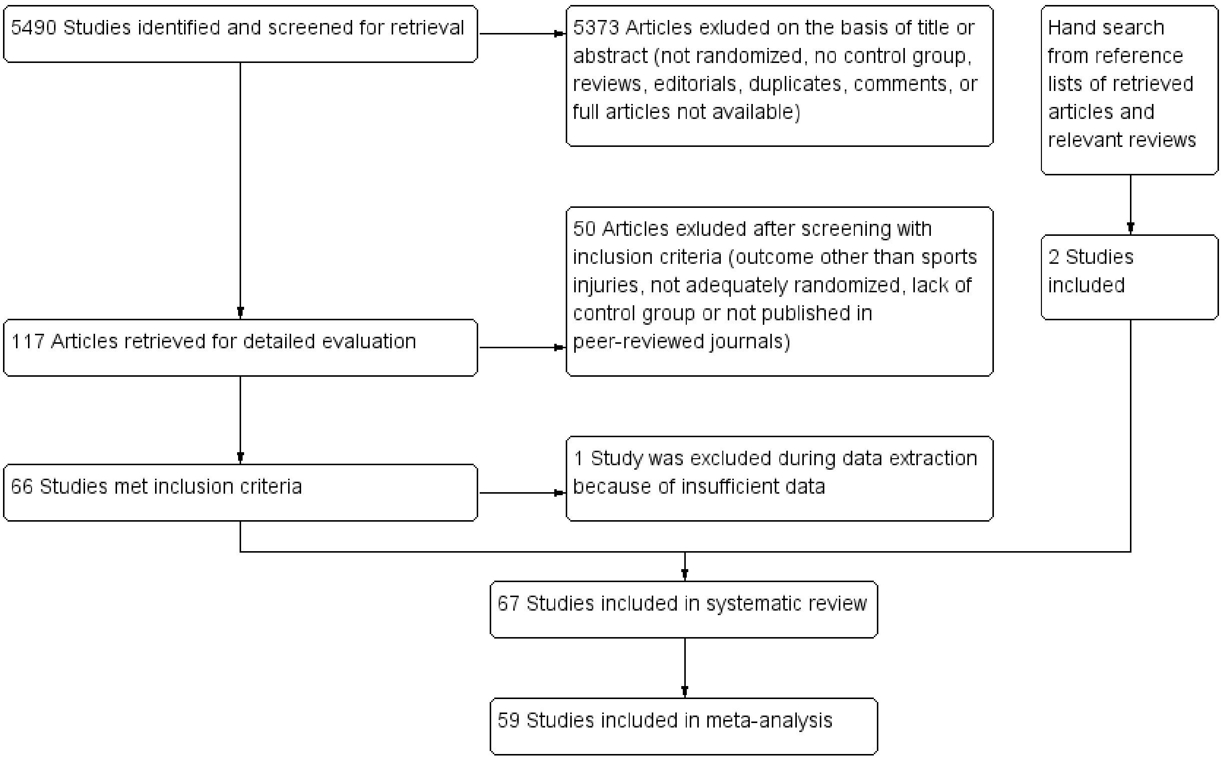

Figure 3. Literature search flow chart.

3.3.1 Inclusion criteria

Selected articles had to examine the effects of any preventive intervention on sports injuries. Selected trials had to be randomized or quasi-randomized and controlled trials and published in a peer-reviewed journal. In the second search, articles published before 2006 were included if they met other inclusion criteria and if they were not included in the previous systematic review of sports injuries by Aaltonen et al. (2007). Outcome of the trial had to be injury rate or the number of injured individuals.

3.3.2 Exclusion criteria

Trials were excluded if they were not adequately randomized, if there were no control group or if the outcome was other than sports injuries. Also abstracts without the full text available and published in a peer-reviewed journal were excluded. The study report had to contain adequate information about the trial protocol and the injury rate or the number of injured individuals as an outcome. One article was excluded because article had been retracted afterwards on the basis of ethical reasons. In addition, one article was excluded during the data extraction because of insufficient data.

3.4 Data extraction

Data from each included study was extracted based on the full article. In case of insufficient data, the authors were contacted via email. Study design, description of intervention, characteristics of participants, and main outcomes from each article were extracted and are presented in Appendix 1.

Calculations for meta-analysis were proceeded with the Cochrane Collaboration Review Manager 5.1 software. All the calculations were made according to the primary outcomes of the studies. The calculations were primarily based on the number of injured individuals in the intervention group and in the control group. In a case when the number of injured individuals was not available, the number of injuries was used instead. Odds ratio (OR) was used as effect measure, statistical method was inverse variance and analysis model was based on random effects. Confidence intervals of 95 % were calculated. Statistical heterogeneity (I^2) and test for overall effect was calculated and p-values < 0.05 were regarded statistically significant.

3.5 Methodological quality assessment of the selected trials

Methodological quality assessment of the included trials (Appendix 2) was made as recommended by Furlan et al. (2009). The quality assessment was made independently by two persons: the author and one supervisor. In case of disagreements, consensus was found through discussion. The quality assessment list consists of 12 criteria: method of randomization, concealed allocation, blinding of participants, blinding of care providers, blinding of outcome assessors, drop-out rate, analysis according to allocated group, reporting without selective outcome, baseline similarity of the groups, co-interventions, compliance and timing of outcome assessment. Each criterion was scored as ‘yes’, ‘unclear’ or ‘no’, and ‘yes’ indicated one point. The studies were rated as having a low risk of bias when at least six of twelve points were scored and study had no other serious flaws. Studies were rated as having a high risk of bias, if less than six points was scored or in case study had one or more serious flaws.

4 RESULTS

Altogether 67 randomized controlled trials examining the effects of preventive intervention on sports injuries were discovered through systematic literature search. Results from the methodological quality assessment are presented in Appendix 2. The highest score a study received was 9/12 and the lowest 2/12. An average score received was 5/12.

Trials were divided into seven groups (insoles, external joint supports, training programs, stretching, protective head equipment, modified shoes and injury prevention videos) based on the type of the intervention. Groups were further divided into subgroups if noticeable similarities between certain interventions were noticed, even though interventions were not necessarily identical and there might have been other methodological heterogeneity between the studies. Note that five trials (Smith et al. 1985, Tropp et al. 1985, Barrett et al. 1993, Mohammadi 2007, McIntosh et al. 2009) had two or more intervention groups tested, but only one control group. These interventions were pooled as individual trials. Therefore, in the forest plots, the number of participants in the control groups of these trials is actually multiple. Seven of the included trials (Finestone 1992, Larsen et al. 2002, Finestone et al. 2004, Finch et al. 2005, Gabbe et al. 2006, Bello et al. 2011, Kinchington 2011) could not be pooled, because of insufficient injury data. In addition, one included study could not be pooled because of its singular intervention (Lappe et al. 2008).

4.1 Insoles

Nine of the trials studied the effects of insoles to reduce the risk of lower limb injuries among military recruits (total of 4788 subjects). In the study of Smith et al. (1985) there were two different types of insoles used and these interventions were treated as individual studies. Eight individual interventions were pooled and six of these showed effective results. Although two interventions (Withnall et al. 2006, Mattila et al. 2011) failed to show preventive effect, test for overall effect ($Z= 2.83$, $p= 0.005$) remained statistically significant and insoles significantly reduced the risk of injuries (pooled OR 0.51, 95% CI 0.32–0.81). Heterogeneity between the studies was strong ($I^2= 82\%$, $p< 0.001$) (Figure 4). Two studies could not be pooled; result from the study of Larsen et al. (2002) favoured intervention (RR 0.70, 95% CI 0.50–1.10), whereas no group differences were observed in the study of Finestone et al. (2004).

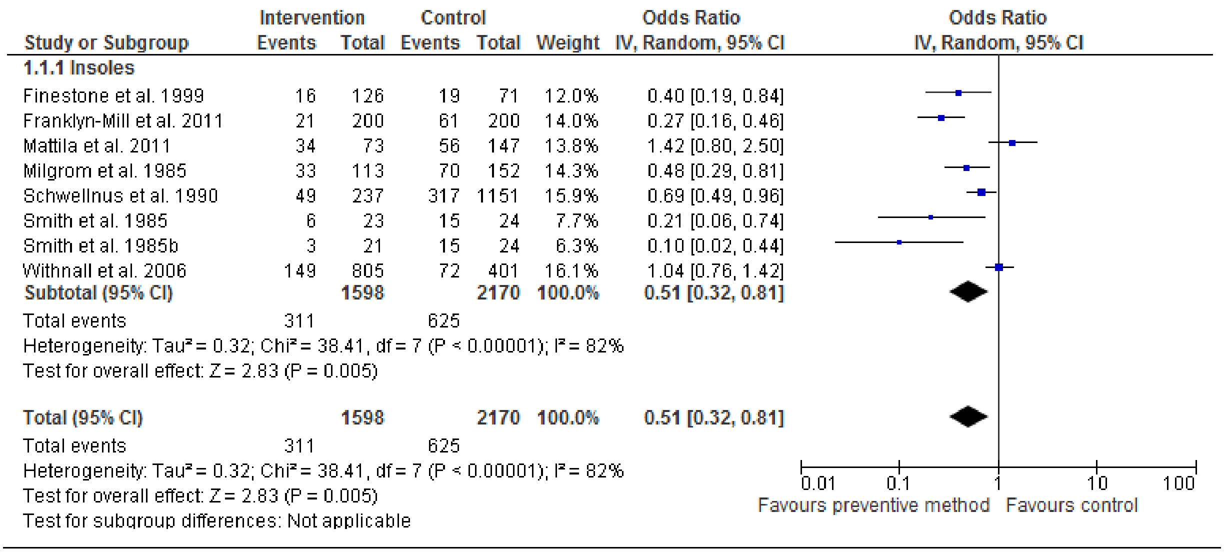

Figure 4. Insoles vs. control. OR, pooled OR, 95% confidence intervals and test of heterogeneity.

4.2 External joint supports

The effects of external joint supports was studied in ten trials (total of 13 808 subjects). All seven interventions assessing different ankle supports [ankle orthosis (Tropp et al. 1985, Surve et al. 1994, Mohammadi 2007, McGuine et al. 2011, McGuine et al. 2012), ankle stabilizers (Sitler et al. 1994) and outside-the-boot braces (Amoroso et al. 1998)] reduced ankle injuries compared to no ankle supports, with results being significant in six of the studies (pooled OR 0.40, 95%CI 0.30–0.53) (Figure 5). The subjects in these trials (total of 6662 subjects) were young male and female athletes in basketball, male athletes in soccer and football and military paratroopers.

In two trials assessing wrist supports (Rønning et al. 2001, Machold et al. 2002), within total of 5750 subjects, wrist supports were effective in protecting snowboarders against wrist injury (pooled OR 0.25, 95%CI 0.12–0.51). Knee supports were studied in one trial (Sitler et al. 1990) in which the use of prophylactic knee braces significantly reduced the number of knee injuries among 1396 military cadets while playing football (OR 0.43, 95%CI 0.24–0.78) (Figure 5).

On the basis of ten trials studying the effects of external joint supports, intervention group experienced significantly less injuries compared to control group (pooled OR 0.39, 95%CI 0.31–0.49). Heterogeneity between the studies was very low (I^2= 13%, p= 0.32) (Figure 5).

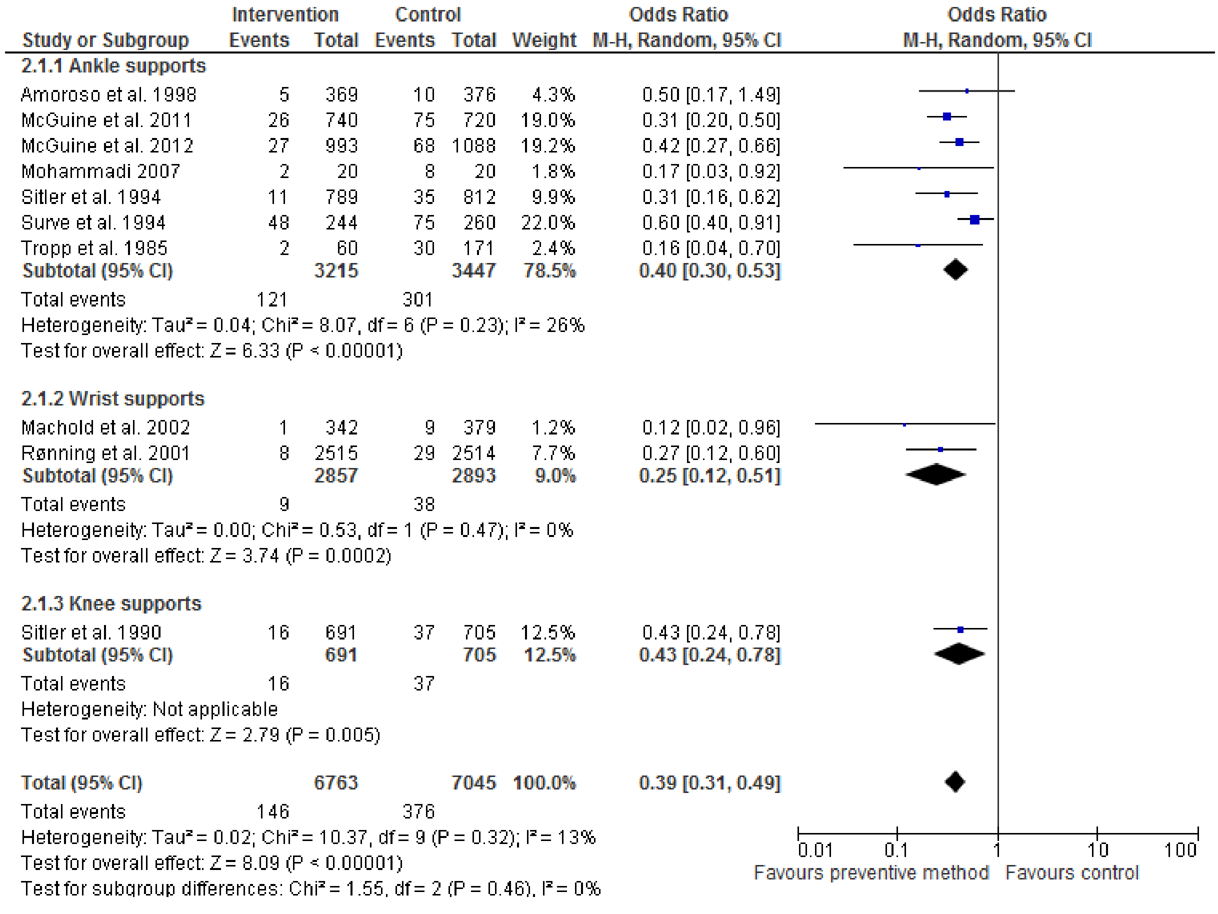

Figure 5. External joint supports vs. control. OR, pooled OR, 95% confidence intervals and test of heterogeneity.

4.3 Training programs

The effects of training intervention on sports injury prevention were studied most often; altogether in 37 of included trials. These interventions were divided into six subgroups: balance board training, multi-intervention with balance board training, other multi-interventions, warm-up programs, strength training and graded running programs. The results of the training interventions are illustrated as a forest plot in Figure 6.

Study or Subgroup	Intervention Events	Intervention Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
3.1.1 Balance board training						
Emery et al. 2005	2	66	10	61	1.0%	0.16 [0.03, 0.76]
Hupperets et al. 2009	56	256	89	266	3.8%	0.56 [0.38, 0.82]
Mohammadi 2007	1	20	8	20	0.6%	0.08 [0.01, 0.71]
Söderman et al. 2000	23	62	25	78	2.7%	1.25 [0.62, 2.52]
Tropp et al. 1985b	7	142	30	171	2.2%	0.24 [0.10, 0.57]
Verhagen et al. 2004	29	392	41	340	3.4%	0.58 [0.35, 0.96]
Wester et al. 1996	6	24	13	24	1.4%	0.28 [0.08, 0.96]
Subtotal (95% CI)		**962**		**960**	**15.0%**	**0.45 [0.28, 0.73]**
Total events	124		216			
Heterogeneity: Tau² = 0.22; Chi² = 15.37, df = 6 (P = 0.02); I² = 61%						
Test for overall effect: Z = 3.20 (P = 0.001)						
3.1.2 Multi-intervention with balance board training						
Eils et al. 2010	7	81	21	91	2.1%	0.32 [0.13, 0.79]
Emery & Meeuwisse 2010	48	380	70	364	3.7%	0.61 [0.41, 0.91]
Emery et al. 2007	130	494	141	426	4.1%	0.72 [0.54, 0.96]
McGuine & Keene 2006	23	373	39	392	3.2%	0.59 [0.35, 1.02]
Pasanen et al. 2008	20	256	40	201	3.1%	0.34 [0.19, 0.60]
Wedderkopp et al 1999	11	111	45	126	2.6%	0.20 [0.10, 0.41]
Wedderkopp et al. 2003	6	77	16	86	1.9%	0.37 [0.14, 1.00]
Subtotal (95% CI)		**1772**		**1686**	**20.7%**	**0.46 [0.32, 0.64]**
Total events	245		372			
Heterogeneity: Tau² = 0.12; Chi² = 16.27, df = 6 (P = 0.01); I² = 63%						
Test for overall effect: Z = 4.46 (P < 0.00001)						
3.1.3 Other multi-interventions						
Brushøj et al. 2008	108	507	91	513	4.0%	1.26 [0.92, 1.71]
Collard et al. 2010	100	1015	104	996	4.1%	0.94 [0.70, 1.25]
Ekstrand et al. 1983	23	90	62	90	2.8%	0.16 [0.08, 0.30]
Engebretsen et al. 2008	114	193	114	195	3.7%	1.03 [0.68, 1.54]
Heidt et al. 2000	6	42	87	258	2.1%	0.33 [0.13, 0.81]
Holme et al. 1999	2	29	11	38	1.0%	0.18 [0.04, 0.90]
Hägglund et al. 2007	10	90	23	79	2.3%	0.30 [0.13, 0.69]
Parkkari et al. 2011	114	501	120	467	4.1%	0.85 [0.63, 1.14]
van Mechelen et al. 1993	24	159	20	167	2.9%	1.31 [0.69, 2.47]
Subtotal (95% CI)		**2626**		**2803**	**27.1%**	**0.63 [0.42, 0.95]**
Total events	501		632			
Heterogeneity: Tau² = 0.28; Chi² = 49.37, df = 8 (P < 0.00001); I² = 84%						
Test for overall effect: Z = 2.21 (P = 0.03)						
3.1.4 Warm-up programs						
Gilchrist et al. 2008	2	583	10	852	1.0%	0.29 [0.06, 1.33]
LaBella et al. 2011	47	737	83	755	3.8%	0.55 [0.38, 0.80]
Longo et al. 2012	14	80	17	41	2.2%	0.30 [0.13, 0.70]
Olsen et al. 2005	46	958	76	879	3.8%	0.53 [0.37, 0.78]
Soligard et al. 2008	121	1055	143	837	4.2%	0.63 [0.48, 0.82]
Steffen et al. 2008	204	1073	192	947	4.3%	0.92 [0.74, 1.15]
van Beijsterveldt et al.	135	223	139	233	3.8%	1.04 [0.71, 1.51]
Waldén et al. 2012	7	2479	14	2085	2.1%	0.42 [0.17, 1.04]
Subtotal (95% CI)		**7188**		**6629**	**25.3%**	**0.64 [0.49, 0.83]**
Total events	576		674			
Heterogeneity: Tau² = 0.08; Chi² = 20.81, df = 7 (P = 0.004); I² = 66%						
Test for overall effect: Z = 3.39 (P = 0.0007)						
3.1.5 Strenght training						
Askling et al. 2003	3	15	10	15	0.9%	0.13 [0.02, 0.66]
Mohammadi 2007	4	20	8	20	1.2%	0.38 [0.09, 1.54]
Petersen et al. 2011	15	461	52	481	3.0%	0.28 [0.15, 0.50]
Subtotal (95% CI)		**496**		**516**	**5.1%**	**0.27 [0.16, 0.45]**
Total events	22		70			
Heterogeneity: Tau² = 0.00; Chi² = 1.04, df = 2 (P = 0.59); I² = 0%						
Test for overall effect: Z = 5.00 (P < 0.00001)						
3.1.6 Graded running program						
Bredeweg et al. 2012	26	171	32	191	3.1%	0.89 [0.51, 1.57]
Buist et al. 2008	52	250	48	236	3.6%	1.03 [0.66, 1.60]
Subtotal (95% CI)		**421**		**427**	**6.7%**	**0.97 [0.69, 1.38]**
Total events	78		80			
Heterogeneity: Tau² = 0.00; Chi² = 0.15, df = 1 (P = 0.69); I² = 0%						
Test for overall effect: Z = 0.15 (P = 0.88)						
Total (95% CI)		**13465**		**13021**	**100.0%**	**0.55 [0.46, 0.66]**
Total events	1546		2044			
Heterogeneity: Tau² = 0.17; Chi² = 138.26, df = 35 (P < 0.00001); I² = 75%						
Test for overall effect: Z = 6.60 (P < 0.00001)						
Test for subgroup differences: Chi² = 20.77, df = 5 (P = 0.0009), I² = 75.9%						

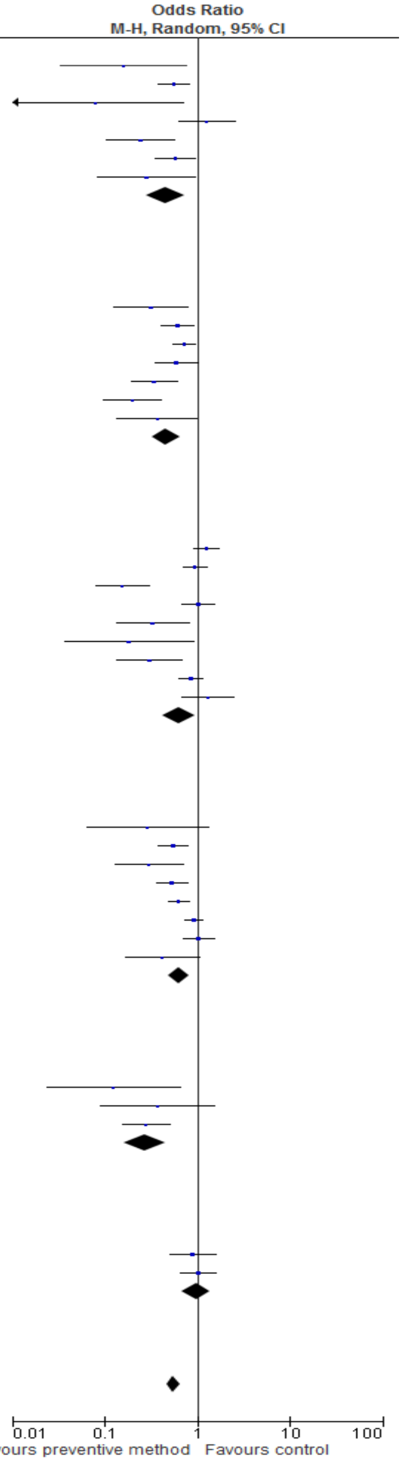

Figure 6. Training programs vs. control. OR, pooled OR, 95% confidence intervals and test of heterogeneity.

On the basis of seven trials (total of 1922 participants), balance board training significantly reduced the number of sports injuries in intervention group compared to control group (pooled OR 0.45, 95%CI 0.28–0.73). In six of the studies balance board training showed a significant reduction of the injuries with considerable variation (odds ratios 0.08–0.58). In one study (Söderman et al. 2000) the balance board training was not effective to reduce the risk of lower extremity injuries in female soccer players (OR 1.25, 95%CI 0.62–2.52). The results showed heterogeneity (I^2= 61%, p= 0.02). When exploring the studies investigating multi-intervention with balance board training (total of 3458 participants), the results were consistent. Multi-interventions using balance board training were effective to reduce the risk of sports injuries (pooled OR 0.46, 95%CI 0.31–0.64). Furthermore other multi-intervention studies (total of 5429 participants) showed preventive effects (pooled OR 0.63, 95%CI 0.42–0.95), although the results were rather inconsistent and heterogeneity was strong (I^2= 84%, p< 0.001).

Of the eight trials investigating the effects of warm-up program (total of 13 817 subjects) significant results were found in half of them (ORs 0.29–0.92). However, the pooled results reached significant level; warm-up programs tended to reduce the risk of sports injuries (pooled OR 0.64, 95%CI 0.49–0.83). The results showed statistically significant heterogeneity (I^2= 66%, p< 0.01).

The effects of strength training on lower extremity injuries were assessed in four studies (total of 1232 participants). In the studies of Askling et al. (2003) and Petersen et al. (2011) eccentric strength training significantly reduced the risk of hamstring injuries among soccer players, whereas Mohammadi (2007) found no significant effect of strength training on ankle sprain recurrence. Combined results supported that strength training yielded a significant reduction in the risk of injuries in intervention group compared to the control group (pooled OR 0.27, 95%CI 0.16–0.45). Results showed no heterogeneity (I^2= 0%, p= 0.59). The results of the study of Gabbe et al. (2006) couldn't be pooled, but no differences in the rates of hamstring injuries between the intervention and control group were found (RR 1.2, 95%CI 0.5–2.8).

In the studies of Bredeweg et al. (2012) and Buist et al. (2008), graded training program in the prevention of running related injuries (total of 848 participants) failed to show preventive effects (pooled OR 0.97, 95%CI 0.69–1.38). No heterogeneity was observed (I^2= 0%, p= 0.69).

On the basis of the 38 trials, training programs were effective to reduce the risk of sports injuries (pooled OR 0.55, 95%CI 0.46–0.66). Statistical heterogeneity between the studies was strong (I^2= 75%, p< 0.001) (Figure 6).

4.4 Stretching

Four trials investigated the effects of stretching on lower extremity injuries (total of 4812 participants). All the results were similar. Stretching appeared to have no effect on the rate of injuries (pooled OR 0.92, 95%CI 0.80–1.06) (Figure 7). There was no statistical heterogeneity between the studies. The study of Bello et al. (2011) could not be pooled, but the results showed no differences in the risk of injury in rhythmic stabilization method compared to regular stretching.

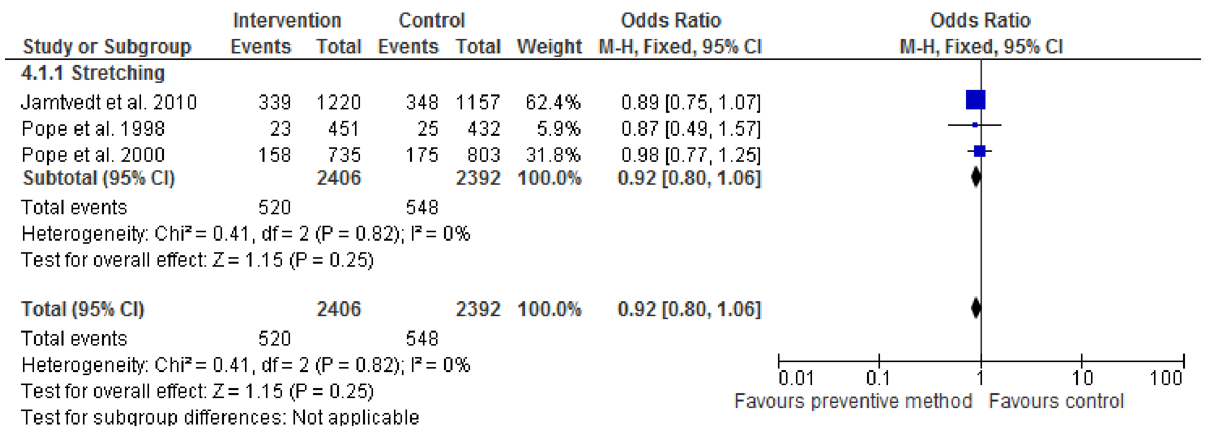

Figure 7. Stretching vs. control. OR, pooled OR, 95% confidence intervals and test of heterogeneity.

4.5 Protective head equipment

Three trials (total of 5010 participants) with four different comparisons studied the effects of protective head equipment on head injuries or concussions. In the study of

McIntosh et al. (2009), two different types of head gears were tested among 4095 rugby players and both of them failed to show preventive effects (pooled OR 1.06, 95%CI 0.91-1.24). Similar results were found in the study of Barbic et al. (2005), in which the use of mouth guards was not effective to reduce the rate of concussions among 614 university football and rugby players (OR 1.04, 95%CI 0.56–1.94). Consequently, pooled OR of protective head equipment was 1.06 (95%CI 0.91–1.24), with no heterogeneity between the studies (I^2= 0%, p= 0.66) (Figure 8). The results of the study of Finch et al. (2005) with 301 Australian football players could not be pooled, but showed opposite results: custom-made mouth guard had a significant effect on the rates of head and orofacial injuries in intervention group compared to control group (RR 0.56, 95%CI 0.32–0.97).

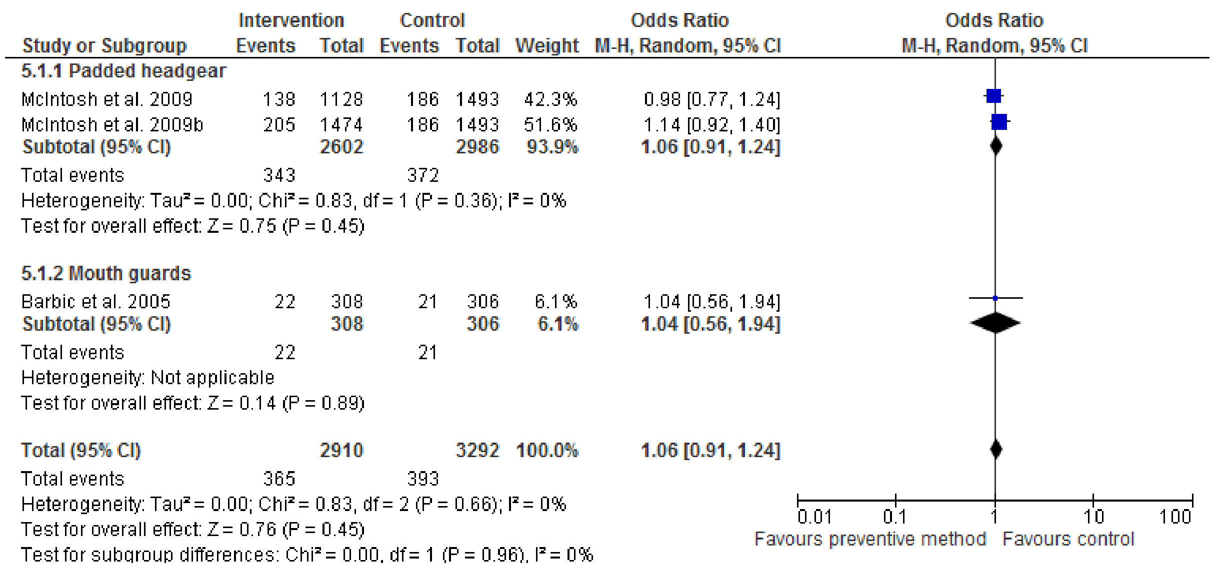

Figure 8. Protective head equipment vs. control. OR, pooled OR and 95% confidence intervals.

4.6 Modified shoes

The effects of modified shoes on lower limb injuries were studied in four trials (total of 1408 participants) with five different interventions. The results of the three individual comparisons were pooled and are illustrated in Figure 9. Barrett et al. (1993) compared two different types of high-top basketball shoes to low-top shoes among basketball players. Milgrom et al. (1992) studied modified basketball shoes among military recruits. None of these three interventions were able to show reduction of injury risk (pooled OR 1.23, 95%CI 0.81–1.87). No heterogeneity was observed (I^2= 0%, p=0.79). In addition, two studies couldn't be pooled. In the study of Finestone et al. (1992), no group differences were observed, but the results of the study of Kinchington et al. (2011) investigating the effects of tailored footwear program, favoured intervention group.

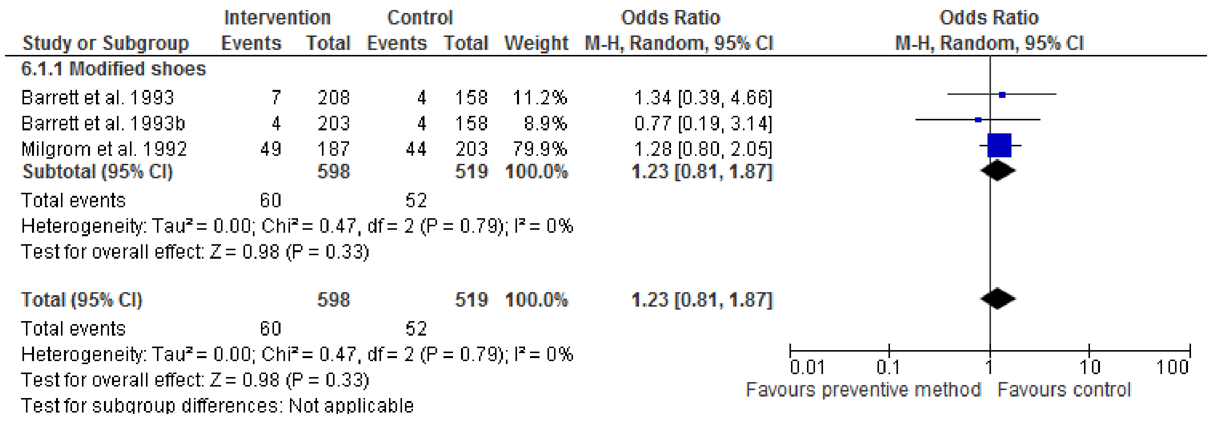

Figure 9. Modified shoes vs. control. OR, pooled OR and 95% confidence intervals.

4.7 Injury prevention videos

Two types of intervention with injury prevention videos (total of 1034 participants) showed controversial results. An instructional ski-video (Jørgensen et al. 1998) reduced the injury risk in downhill skiers, but video-based awareness program (Arnason et al. 2005) had no effect on the rate of injuries among soccer players. There was strong heterogeneity between the studies (I^2= 82%, p= 0.02) and combined effects of the injury prevention videos was not significant (pooled OR 0.94, 95%CI 0.43–2.04) (Figure 10).

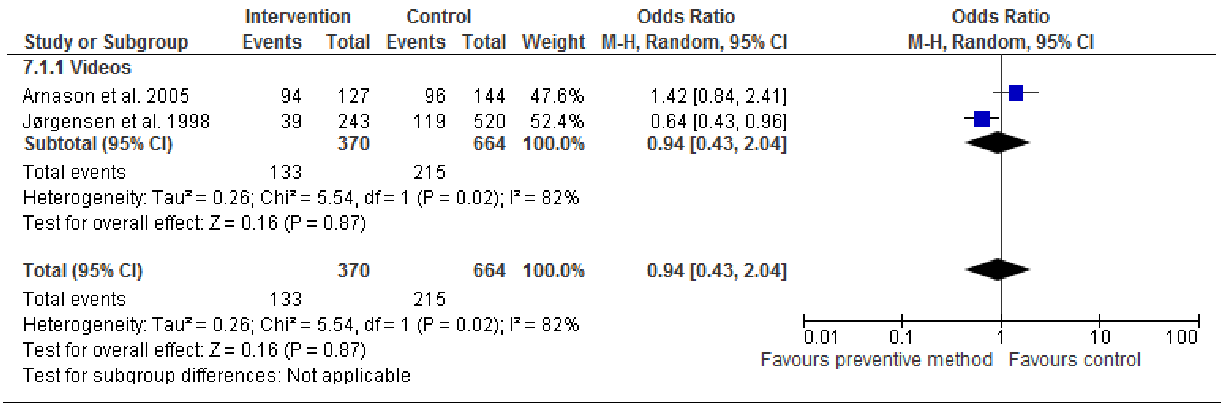

Figure 10. Injury prevention videos vs. control. OR, pooled OR and 95% confidence intervals.

4.8 Other interventions

Lappe et al. (2008) investigated the effects of calcium and vitamin D supplementation on the incidence of stress fractures in female military recruits (total of 5201 subjects). The study could not be pooled because of its uniqueness. The results showed that supplementation of calcium and vitamin D was effective to reduce the risk of stress fractures (OR 0.80, 95%CI 0.67–0.97).

5 DISCUSSION

This systematic review enabled the meta-analysis of the effects of different preventive interventions on the risk of sports injuries. The meta-analysis was conducted on 59 RCTs with 65 comparisons. Studies were divided into subgroups based on the type of intervention examined. Based on the available data, insoles, external joint supports and training programs with different components appear to be effective to reduce the risk of sports injuries, whereas stretching, modified shoes and injury prevention videos failed to show preventive effects.

5.1 Results in relation to other studies

Orthotic insoles are widely used to prevent overuse injuries (Mattila et al. 2011); nevertheless, the evidence of their effectiveness has been controversial (Hume et al. 2008, Mattila et al. 2011). Evidence from previous reviews has stated that the use of orthotic insoles may prevent first-time overuse lower limb conditions (Collins et al. 2007) and tibial stress fractures (Hume et al. 2008) and that shock-absorbing insoles may be effective to reduce the incidence of stress fractures (Rome et al. 2009). However, insoles appear not be effective to reduce lower limb soft-tissue running injuries (Yeung et al. 2011). In this meta-analysis, six of the eight pooled studies supported the use of insoles to prevent lower limb injuries, whereas studies by Withnall et al. (2006) and Mattila et al. (2011) found no preventive effects. Interestingly, the quality assessment of these trials revealed that only trials by Withnall et al. (2006) and Mattila et al. (2011) were rated as having a low risk of bias, whereas other trials were at high risk of bias. Although the pooled results showed significant preventive effect, there is a potential risk of bias. These results therefore need to be interpreted with cautious. Also applicability of these results is limited primely to young men undergoing military training and cannot be generalized to athletes straight-ahead, even though the military training includes high-intensity physical training (Aaltonen et al. 2007).

Trials assessing the effectiveness of external joint supports have mostly been conducted among high-risk sporting activities, such as soccer, basketball, football, parachute jumping and snowboarding. In all trials of the present study, except one, the use of external joint support provided beneficial protection against ankle, knee or wrist injuries. Interestingly, the heterogeneity between the trials of external joint supports was very low, even though there were differences in the study designs, whereas in most of the other groups with multiple trials, heterogeneity was high. The external joint supports were used among high-risk sports, where injuries of the joints and ligaments are common; hence the use of external joint supports is likely to provide protection against injuries. Ankle sprains have often been reported as the most common injury type encountered in sports (Dizon & Reyes 2010, Verhagen & Bay 2010). The present finding of a preventive role of external ankle supports is consistent with previous research (Handoll et al. 2001, Dizon & Reyes 2010, Verhagen & Bay 2010). However, in this current analysis, external ankle supports used were different kind of stabilizing devices, such as orthoses and braces, but for instance taping, which has also been reported effective to reduce ankle sprains (Dizon & Reyes 2010, Verhagen & Bay 2010), was not used in these RCTs. Although anterior cruciate ligament (ACL) injuries of knee are well known problem especially among female athletes participating pivoting and cutting sports (Hewett et al. 2006), the effects of prophylactic braces to reduce the incidence of knee injuries has not been commonly studied in RCTs. This is probably because previous studies have reported lack of evidence of their effectiveness to prevent ACL injuries (Hewett et al. 2006), but also due to growing interest on the effects of training interventions to reduce the risk of lower extremity injuries. In this meta-analysis only one trial demonstrated the effect of prophylactic knee braces and reported a reduced risk of knee injuries. Note that this trial was conducted among military recruits while playing football and the reduction of knee injuries was dependent on a player position. Based on this trial only, implications of effectiveness of knee bracing cannot be drawn.

The number of interventions assessing training programs has increased nearly three-fold from the previous systematic review (Aaltonen et al. 2007) to date. This reflects the current trend in sports injury research. Due to increased leisure time physical activity in developed countries (Hallal et al. 2012), people get injured more often, and that has increased the interest to study preventive methods. Moreover, it seems possible, that increasing knowledge of factors that dispose athlete to injuries has led to thinking that certain risk factors can be influenced. Exposure to extrinsic risk factors, such as environmental conditions or other players, can seldom be influenced.

Even though not all intrinsic risk factors are changeable, factors such as physical fitness, muscle strength, motor abilities and sports specific skills are highly trainable. Most of the training programs designed for prevention of injuries aims to influence these risk factors by practicing athlete’s intrinsic abilities. What makes the interpretation of these results complex is the variety of different components used in training interventions.

The previous review of the prevention of sports injuries (Aaltonen et al. 2007) showed preliminary findings of balance board training as a preventive strategy. Since then seven new RCTs of balance board training alone or as a part of multi-intervention have been published. Balance training can improve both static and dynamic balance and enhance postural control in athletic situations, which may reduce the risk of injury (Emery et al. 2005). Current findings further support the benefits of balance board training. Balance board training seems to be effective especially to reduce the risk of ankle injuries, but also to some extent, as a part of neuromuscular training, other lower extremity injuries. However, when the balance board training is merged with other components of multi-interventional training program, the actual effect of balance board remains unclear. Interestingly, data from Appendix 3 indicates that 80% of all effective training interventions included some sort of balance or coordination component. Five trials used balance board training as a home-based training and four of these home-based interventions were effective. At least among athletes, who often are used to perform exercises also on their leisure time, home-based training intervention can be as effective as supervised intervention.

According to Fradkin’s et al. (2006) review, the evidence of warming up has been insufficient. The present findings of the effectiveness of warm-up programs are more promising, but still, to some extent conflicting. Although the pooled result showed preventive effect, half of the trials failed to reach significant results. The conflicting results may be because there was a large variety of training components used in these interventions. While using multiple training methods, it remains unclear what are the most beneficial components of preventive intervention. Also independent trials had some major limitations, such as lack of compliance in the study by Steffen et al. (2008) and small number of events in the study by Waldén et al. (2012), which could have influenced the pooled result. Most of the warm-up programs were conducted among soccer players and included exercises targeted to enhance neuromuscular control.

When dividing training interventions into subgroups, some overlaps between the groups could not be avoided. Due to this, neuromuscular training method was a part of many training interventions. It has been hypothesized that neuromuscular type of training can induce such changes within neuromuscular system that may affect to the risk of injuries (Eils 2010, Herman et al. 2012). Neuromuscular training has beneficial effects to joint position sense, stability and reflexes. Also, according to recent review (Herman et al. 2012), neuromuscular training can be implemented effectively with no additional equipment, which further provides practical, cost-effective way to reduce the injury risk.

Eccentric strength training seems to reduce the risk of hamstring injuries among soccer players according to two high quality trials (Askling 2003, Petersen et al. 2011). This finding is consistent with other systematic review (Hibbert et al. 2008). However, strength training was not effective among Australian football players (Gabbe et al. 2006) and among soccer players, who practiced strength of the evertor muscles to reduce the recurrence of ankle sprains (Mohammadi 2007). Interventions planned to increase strength and power, are not yet commonly studied in RCTs. Instead, strength and power training has successfully been used as a part of multi-interventions. Approximately half of the effective training multi-interventions included strength or power training components and almost all of them combined elements from both strength and power and balance and coordination training (Appendix 3).

It is likely that the preventive effect of the training programs using several components is the sum of individual effective methods. It is almost impossible to simplify which part of the training intervention is the actual effective component and which part has no influence on the injury risk (Aaltonen et al. 2007). The preventive effect can also be a result from interaction of the different components, when two single elements may not be effective apart from each other, but have effective interaction. Nevertheless, these multi-intervention training programs seem to be popular in sports injury research. In order to increase the knowledge of training interventions, effective programs should be structured and then tested similarly in other RCTs among other study groups. This could allow better comparison and generalizability of the results of different studies.

Stretching has not been commonly studied in RCTs. In this review, four RCTs studied the effectiveness of stretching and only three of those were able to be taken in to the meta-analysis. This limited number of trials is probably due to the fact that there is evidence from previous studies implying that stretching has no effect on overall injury risk (Herbert & Gabriel 2002, Thacker et al. 2004, Small et al. 2008). The present finding brings no change to this. However, some previous reviews have stated that there is preliminary evidence that stretching may reduce the risk of musculotendinous strains (Small et al. 2008, McHugh & Cosgrave 2010) and ligament sprains (Small et al. 2008), but this needs further investigation. Evidently, the lack of well-conducted controlled trials is a problem and therefore the definitive role of stretching cannot be announced (Thacker et al. 2004, McHugh & Cosgrave 2010).

Some of other methods, such as protective head equipment, modified shoes and injury prevention videos, have still been less studied in RCTs and therefore drawing firm conclusions about their effectiveness is not reasonable. In addition, there were other limitations, such as poor compliance and co-interventions, affecting results of individual trials.

5.2 The quality assessment of included trials

The quality assessment of the included trials uncovered various methodological weaknesses in the trials. The results of the quality assessment criteria varied between two and nine points with average score being five points. According to recommendations of Furlan et al. (2009) studies should be rated as having a low risk of bias when at least six of the 12 criteria have been met and the study has no serious flaws. Studies should be rated as having a high risk of bias if received score is less than six or if the study has serious flaws (Furlan et al. 2009). Based on these recommendations, in this review, only 20 studies were rated as having a low risk of bias, whereas 47 studies were considered as having a high risk of bias. Under the circumstances, issues with interval validity of the studies ought to be acknowledged.

There is a possibility of selection bias because of inadequate concealment of allocation or baseline dissimilarities between groups in 63 trials, performance bias due to the lack of the blinding of participants or care providers, or because of co-interventions or unacceptable compliance in all 67 trials, detection bias due to the lack of blinding of outcome assessors or dissimilar timing of the outcome assessment in 48 trials, and attrition bias due to lack of intention-to-treat-analysis or unacceptable drop-out rate in 44 trials. Because of the nature of sports injury prevention interventions, the blinding of the patients, care providers and outcome assessors simultaneously, and avoiding co-interventions is in most cases very problematic. Therefore it is almost impossible to a study to receive highest quality assessment score (Aaltonen et al. 2007). Of the 20 studies that were considered as having a low risk of bias, all except one were made during 2000-century, which refers to studies being more properly conducted and reported nowadays than before. Nevertheless, among studies receiving less than six points there were also several recently published trials. Quality of research reporting plays an essential role in methodological quality of the trial, because inadequate reporting may cause a study to receive lower score than it would if the reporting was more adequate (Jüni et al. 2001).

5.3 Strengths and limitations

This systematic review and meta-analysis is presumably the first meta-analysis that has taken into account all interventions aiming at prevention of sports injuries. Summarizing the effects of RCTs, provides information on what has been studied and what needs to be studied more, and furthermore, what are the actual preventive means and what are the means that do not have preventive effect.

This systematic review and meta-analysis included only RCTs. In the hierarchy of research design, RCT is the highest level of clinically based experimental research and provides evidence for the efficacy of interventions (McKeon et al. 2006). The benefit of systematic review and analysis of RCTs is that this research design is more likely to give valid information and less likely to provide biased information. That is why systematic review and meta-analysis of well-designed RCTs has been referred as the “gold standard” (Sackett et al. 1996, McKeon et al. 2006).

This study had some limitations. As mentioned earlier, many of the included trials had various methodological weaknesses. Furthermore, there were limitations of external validity. In general, most of the participants in the studies were young adult athletes, both male and female. Only few of the studies included senior athletes or children. When divided into subgroups according to intervention, study participants of the different trials tended to represent particular sport or group of people. Especially, studies with insoles, participants were all military recruits and mainly males aged under 30-years. Also interventions with strength training were all conducted among male soccer players and with rather small sample sizes. Consequently the applicability of these findings to other age and sports groups is limited and should be tested in future studies.

The trials were divided into subgroups on the basis of similarity of the preventive means. This was done even though the interventions were not identical in all respects and the study designs and participants were considerably heterogeneous. Unfortunately, this limits the generalizability of the results. Furthermore, the results also showed relatively strong heterogeneity between the results of the independent trials. This can be due to at least three reasons. Firstly, limitations, such as poor compliance and low number of events, can reduce the effect of a preventive intervention. Secondly, alterations in the effectiveness of similar interventions may be because of large differences in the study designs. For instance, an intervention might be effective only in some study group or sporting activity. And thirdly, the risk of bias was high in many trials, so the possibility of bias is present in some trials. This study included only RCTs. However, some of preventive means of sports injuries has been studied in other, non-randomized study designs and therefore are not part of the current meta-analysis. Although the literature search was thoroughly performed using various key words and databases, it is possible that some RCTs filling inclusion criteria were not discovered through the search process.

5.4 Directions for future research

Because sports injuries affect negatively an athlete’s career and health, and have major costs for society, it is essential to promote evidence-based preventive methods. Many sporting clubs and athletes have limited financial resources, especially in youth sports, and this ought to be recognized in planning preventive interventions. Time and resource-efficient preventive methods are needed. Future research should focus on commonly practiced, high-risk sporting activities. The mechanisms behind effective methods and the most beneficial elements of preventive intervention need to be clarified. Sports specific preventive training programs should be developed and tested properly, because specified training aiming at increasing neuromuscular control and sports specific skills probably has multiple advantages. Better understanding of risk factors that dispose athletes to injuries is essential and more research is needed to clarify the role of intrinsic risk factors, such as range of motion and strength, but also skills and technique. Carefully planned and well-conducted RCTs are needed when testing preventive measure.

Finally, although most of the sports injuries seem to be acute injuries, overuse injuries may actually represent a bigger issue than thought (Bahr 2009). It is possible that a large proportion of overuse injuries remain unrecognized in sports injury research due to variations between injury definitions used, and the registered overuse injuries only represent the tip-of-the-iceberg phenomenon. More research of epidemiology and prevention of overuse injuries is needed.

5.5 Conclusion

This study set out to determine what the means to prevent sports injuries are. In conclusion, this systematic review and meta-analysis of 67 RCTs shows evidence that different interventions, such as insoles, external joint supports and training programs seem to be effective to reduce the risk of sporting injuries. In the field of sports, there may be a gap between practice guidelines and evidence-based preventive methods. This is the case especially in amateur and youth sports, where coaches may not have adequate education and knowledge on injury prevention and where accustomed behavior may be difficult to change. The significance of the current findings is that at least to a certain extent sports injuries can be prevented and by taking these preventive actions to practice, major benefits can be accomplished.

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Characteristics of included trials.

Source	Intervention	Participants (% male)	Age Range, y	Participants, Intervention/ Control, No.	Duration	Outcome	OR or RR (95% CI)	Quality Score
			Insoles					
Finestone et al. 1999	Biomechanical shoe orthoses (custom)	Infantry recruits (100%)	17-27	260/144	14 wk	Lower extremity stress fractures	OR, 0.40 [0.19, 0.84][c]	4/12
Finestone et al. 2004	(1) Soft orthoses (custom) (2) Soft orthoses (prefabricated) (3) Semirigid biomechanical orthoses (custom) (4) Semirigid orthoses (prefabricated)	Infantry recruits (100%)	18-20	(1) 227 (2) 224 (3) 215 (4) 208	14 wk	Lower extremity overuse injuries	NC; no group differences observed	5/12
Franklyn-Miller et al. 2011	Foot orthoses	Military officer trainees (65%)	25 (mean)	200/200	7 wk	Overuse lower limb injuries	OR, 0.27 [0.16, 0.46][c]	5/12
Larsen et al. 2002	Biomechanical shoe orthoses (custom)	Military conscripts (99,3%)	18-24	77/69	3 mo	Back and lower extremity problems	RR, 0.70 [0.50-1.10] (NC)	7/12
Mattila et al. 2011	Orthotic insoles	Military conscripts (100%)	18-29	73/147	6 mo	Lower limb overuse injury	OR, 1.42 [0.80, 2.50][c]	9/12
Milgrom et al. 1985	Shock-absorbing orthotic devices (prefabricated)	Military recruits (100%)	NR	143/152	14 wk	Lower extremity stress fractures	OR, 0.48 [0.29, 0.81][c]	3/12
Schwellnus et al. 1990	Neoprene insoles (prefabrecated)	Military recruits (NR)	17-25	250/1261	9 wk	Lower extremity overuse injuries	OR, 0.69 [0.49, 0.96][b]	3/12
Smith et al. 1985	(1) Poron insoles (prefabricated) (2) Spenco insoles (prefabricated) (3) Control	Coast guard recruits (NR)	17-25	(1) 30 (2) 30 (3) 30	8 wk	Lower extremity injuries	(1) vs (3) OR, 0.21 [0.06, 0.74][c] (2) vs (3) OR, 0.10 [0.02, 0.44][c]	2/12
Withnall et al. 2006	(1) Shock absorbing insole (Sorbothane SAI) (2) Shock absorbing insole (Poron SAI) (3) Non-shock absorbing insole (control)	Military recruits (77.8%)	16-35	(1) 421 (2) 383 (3) 401	8 mo	Any lower limb injury	(1) and (2) vs (3) OR,1.04 [0.76, 1.42][c]	6/12

Source	Intervention	Participants (% male)	Age Range, y	Participants, Intervention/ Control, No.	Duration	Outcome	OR or RR (95% CI)	Quality Score
External Joint Supports								
Amoroso et al. 1998	Outside-the.boot braces	Military paratrooper students (100%)	>18	369/376	1 wk	Ankle injuries	OR, 0.50 [0.17, 1.49][c]	6/12
McGuine et al. 2011[e,f]	Lace-up ankle braces	High-school basketball players (49.6%)	16 (mean)	740/720	1 Playing season	Acute ankle injuries	OR, 0.31 [0.20, 0.50][c]	3/12
McGuine et al. 2012[e,f]	Lace-up ankle braces	High-school football players (NR)	NR	993/1088	1 Playing season	Acute ankle injuries	OR, 0.42 [0.27,0.66][b]	3/12
Machold et al. 2002	Wrist protectors	Students (60%)	14.8 (mean)	342/379	1 wk	Wrist injuries	OR, 0.12 [0.02, 0.96][c]	5/12
Mohammadi 2007	Sport-Stirrup ankle orthoses	Soccer players (100%)	24.6 (mean)	20/20	1 Playing season	Ankle sprain recurrences	OR, 0.17 [0.03, 0.92][c]	3/12
Rønning et al. 2001	Wrist protectors	Snowboarders (64.2%)	10-68	2515/2514	3 mo	Wrist injuries	OR, 0.27 [0.12, 0.60][c]	7/12
Sitler et al. 1990	Prophylactic knee braces	Military academy cadets (NR)	18-21	691/705	2 y	Knee injuries	OR, 0.43 [0.24, 0.78][c]	4/12
Sitler et al. 1994	Semirigid ankle stabilizers	Military academy cadets (NR)	18-21	789/812	2 y	Ankle injuries	OR, 0.31 [0.16, 0.62][c]	3/12
Surve et al. 1994	Sport-Stirrup ankle orthoses	Senior soccer players (100%)	NR	244/260	1 Playing season	Ankle sprains	OR, 0.60 [0.40, 0.91][c]	2/12
Tropp et al. 1985[e]	Ankle orthoses	Senior soccer players (100%)	NR	124/180	6 mo	Ankle sprains	OR, 0.16 [0.04, 0.70][c]	3/12
Training programs: Balance Board Training								
Emery et al. 2005[e,f]	Home-based balance training program	Physical education students (50%)	14-19	66/61	6 mo	Sports injuries	OR, 0.16 [0.03, 0.76][c]	6/12
Hupperets et al. 2009	Home based proprioceptive training program	Athletes with previous ankle sprain (52.5%)	12-70	256/266	1 y	Recurrence of ankle sprain	OR, 0.56 [0.38, 0.82][c]	7/12
Mohammadi 2007	Proprioceptive ankle disk training	Soccer players (100%)	24.6 (mean)	20/20	1 Playing season	Ankle sprain recurrences	OR, 0.08 [0.01, 0.71][c]	3/12
Söderman et al. 2000[e]	Balance-board training program	Soccer players (0%)	15-25	121/100	7 mo	Lower extremity injuries	OR, 1.25 [0.62, 2.52][c]	3/12
Tropp et al. 1985[e]	Ankle disk training	Senior soccer players (100%)	NR	144/180	6 mo	Ankle sprains	OR, 0.24 [0.10, 0.57][c]	3/12
Verhagen et al. 2004	Balance board training program	Volleyball players (42,9%)	21-27	641/486	36 wk	Ankle injuries	OR, 0.58 [0.35,0.96][b]	4/12
Wester et al. 1996	Wobble board training	Athletes with primary ankle sprain (60,4%)	25 (mean)	24/24	12 wk	Recurrent ankle sprain	OR, 0.28 [0.08, 0.96][c]	2/12

Source	Intervention	Participants (% male)	Age Range, y	Participants, Intervention/ Control, No.	Duration	Outcome	OR or RR (95% CI)	Quality Score
Training Programs: Multi-Intervention With Balance Board								
Eils et al. 2010	Multistation proprioceptive exercise program	Basketball players (59%)	14-43	96/102	1 Playing season	Ankle injuries	OR, 0.32 [0.13, 0.79][b]	4/12
Emery & Meeuwisse 2010[e,f]	Neuromuscular training program and home-based balance training program	Indoor soccer players (42%)	13-18	481/537	1 y	All injuries	OR, 0.61 [0.41, 0.91][c]	5/12
Emery et al. 2007[e,f]	Balance training program	High-school basketball players (50.4%)	12-18	494/426	1 y	All injuries	OR, 0.72 [0.54, 0.96][b]	5/12
McGuine & Keene 2006	Balance training program	High-school soccer and basketball players (31.6%)	16.5 (mean)	373/392	1 Playing season	Ankle sprains	OR, 0.59 [0.35, 1.02][c]	5/12
Pasanen et al. 2008[e,f]	Neuromuscular training program	Floorball players (0%)	24 (mean)	256/201	6 mo	Acute non-contact injuries of the legs	OR, 0.34 [0.19, 0.60][c]	8/12
Wedderkopp et al. 2003[e,f]	Ankle disk and functional strength training	Handball players (0%)	14-16	77/86	9 mo	Sports injuries	OR, 0.37 [0.14, 1.00][b]	4/12
Wedderkopp et al. 1999[e]	Ankle disk and functional warm-up training	Handball players (0%)	16-18	111/126	10 mo	Sports injuries	OR, 0.20 [0.10, 0.41][c]	2/12
Training Programs: Other Multi-Interventions								
Brushøj et al. 2008[g]	Preventive training program	Military soldiers (100%)	19-26	507/513	12 wk	Lower extremity injuries	OR, 1.26 [0.92, 1.71][c]	7/12
Collard et al. 2010[e,f]	School-based physical activity injury prevention program	Children (44.7%)	10-12	1117/1091	8 mo	Sports injuries	OR, 0.94 [0.70, 1.25][c]	5/12
Ekstrand et al. 1983[e]	Prophylactic program	Senior soccer players (100%)	17-37	90/90	6 mo	Sports injuries	OR, 0.16 [0.08, 0.30][b]	2/12
Engebretsen et al. 2008	(1) Targeted exercise program, high risk players (intervention) (2) High-risk players (control) (3) Low-risk players (control)	Soccer players (100%)	NR	(1) 193 (2) 195 (3) 120	10 wk	Ankle, knee, hamstring and groin injuries	(1) vs (2) OR, 1.03 [0.68, 1.54][c]	4/12
Heidt et al. 2000	Preseason training program	Soccer players (100%)	14-18	42/258	12 mo	Sports injuries	OR, 0.33 [0.13, 0.81][c]	3/12
Holme et al. 1999	Rehabilitation program	Recreational athletes (62%)	21-32	46/46	12 mo	Ankle sprain re-injuries	OR, 0.18 [0.04, 0.90][c]	3/12
Hägglund et al. 2007[e]	Coach-controlled rehabilitation program	Amateur soccer players (100%)	15-46	282/300	1 Playing season	All injuries Recurrence of injuries	OR, 0.30 [0.13, 0.69][c]	6/12
Parkkari et al. 2011[e]	Neuromuscular training program with injury prevention counselling	Military conscripts (100%)	18-28	501/467	6 mo	Acute lower- and upper-limb injury	OR, 0.85 [0.63, 1.14][c]	7/12
van Mechelen et al. 1993	Warm-up, cooldown, and stretching program	Recreational runners (100%)	NR	210/211	16 wk	Lower extremity and back injuries	OR, 1.31 [0.69, 2.47][c]	2/12

Source	Intervention	Participants (% male)	Age Range, y	Participants, Intervention/ Control, No.	Duration	Outcome	OR or RR (95% CI)	Quality Score
			Training Programs: Warm-up Programs					
Gilchrist et al. 2008[e]	Warm-up program to enhance neuromuscular and proprioceptive control	Soccer players (0%)	20 (mean)	583/852	1 Playing season	Anterior cruciate ligament injuries	OR, 0.29 [0.06, 1.33][b]	4/12
LaBella et al. 2011[e,f]	Neuromuscular warm-up program	High-school soccer and basketball players (0%)	16 (mean)	760/798	1 Playing season	Lower limb injuries	OR, 0.55 [0.38, 0.80][c]	6/12
Longo et al. 2012[e]	The FIFA 11+ warm-up program	Basketball players (100%)	14 (mean)	80/41	9 mo	All injuries	OR, 0.30 [0.13, 0.70][b]	8/12
Olsen et al. 2005[e,f]	Structured warm-up program	Handball players (13.7%)	15-17	958/879	8 mo	Ankle and knee injuries	OR, 0.53 [0.37, 0.78][c]	7/12
Soligard et al. 2008[e,f]	Comprehensive warm-up program	Football players (0%)	13-17	1055/837	8 mo	Lower extremity injuries	OR, 0.63 [0.48, 0.82][c]	5/12
Steffen et al. 2008[e,f]	Training program focusing on core stability, balance, dynamic stabilization and eccentric hamstring strength	Football players (0%)	13-17	1091/1001	8 mo	All injuries	OR, 0.92 [0.74, 1.15][c]	6/12
van Beijsterveldt et al. 2012[e]	'The 11' Injury prevention program	Amateur soccer players (100%)	18-40	223/233	9 mo	All injuries	OR, 1.04 [0.71, 1.51][c]	5/12
Waldén et al. 2012[e]	Neuromuscular warm-up program	Football players (0%)	12-17	2479/2085	1 Playing season	Anterior cruciate ligament injuries	OR, 0.42 [0.17, 1.04][c]	8/12
			Training Programs: Strength Training					
Askling et al. 2003	Eccentric strength training for the hamstring muscles	Elite soccer players (100%)	25 (mean)	15/15	10 wk	Hamstring injuries	OR, 0.13 [0.02, 0.66][c]	6/12
Gabbe et al. 2006	Eccentric exercise program	Amateur australian football players (100%)	17-36	114/106	12 wk	Hamstring injuries	RR (NC), 1.2 [0.5, 2.8]	5/12
Mohammadi 2007	Specific strength training of evertor muscles	Soccer players (100%)	24,6 (mean)	20/20	1 Playing season	Ankle sprain recurrences	OR, 0.38 [0.09, 1.54][c]	3/12
Petersen et al. 2011[e,f]	Eccentric training program	Soccer players (100%)	23 (mean)	461/481	10 wk	Acute hamstring injuries	OR, 0.28 [0.15, 0.50][c]	7/12
			Training Programs: Graded Running Programs					
Bredeweg et al. 2012	Preconditioning program	Novice runners (34,5%)	38.1 (mean)	171/191	13 wk	Running-related injuries	OR, 0.89 [0.51, 1.57][c]	6/12
Buist et al. 2008	Graded training program	Novice runners (42.5%)	39.8 (mean)	264/268	13 wk	Running-related injuries	OR, 1.03 [0.66, 1.60][c]	4/12

Source	Intervention	Participants (% male)	Age Range, y	Participants, Intervention/ Control, No.	Duration	Outcome	OR or RR (95% CI)	Quality Score
Stretching								
Bello et al. 2011	Rhytmic stabilization (RS) streching technique	Indoor soccer players (NR)	18-27	7/7	4 mo	Lower limb injuries	NC; no group differences observed	2/12
Jamtvedt et al. 2010	Stretching program	Physically active adults (36.4%)	40 (mean)	1220/1157	12 wk	Any injury to the lower limb or back	OR, 0.89 [0.75, 1.07][c]	4/12
Pope et al. 1998[e,g]	Preexercise calf muscle stretching	Army recruits (100%)	17-35	594/544	12 wk	Lower extremity injuries	OR, 0.87 [0.49, 1.57][c]	4/12
Pope et al. 2000[e,g]	Lower extremity stretching program	Army recruits (100%)	17-35	735/803	12 wk	Lower exremity injuries	OR, 0.98 [0.77, 1.25][c]	5/12
Protective Head Equipment								
Barbic et al. 2005[e,f]	Type II (boil-and-bite) mouth guard	University students (81%)	20.9 (mean)	322/324	3 mo	Concussions	OR, 1.04 [0.56, 1.94][c]	4/12
Finch et al. 2005[e,f]	Custom-made mouth guard	Australian football players (100%)	15-31	190/111	1 Playing season	Head/ Orofacial injuries	RR (NC), 0.56 [0.32-0.97]	4/12
McIntosh et al. 2009[e,f]	(1) Standard headgear (2) Modified padded headgear (3) Control	Rugby union players (100%)	<20	(1) 1128 (2) 1474 (3) 1493	2 Playing seasons	Head injury or concussion	(1) vs (3) OR, 0.98 [0.77, 1.24][b] (2) vs (3) OR, 1.14 [0.92, 1.40][b]	3/12
Modified Shoes								
Barrett et al. 1993	(1) High-top shoes (2) High-top shoes with air chambers (3) Low-top shoes	College basketball players (91.7%)	20.6 (mean)	(1) 227 (2) 212 (3) 183	2 mo	Ankle sprains	(1) vs (3) OR, 1.34 [0.39, 4.66][c] (2) vs (3) OR, 0.77 [0.19, 3.14][c]	4/12
Finestone et al. 1992	Modified basketball shoes	Infantry recruits (100%)	18-20	187/203	14 wk	Lower extremity overuse injuries	NC; no group differences observed	2/12
Kinchington et al. 2011	Tailored footwear programme	Professional rugby players (100%)	24 (mean)	32/27	30 wk	Lower limb injuries	NC; result favors intervention	3/12
Milgrom et al. 1992	Modified basketball shoes	Infantry recruits (100%)	NR	187/203	14 wk	Lower extremity stress fractures	OR, 1.28 [0.80, 2.05][c]	2/12
Videos								
Arnason et al. 2005[d]	Video-based awereness program	Soccer players (100%)	NR	127/144	5 mo	Sports injuries	OR, 1.42 [0.84, 2.41][b]	3/12
Jørgensen et al. 1998	Instructional ski video	Downhill skiers (58%)	15-61	243/520	1 wk	Sports injuries	OR, 0.64 [0.43, 0.96][c]	3/12
Other Interventions								
Lappe et al. 2008	Calcium and vitamin D supplementation	Navy recruits (0%)	17-35	2626/2575	8 wk	Stress fractures	OR, 0.80 [0.67, 0.97][b]	9/12

Abbreviations: CI, confidence interval; NC, not calculated; NR, not reported; OR, odds ratio; RR, risk ratio.

[a] Comparison is made with a control group that has not participated in any intervention (except for Finestone et al., Barrett et al. and Bello et al.).

[b] Calculated by using the number of injured individuals in the intervention vs control groups.

[c] Calculated by using the number of injuries in the intervention vs control groups.

[d] Calculated by using detailed information received from the authors.

[e] Cluster randomized.

[f] Cluster randomization was taken into account in the analyses of the original report.

[g] Quasi-randomized.

Appendix 2/1

Methodological quality assessment of included trials.

Trial	A1	B2	C3	C4	C5	D6	D7	E8	F9	F10	F11	F12	TOT
Amoroso et al. 1998	YES	US	US	US	YES	NO	US	YES	YES	US	YES	YES	6
Arnason et al. 2005	US	US	US	US	US	YES	NO	YES	US	US	US	YES	3
Askling et al. 2003	US	US	US	US	YES	YES	US	YES	YES	US	YES	YES	6
Barbic et al. 2005	US	US	NO	NO	NO	NO	NO	YES	YES	US	NO	YES	3
Barrett et al. 1993	YES	US	US	US	US	YES	US	YES	US	US	US	YES	4
Bello et al. 2011	US	US	US	US	US	US	US	YES	US	US	US	YES	2
Bredeweg et al. 2012	YES	US	US	US	US	YES	YES	YES	YES	US	NO	YES	6
Brushoj et al. 2008	NO	YES	YES	US	YES	NO	US	YES	YES	US	YES	YES	7
Buist et al. 2008	YES	US	US	US	US	YES	YES	YES	NO	US	NO	US	4
Collard et al. 2010	YES	US	NO	NO	NO	YES	YES	YES	NO	US	US	YES	5
Eils et al. 2010	YES	US	US	US	US	YES	US	YES	US	US	US	YES	4
Ekstrand et al. 1983	US	US	US	US	US	US	US	YES	US	US	US	YES	2
Emery et al. 2005	YES	US	US	US	US	YES	YES	YES	YES	US	US	YES	6
Emery & Meeuwisse 2010	US	US	YES	US	YES	NO	YES	YES	NO	US	US	YES	5
Emery et al. 2007	YES	US	US	US	YES	US	US	YES	YES	US	NO	YES	5
Engebretsen et al. 2008	US	US	US	US	US	YES	YES	YES	US	NO	NO	YES	4
Finch et al. 2005	US	US	NO	NO	NO	YES	YES	YES	US	NO	US	YES	4
Finestone et al. 1992	US	US	US	US	US	US	US	YES	US	US	US	YES	2
Finestone et al. 1999	YES	US	US	US	US	NO	NO	YES	US	US	YES	YES	4
Finestone et al. 2004	YES	US	YES	NO	NO	NO	US	YES	US	US	YES	YES	5
Franklyn-Miller et al. 2011	YES	US	NO	NO	NO	YES	YES	YES	US	US	US	YES	5
Gabbe et al. 2006	YES	NO	US	US	NO	US	YES	YES	YES	US	NO	YES	5
Gilchrist et al. 2008	US	US	US	US	US	NO	NO	YES	YES	US	YES	YES	4
Heidt et al. 2000	US	US	US	US	YES	US	US	YES	US	US	US	YES	3
Holme et al. 1999	YES	US	US	US	US	NO	US	YES	NO	US	US	YES	3
Hupperets et al. 2009	US	YES	US	US	YES	YES	YES	YES	YES	NO	NO	YES	7
Hägglund et al. 2007	US	YES	NO	NO	YES	YES	YES	YES	US	US	NO	YES	6
Jamtvedt et al. 2010	YES	US	NO	US	US	US	YES	YES	US	US	NO	YES	4
Jørgensen et al. 1998	US	US	US	US	US	US	US	YES	YES	US	US	YES	3
Kinchington et al. 2011	US	US	US	US	US	YES	NO	YES	US	NO	US	YES	3
LaBella et al. 2011	YES	YES	US	NO	NO	YES	YES	YES	NO	US	US	YES	6
Lappe et al. 2008	YES	YES	YES	YES	YES	NO	YES	YES	YES	US	US	YES	9
Larsen et al. 2002	YES	US	US	YES	US	YES	YES	YES	US	US	YES	YES	7
Longo et al. 2012	YES	YES	NO	NO	YES	YES	YES	YES	NO	US	YES	YES	8
Machold et al. 2002	YES	US	US	US	US	US	YES	YES	US	US	YES	YES	5
Mattila et al. 2011	YES	US	US	YES	YES	YES	YES	YES	YES	US	YES	YES	9
McGuine & Keene 2006	US	YES	NO	NO	US	NO	YES	YES	YES	US	US	YES	5
McGuine et al. 2011	US	US	NO	NO	NO	YES	YES	US	US	US	US	YES	3
McGuine et al. 2012	US	US	NO	NO	NO	YES	YES	US	US	US	US	YES	3
McIntosh et al. 2009	US	US	US	US	US	YES	YES	YES	US	US	NO	US	3
Milgrom et al. 1985	US	US	US	US	US	YES	US	YES	US	US	US	YES	3
Milgrom et al. 1992	US	US	US	US	US	US	US	YES	US	US	US	YES	2
Mohammadi 2007	US	US	US	US	US	YES	US	YES	US	US	NO	YES	3
Olsen et al. 2005	US	YES	US	US	YES	YES	YES	YES	US	NO	YES	YES	7
Parkkari et al. 2011	YES	YES	NO	NO	YES	NO	YES	YES	NO	US	YES	YES	7
Pasanen et al. 2008	YES	YES	NO	NO	YES	YES	YES	YES	YES	US	NO	YES	8
Petersen et al. 2011	YES	YES	NO	NO	NO	YES	US	YES	YES	US	YES	YES	7
Pope et al. 1998	US	YES	YES	US	US	NO	US	YES	US	US	US	YES	4
Pope et al. 2000	US	YES	US	US	YES	NO	YES	YES	US	US	US	YES	5
Rønning et al. 2001	US	US	US	US	YES	YES	YES	YES	YES	US	YES	YES	7
Schwellnus et al. 1990	US	US	US	US	US	US	US	YES	US	US	YES	YES	3
Sitler et al. 1990	YES	US	US	US	US	US	US	YES	US	US	YES	YES	4
Sitler et al. 1994	US	US	US	US	US	US	US	YES	US	US	YES	YES	3
Smith et al. 1985	US	US	US	US	US	NO	US	YES	US	US	US	YES	2
Soligard et al. 2008	US	YES	NO	NO	YES	NO	YES	YES	US	US	US	YES	5
Steffen et al. 2008	US	YES	NO	NO	YES	YES	YES	YES	US	US	NO	YES	6
Surve et al. 1994	US	US	US	US	US	US	US	YES	US	US	US	YES	2
Söderman et al. 2000	US	US	US	US	US	NO	NO	YES	YES	US	NO	YES	3
Tropp et al. 1985	US	US	US	US	US	YES	US	YES	US	US	US	YES	3
van Beijsterveldt et al. 2012	YES	US	NO	NO	NO	YES	US	YES	NO	US	YES	YES	5
van Mechelen et al. 1993	US	US	US	US	US	NO	US	YES	US	US	NO	YES	2
Verhagen et al. 2004	US	US	US	US	YES	NO	US	YES	YES	US	US	YES	4
Walden et al. 2012	YES	YES	NO	NO	YES	YES	YES	YES	YES	US	US	YES	8
Wedderkopp et al. 1999	US	US	US	US	US	US	US	YES	US	US	US	YES	2
Wedderkopp et al. 2003	US	US	US	US	NO	YES	YES	YES	US	US	US	YES	4
Wester et al. 1996	YES	US	US	US	US	NO	US	YES	US	US	US	NO	2
Whitnall et al. 2006	YES	YES	NO	NO	NO	YES	YES	YES	US	US	US	YES	6

Abbreviations:
A1, adequate randomization (yes = random assignment was performed by using a computer-generated random sequence, pre-ordered sealed envelopes, or another clearly described and acceptable random method).
B2, concealed allocation (yes = assignment was generated by an independent person not responsible for determining the eligibility of the study participants).
C3, blinding of the study participants (yes = the index and control groups were indistinguishable for the study participants).
C4, blinding of the care providers (yes = the index and control groups were indistinguishable for the care providers (eg. physicians, physiotherapists, trainers) involved in the study).
C5, blinding of the outcome assessors (yes = physicians, physiotherapists, radiologists, researchers, and other staff who evaluated the injuries were blinded regarding group assignment).
D6, described and acceptable drop-out rate (yes = drop-out rate was < 20% for short-term follow-up [0-3 months] or < 30% for long-term follow-up [over 3 months] and reasons for drop-out was given).
D7, intention-to-treat analysis (yes = all randomized participants were analyzed in the group they were allocated to by randomization irrespective of non-compliance and co-interventions).
E8, reports of the study free of suggestion of selective outcome reporting (yes = published report includes enough information and all the results from outcomes have been adequately reported).
F9, similarity between groups at baseline (yes = study groups were similar at baseline regarding demographic factors and other important prognostic factors).
F10, avoided or similar co-interventions (yes = there were no co-interventions or they were similar between the index and control groups).
F11, acceptable compliance (yes = compliance was regularly checked or otherwise supervised and it was more than 70% in every study group).
F12, similar timing of the outcome assessment (yes = duration of the intervention was similar for all study groups).
YES, criterion was described and acceptable (1 point).
NO, criterion was not acceptable (0 points).
US, unsure, criterion was unclear or not described adequately (0 points).
TOT, total points of quality assessment (maximum of 12 points) (Furlan et al. 2009).

Appendix 3

Characteristics of effective training interventions.

Study	Intervention	Athletes	Adults	Adoles-cents	Males	Females	Pre-season	On season	Home-based	Warm-up	Stretching	Balance/ Coordination	Strenght/ power	Equipment	Progressive	Other
Askling et al. 2003	Eccentric strenght training program	x	x		x		x						x	Resistance training		
Emery et al. 2005	Home-based balance training program			x	x	x			x			x		Balance board		
Hupperets et al. 2009	Home based proprioceptive training program	x	x	x	x	x			x			x		Balance board		
Mohammadi 2007	Proprioceptive training program	x	x		x			x				x		Balance board	x	
Tropp et al. 1985b	Ankle disk training	x	x		x		x	x				x		Balance board		
Verhagen et al. 2004	Balance board training program	x	x		x	x		x		x		x		Balance board, ball	x	
Eils et al. 2010	Multistation proprioceptive exercise program	x	x	x	x	x		x				x			x	
Emery & Meeuwisse 2010	Neuromuscular training program and home-based balance training program	x		x	x	x			x	x	x	x	x	Balance board		
Emery et al. 2007	Basketball-spesific balance training program	x		x	x	x		x	x	x		x		balance board	x	
Pasanen et al. 2008	Neuromuscular training program	x	x			x		x		x		x	x	Balance board, balance pad, medicine ball	x	
Wedderkopp et al 1999	Ankle disk and functional warm-up training	x		x		x		x		x		x		Balance board		
Wedderkopp et al. 2003	Ankle disk and functional strenght training	x		x		x		x		x		x	x	Balance board		
Ekstrand et al. 1983	Prophylactic program	x	x		x			x		x	x			Insoles, prophylactic taping		Controlled rehabilitation, correction and supervision
Heidt et al. 2000	Preseason training program	x		x		x	x					x	x	Treadmill	x	
Holme et al. 1999	Rehabilitation program	x	x		x	x						x	x	Balance board		Supervised physical therapy
Hägglund et al. 2007	Coach-controlled rehabilitation program	x	x		x								x		x	10-step rehabilitation program
LaBella et al. 2011	Neuromuscular warm-up program	x		x		x		x		x		x	x			
Longo et al. 2012	The FIFA 11+ warm-up program	x	x	x	x			x		x	x	x	x			
Olsen et al. 2005	Structured warm-up program	x		x	x	x		x		x		x	x	Balance mat, balance board	x	
Soligard et al. 2008	Comprehensive warm-up program	x		x		x		x		x		x	x			
Petersen et al. 2011	Eccentric training program	x	x		x								x		x	