PREVENTION OF SPORTS INJURIES

Systematic Review of Randomized Controlled Trials

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TIIVISTELMÄ

Liikuntavammojen ehkäisy. Systemaattinen katsaus satunnaistetuista, kontrolloiduista tutkimuksista.

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Liikuntavammojen määrä on kasvanut viime aikoina lisääntyneen liikunnan harrastamisen johdosta, minkä seurauksena myös liikuntavammojen ehkäisyn merkitys on korostunut. Tämän systemaattisen katsauksen tarkoituksena on tiivistää liikuntavammojen ehkäisyyn tähtäävien interventioiden vaikuttavuus.

Tutkimuksia haettiin MEDLINE (1966–syyskuu 2005), the Cochrane Central Register of Controlled Trials (2005), SPORTDiscus, CINAHL (1982–syyskuu 2005) ja PEDro tietokannoista sekä katsausartikkeleiden lähdeluetteloista. Katsaukseen hyväksyttiin satunnaistetut ja kontrolloidut tutkimukset, jotka käsittelivät liikuntavammojen ehkäisyä koskevia interventioita. Kumpikin tutkija suoritti tutkimusten laadun arvioinnin ja tiedon erittelyn itsenäisesti. Tilastolliset analyysit suoritettiin the Cochrane Collaborationin Review Manager -ohjelmalla, versiolla 4.2.8.

Katsaukseen hyväksyttiin 29 tutkimusta, joissa oli yhteensä 22 933 tutkimushenkilöä. Eri liikuntavammojen ehkäisyä koskevien interventioiden vaikutusta arvioitiin alaryhmittäin. Pohjallisten käyttö (3 tutkimusta/775 tutkimushenkilöä) vähensi alaraajavammoja varusmiehillä (OR 0.41; 95 % LV 0.16–1.06). Nilkkatukien käyttö (5/3776) vähensi nilkkavammojen määrää (OR 0.50; 0.32–0.79) ja rannetukien käyttö (2/5750) vähensi rannevammoja (OR 0.25; 0.12–0.51). Myös moni-interventio -ohjelmat (3/2229) olivat tehokkaita liikuntavammojen ehkäisyssä (OR 0.44; 0.28–0.70). Moni-interventio -ohjelmat, joissa osana harjoittelua käytettiin tasapainolautaa (2/400), vähensivät vammojen määrää (OR 0.22; 0.13–0.40), mutta yksinään suoritetun tasapainolautaharjoittelun (4/1799) vaikuttavuus oli heikompi (OR 0.57; 0.25–1.32). Venyttely- ja lämmittelyohjelmat (3/3052) eivät osoittautuneet liikuntavammojen ehkäisyn kannalta vaikuttaviksi (OR 0.99; 0.81–1.23).

Tähän systemaattiseen katsaukseen sisältyvien 29:än satunnaistetun, kontrolloidun tutkimuksen perusteella on näyttöä, että liikuntavammoja voidaan ehkäistä. Pohjalliset, ulkoiset tuet ja moni-interventiot osoittivat liikuntavammoja ehkäisevää vaikutusta, mutta venyttely- ja lämmittely eivät olleet tehokkaita menetelmiä liikuntavammojen ehkäisyssä. Lisätutkimusta ehkäisevistä menetelmistä tarvitaan eri urheilulajien ja eri kohderyhmien osalta.

Asiasanat: liikuntavammat, ehkäisy, interventio, satunnaistettu, kontrolloitu, meta-analyysi

ABSTRACT

Prevention of Sport Injuries. Systematic Review of Randomized Controlled Trials.
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The number of sports injuries has grown because more people participate in sports activities nowadays. At the same time the importance of sports injury prevention has increased. The aim of this systematic review is to summarize the effects of randomized sports injury prevention interventions.

We searched for studies using MEDLINE (1966 to September 2005), the Cochrane Central Register of Controlled Trials (4th quarter 2005), SPORTDiscus, CINAHL (1982 to September 2005) and PEDro databases and reference lists of articles and reviews. We included randomized and quasi-randomized controlled studies investigating the effects of any sports injury prevention intervention. We independently assessed trial quality and extracted data of studies. We performed statistical analyses by the Cochrane Collaboration's Review Manager Software version 4.2.8.

A total of 29 studies with 22 933 participants were included. The effects of different preventive interventions were assessed in subgroups. Insoles (3 studies/775 participants) moderately reduced lower limb injuries in military recruits (pooled OR 0.41; 95% CI 0.16 to 1.06). External ankle supports (5/3776) prevented ankle injuries (OR 0.50; 0.32 to 0.79) and wrist supports (2/5750) reduced wrist injuries (OR 0.25; 0.12 to 0.51). Multi-intervention programs (3/2229) were effective to prevent sports injuries (OR 0.44; 0.28 to 0.70). Preventive programs including balance board training as one component (2/400) reduced injuries (OR 0.22; 0.13 to 0.40), but evidence for preventive effect from trials using balance board training alone (4/1799) is weaker (OR 0.57; 0.25 to 1.32). Stretching and warm-up programs (3/3052) showed no preventive effect (OR 0.99; 0.81 to 1.23).

This systematic review showed evidence from 29 randomized controlled trials (RCTs) that different interventions may prevent sports injuries. There was evidence for that insoles, external supports and training programs with different components prevent injuries, but stretching and warm-up were not effective to reduce sports injuries. More high-quality RCTs in different sports and populations are needed.

Key words: sports injuries, prevention, intervention, randomized, controlled, meta-analysis

CONTENTS

1 INTRODUCTION

Participation in sports and recreational activities has increased in recent years because of positive health and fitness effects (1). As more people participate in sports more injuries will also occur as a side effect. It is estimated from 1997 to 1999 that seven million Americans received medical attention for sports and recreational injuries, incidence being 25.9 injuries per 1000 population (2). Additionally 4.3 million non-fatal sports- and recreation-related injuries were treated during July 2000 through June 2001 in hospital emergency departments within the study area in United States (3). The incidence of treated injuries was 15.4 per 1000 population. These large numbers of sports injuries and high economic costs caused by injuries justifies the importance of the injury prevention (4).

At present many different preventive methods are recommended and applied by sports participants. Several sports injury prevention methods have been studied in randomized and non-randomized studies, but the results of different specific studies have often been inconclusive and sometimes contradictory. The Cochrane Collaboration, among others, recommend the randomized controlled trial (RCT) as the primary acceptable evidence on treatment outcome, because the most reliable findings can be best achieved by using well-planned RCT designs (5). Evidence from RCTs is seriously needed because a significant part of sports injuries can be avoided by the use of effective preventive methods (6).

Some earlier systematic reviews have summarized the effects of specific injury prevention methods based on RCTs and few of them have also included other controlled trials. One wider review of randomized controlled sports injury trials including different preventive methods has been published earlier (7). This review did not include quality assessment of included trials nor pooled effect estimates of different preventive methods.

The aim of this systematic review of published randomized controlled trials is to summarize the effects of sports injury prevention interventions. The effectiveness of different types of prevention methods is presented with the help of pooled odds ratios (ORs).

2 METHODS

2.1 Data sources

Relevant studies were searched using the MEDLINE database (1966 to September 2005), the Cochrane Central Register of Controlled Trials (4^{th} quarter 2005), SPORTDiscus, CINAHL (1982 to September 2005) and the Physiotherapy evidence based database (PEDro). Additionally relevant reviews were searched and assessed from reference lists and retrieved articles for possible information on trials of interest. Keywords in this search were “sports injuries”, “athletic injuries”, “prevention”, “preventive”, “randomized”, “controlled trials” and “randomized controlled trials”. All these terms were combined with each other in different ways.

2.2 Criteria for study selection

To be selected into this review, a study had to investigate the effects of any preventive intervention on sports injuries. Due to abstract it was assessed if the study was potential and based on full article it was decided if the study met inclusion criteria. Studies were included if they were randomized, quasi- or cluster randomized, controlled, and published before October 2005. Additionally the study results had to contain the injury rate or the number of injured subjects as an outcome, the intervention protocol and outcome measures of the studies had to be explicitly described. Studies that most likely were not randomized on the basis of study report and abstracts without full article were excluded from this review.

2.3 Data collection

Two reviewers (H.K and S.A) did data selection together and then extracted the data independently. Information on study design, method and intervention, characteristics of subjects, injury criteria, main outcome and results were extracted from each article. Any disagreements were solved by consensus between the reviewers. If disagreements were not resolved, two supervisors (A.H., U.M.K) were consulted.

2.4 Assessment of methodological quality

The two independent reviewers (H.K and S.A) assessed the methodological quality of the included studies using a criteria list recommended by van Tulder et al. (8). Criteria list is based on Method guidelines for systematic reviews in the Cochrane Collaboration Back Review Group for Spinal Disorders published in 1997. The assessment list consists of 11 criteria: 1.) randomisation, 2.) concealed allocation, 3.) baseline similarity of the study groups, 4.) blinding of subjects, 5.) blinding of care providers, 6.) blinding of assessors, 7.) cointerventions, 8.) compliance, 9.) drop-out rate, 10.) timing of outcome measures, and 11.) intention-to-treat analysis. Every criterion was assessed as “yes”, “no” or “don’t know”. Only “yes” answer scored a point, total score ranging from 0 to 11.

2.5 Data analysis and synthesis

Statistical analyses of the included studies were performed using the Cochrane Collaboration’s Review Manager Software (RevMan), version 4.2.8 (Oxford, England: Cochrane Collaboration). The meta-analysis of dichotomous outcomes was calculated by using a random effect model. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated from independent studies and from subgroups. ORs were calculated by using the same subject rates as were used in analysis of the original studies. Subgroups were combined on the basis of the similarity of preventive methods despite the preventive methods were not always exactly identical and despite other methodological heterogeneity of study designs.

3 RESULTS

A total of 32 potential studies were identified, of these studies 29 met the inclusion criteria and were accepted in this review (Appendix 1). Two of the potential studies (9, 10) were excluded because of missed adequate randomisation and one (11) because it was published after September 2005. Generally most of the included interventions seemed to prevent sports injuries. For the purpose of more precise information about specific intervention methods the studies were analyzed in four subgroups: insoles, external supports, training programs and stretching and warm-up programs. Five included studies could not be pooled because of their unique preventive intervention method or missing information about injured study subjects.

The methodological quality scores of the 29 included studies varied from 1 point to 8 points out of 11 (Appendix 2). A mean score of 3.8 points was indicated as a poor to moderate general methodological quality. From the 29 included studies 19 did not clearly describe the method of randomisation. Only five studies provided sufficient evidence that treatment allocation was adequately concealed. True intention-to-treat analysis was performed in 12 studies.

3.1 Insoles

Five of the included studies (total of 2351 subjects) assessed the effectiveness of different insoles to reduce lower extremity injuries (12–16). In these five studies, the subjects were military recruits. Study of Smith et al. (16) had two different types of insoles and these interventions were assessed as individual studies. Figure 1 shows the effects of four individual interventions and pooled estimate. Three interventions showed to be more effective to prevent sport injuries than in the control groups (15, 16) but one intervention (13) failed to display the preventive effect. As a pooled estimate of different insoles, the risk of getting injured reduced 59 % in the intervention groups (OR 0.41; 95% CI 0.16 to 1.06). Studies of Larsen et al. (12) and Schwellnus et al. (14) could not be pooled, but both study results supported the preventive effect of insoles (RR 0.70; 95% CI 0.50 to 1.10 and RR 0.71; 0.56 to 0.92, respectively).

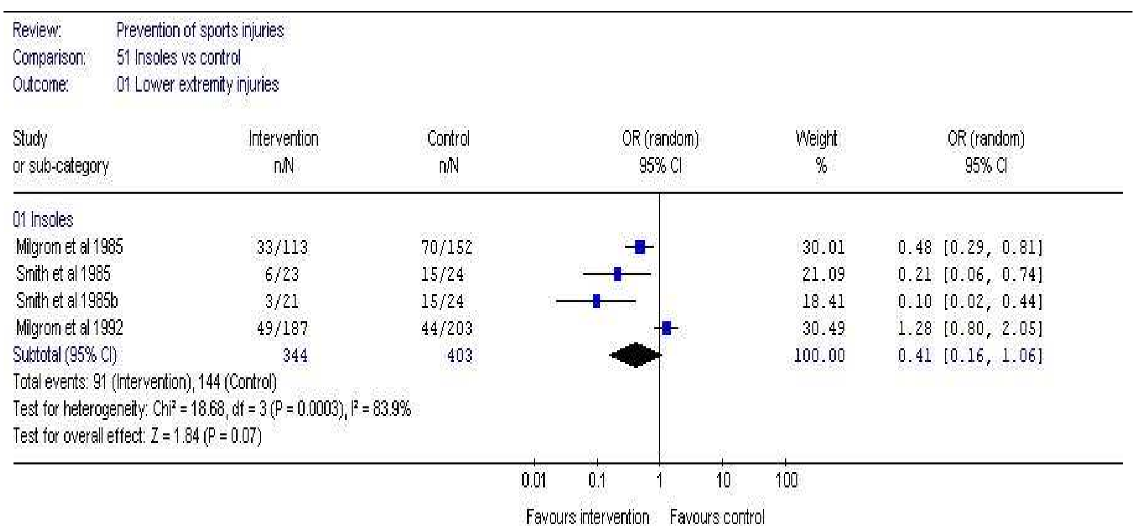

Figure 1 Individual and pooled ORs of insoles

3.2 External supports

In total 3776 subjects used ankle orthosis, braces, stabilizers or special shoes as interventions in five of the included studies (17–21). In study by Barrett et al. (20), two different interventions were analyzed separately. Ankle orthosis (19, 21), ankle stabilizers (18) and outside-the-boot braces (17) markedly reduced ankle injuries. High-top basketball shoes or high-top basketball shoes with air chambers were not able to display preventive effect compared to low-top basketball shoes (20). In spite of contradictory findings, the pooled estimate supported the preventive effect of external ankle supports (OR 0.50; 0.32 to 0.79). (Figure 2.)

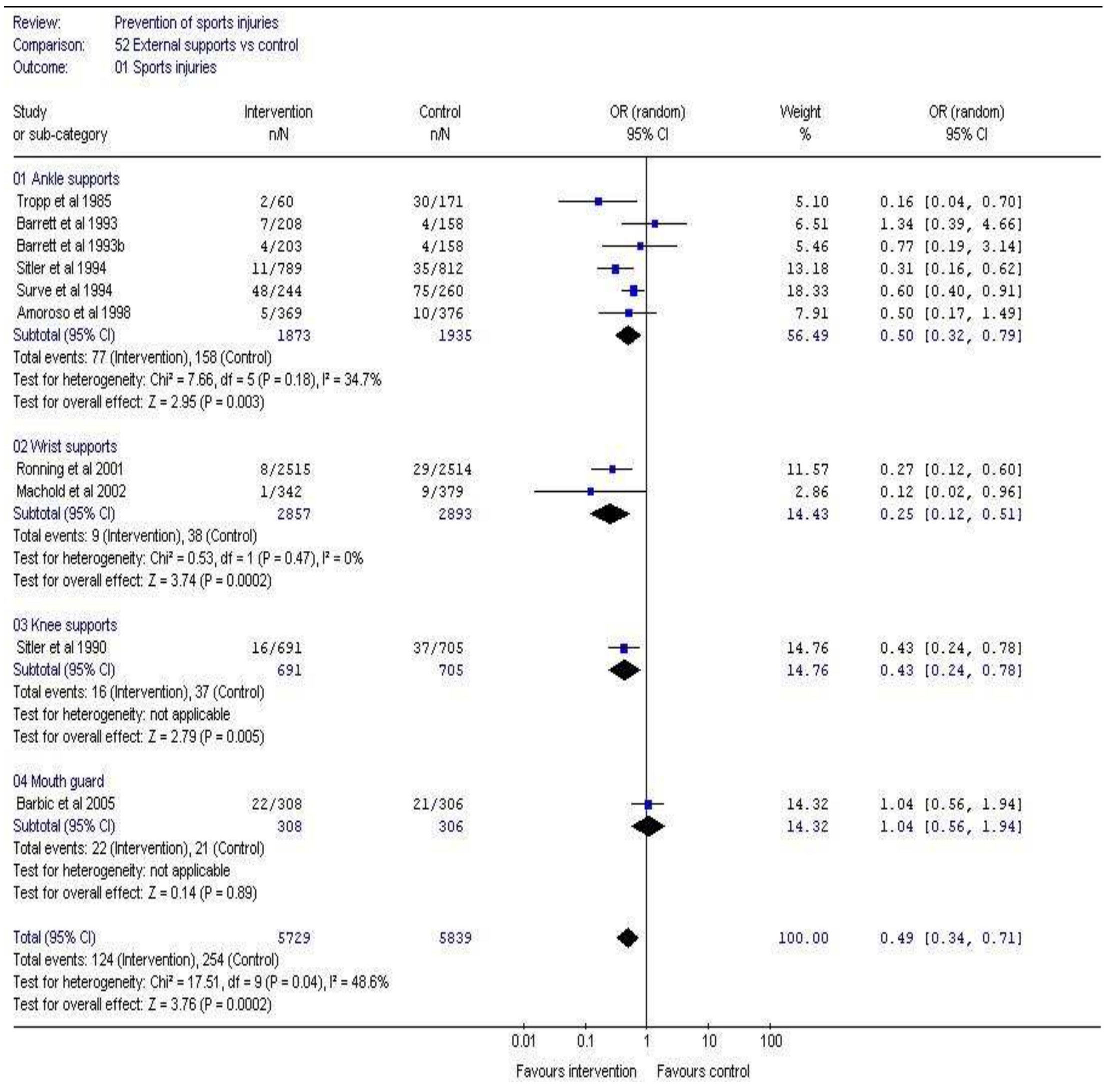

Figure 2 Individual and pooled ORs of external supports

In studies by Machold et al. (22) and Rønning et al. (23), total of 5750 subjects wore wrist protectors while snowboarding. In both these interventions wrist protectors showed similar preventive effect that was associated with markedly reduced number of wrist injuries (OR 0.25; 0.12 to 0.51). The study of Sitler et al. (24), which observed the preventive effect of knee supports on knee injuries among 1396 military cadets while playing football, showed similar preventive results for external supports (OR 0.43; 0.24 to 0.78). The effect of special mouth guard was assessed in study by Barbic et al. (25) in total of 646 university football and rugby players. Observed concussions did not differ between the intervention and control group (OR 1.04; 0.56 to 1.94). (Figure 2.)

The pooled estimate of all evaluated external supports showed to reduce the risk of getting injured by 51 % in the intervention groups (OR 0.49; 0.34 to 0.71). The ORs of all individual external support studies and pooled estimates are given in Figure 2.

3.3 Training programs

Figure 3 reveals the individual and pooled odds ratios of four studies (total of 1799 subjects) for balance board training (21, 26–28). In studies by Tropp et al. (21) and Emery et al. (26) the rate of sports injuries was significantly reduced among intervention subjects but not in studies by Verhagen et al. (27) and Söderman et al. (28). Nevertheless, the pooled estimate favours the use of balance board training but not significantly (OR 0.57; 0.25 to 1.32). Additionally two multi-intervention studies (total of 400 subjects) of Wedderkopp et al. (29, 30) showed a significant reduction (OR 0.22; 0.13 to 0.40) in the number of injuries in the balance board training groups compared to the control groups.

In four studies, multi-intervention prophylactic programs (total of 2409 subjects) were assessed as interventions (31–34). Pooled odds ratio (Figure 3) from three studies (31–33) clearly favours the use of multi-intervention programs (OR 0.44; 0.28 to 0.70). In study by Ekstrand et al. (34), it was not possible to calculate odds ratio because of lack of necessary information. In the original study the authors reported a 75 % reduction of sports injuries, which also supports the preventive effect of multi-intervention programs. The pooled estimate of nine training programs, presented in Figure 3, showed a 59 % reduction in the risk of getting injured in the intervention groups (OR 0.41; 0.24 to 0.69).

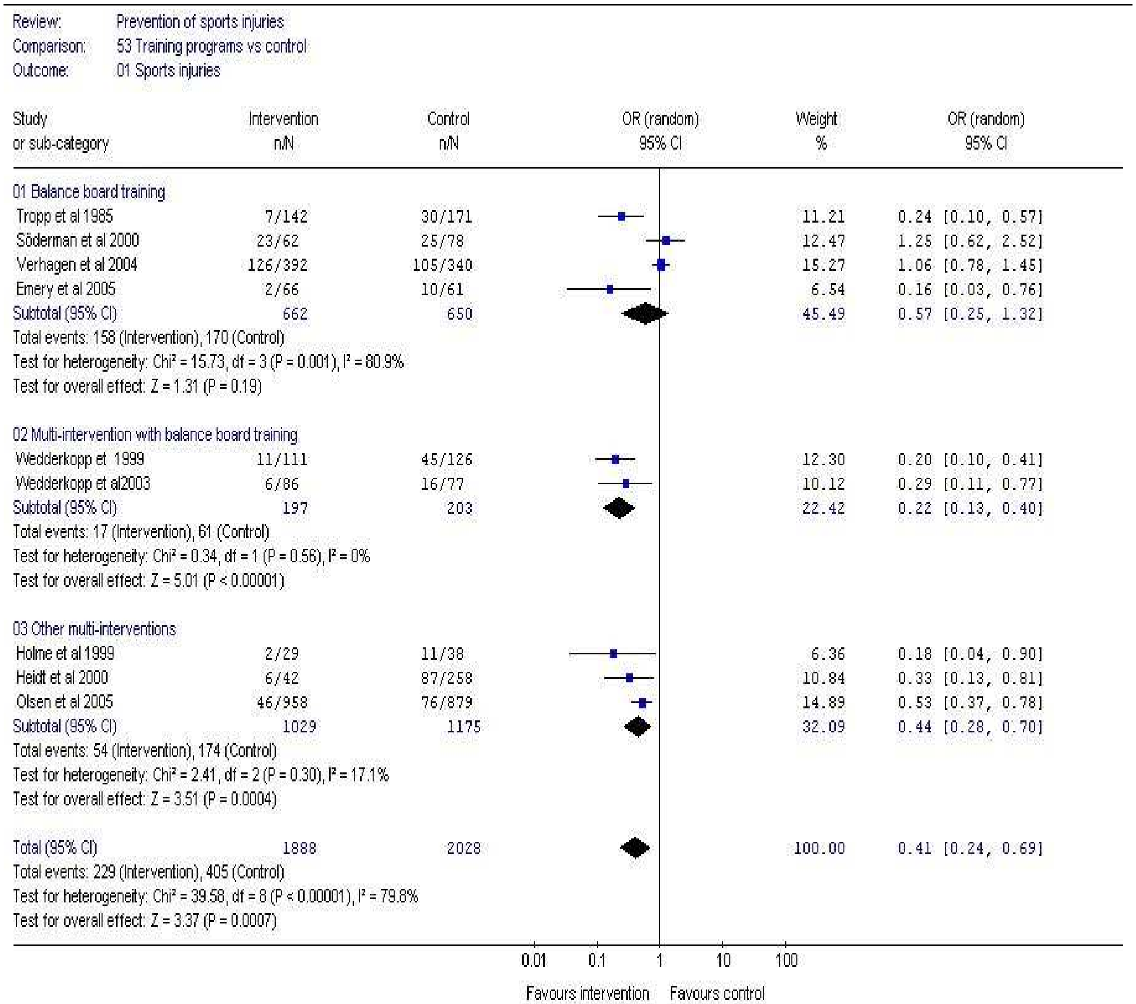

Figure 3 Individual and pooled ORs of training programs

3.4 Stretching and warm-up programs

Three studies (total of 3052 subjects) showed no effects (OR 0.99; 0.81 to 1.23) of stretching and warm-up programs on the rate of lower extremity injuries (35–37). Individual and pooled odds ratios are presented in Figure 4.

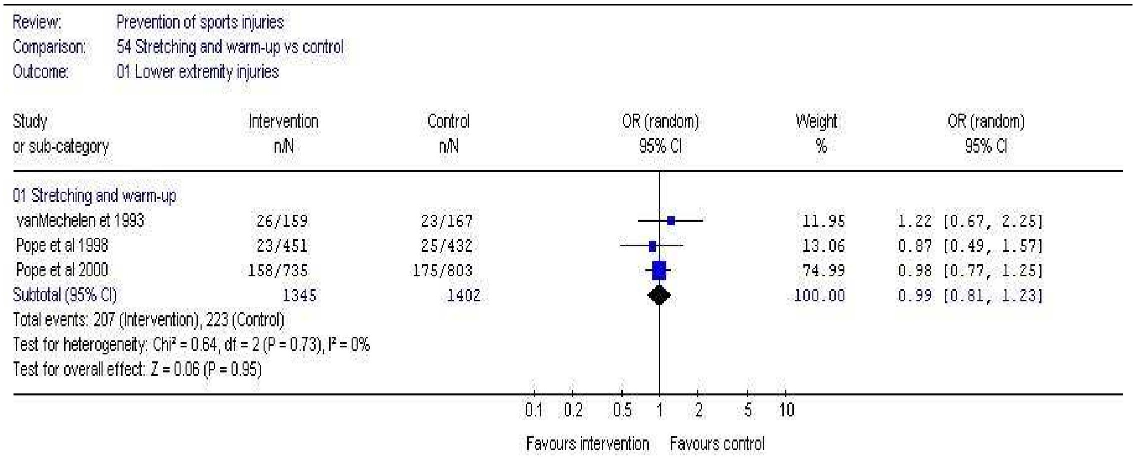

Figure 4 Individual and pooled ORs of stretching and warm-up programs

3.5 Other preventive interventions

In studies by Arnason et al. (38) and Jørgensen et al. (39), a total of 1034 subjects watched an instructional video. The study of Jørgensen et al. (39) showed a reduction in the number of skiing injuries in the intervention group (OR 0.64; 0.43 to 0.96). In the study by Arnason et al. (38), which included also an awareness program added to video, the odds ratio could not be calculated. However, the study did not show the preventive effect of instructional video on sports injuries (RR 1.11; 0.95 to 1.30).

Study of Stasinopoulos (40) compared three different interventions with each other. Study subjects were volleyball players (total of 52 subjects) who were randomized either to technical training program, proprioceptive program or ankle orthosis group. Based on reported ankle injuries during one playing season the author indicated that all programs were effective at reducing the rate of ankle sprains compared to the number of injuries in previous season. The most effective intervention was technical training and the least effective was ankle orthosis.

4 DISCUSSION

Good-quality randomized and controlled studies are considered the most reliable source of scientific evidence. So far there is a limited amount of published RCTs dealing with different preventive methods, but in general most of these study interventions have showed to have a preventive effect on sports injuries. Because many sports participants have only limited resources to pay attention to injury prevention, the recommendations based on RCTs can focus the interest towards preventive methods.

At present many preventive methods are used in the field of sports, although some of these methods lack scientific evidence. Although stretching and warm-up programs did not show preventive effect in this review, it does not mean that they do not have a role within sports and recreational activities.

4.1 Effects of preventive interventions

According to four out of five evaluated studies in this meta-analysis, the use of shock absorbing insoles appears to reduce lower extremity injuries and stress fractures in military recruits. Our results are in line with the findings of Gillespie et al. (41) who concluded that insoles in footwear reduced the incidence of stress fractures in athletes and military personnel. However, opposite results were found in studies of Gardner et al. (9) and Withnall et al. (11), where insoles did not prevent stress fractures in military recruits. Based on epidemiological surveys Jones et al. (42) reviewed that the cumulative incidence of injuries during eight weeks of US Army basic training was about 25% for men and 55% for women. Although recruits usually go through high intensity physical training period, the generalization of findings to athletes is not straightforward. The problem is that usually athletes already have a shock absorbing mechanism in their shoes.

The effectiveness of external supports has been assessed mostly in high risk sporting activities like soccer, American football, basketball, parachute jumping and snowboarding. In five of the assessed studies in this review, the use of external ankle supports provided beneficial protection against traumatic ankle injuries. Non-preventive effect of modified shoes studied by Barrett et al. (20) can probably be explained from a biomechanical aspect. It is understandable, that shoes cannot support the structures of an ankle in the same extent than more rigid orthosis, braces and stabilizers. Similar findings were established in a review of Handoll et al. (43), which included a meta-analysis of the effects of interventions used for the prevention of ankle ligament injuries. Wrist and knee support interventions assessed in this review also showed to confirm the preventive effect of external supports.

Promising findings were found using balance board training program as a preventive strategy. Interventions carried out both in home and in team practices, but the results did not show which one strategy would be more effective. Caraffa et al. (44) conducted a prospective controlled study to assess the effect of a proprioceptive training program including the use of wobble boards in soccer players. This study showed significantly lower incidence of ACL-injuries in the training group compared to controls (0.15 vs. 1.15 injuries per team/season, respectively). Although balance board training has showed to be effective to prevent ankle injuries, there is no reliable evidence that balance board training has a preventive effect on the risk of knee injuries based on this review (27, 28).

All four assessed multi-intervention studies implied that sports-related injuries can be prevented by using different prophylactic programs. It is likely that the preventive effect of these programs is usually the sum of several individual methods. Because of the complexity of study designs, it is almost impossible to clarify which component of the intervention program is the most effective. A prospective controlled study of Hewett et al. (45) evaluated the effect of neuromuscular training in female athletes, and the findings were that a specific three-phase plyometric training program significantly reduced the incidence of knee injuries compared to untrained controls.

The pooled estimate of reviewed stretching and warm-up interventions is consistent with three other reviews (46–48). However, any definitive conclusions of the true effect of stretching cannot be drawn in this review due to lack of good-quality RCTs, and because the role of different stretching protocols should be studied also among other populations than military recruits. A prospective controlled study of Jakobsen et al. (10) investigated the preventive effect of individual training program including stretching, warm-up and cool-down in recreational long-distance runners. In this study the rate of lower limb injuries did not differ between intervention and control groups.

The findings of the two reviewed studies using instructional video as intervention were not consistent (38, 39). In the other reviewed study by Jørgensen et al. (39) a ski-video intervention showed preventive effect to reduce injuries. The study subjects were also downhill skiers in one controlled study by Ettlinger et al. (49), in which the authors observed a reduction in the amount of ACL sprains in the intervention group. Based on these studies of downhill skiing the number of injuries may be reduced by the use of instructional videos.

4.2 Methodological quality

The best methodological quality score given in this review was eight points out of 11. In most sports injury prevention interventions it is almost impossible to score all 11 points, because it is difficult to blind all the three involved parties and to avoid cointerventions. It is possible that in many cases the quality criteria was actually met, but because of inadequate reporting the studies may have scored lower points (50). In general, studies published recently scored higher points than the older ones. This can be explained partially by availability of more precise study reporting instructions.

The criteria list by van Tulder et al. (8) has already been used in various systematic reviews within the Cochrane Collaboration Back Review Group. It includes only the internal validity criteria, which should be used to define methodological quality in the meta-analysis. Few quality criteria proved to be interpretive. We considered intention-to-treat analysis adequate only if it included data from every randomized subject, which is also according to Cochrane Handbook of Systematic Reviews of Interventions 4.2.5 (51). In some original studies the analysis was reported to be based on intention-to-treat principle when it actually included data from subjects who concluded the intervention period. Drop-out rate was considered to be acceptable if it did not exceed 20% for short-term interventions (1–3 months) and 30% for long-term interventions (3 months to 2 years). We considered the compliance to the interventions acceptable when it was about 70% for both study groups. In cases where the rate of compliance was not described numerically, we accepted the compliance if it was explicitly reported and strictly supervised during intervention period. Randomisation of the study subjects was considered adequate only if it was described precisely enough.

4.3 Limitations of this review

Conduction of meta-analysis may have raised a potential risk of problems and biases. This review includes 12 cluster randomized studies. The use of cluster randomisation is practical in study designs, where subjects are a part of a team or an army platoon. In four of these reviewed cluster randomized studies the cluster randomisation was taken into account in statistical analysis by assuming an intracluster correlation. In this review we have included all cluster randomized studies in the meta-analysis. Cluster randomisation may however cause problems in statistical analysis if the outcomes are presented by the individual subject instead of the cluster unit (51). In addition, in three studies included in this review the same control group was compared with two intervention groups. Unfortunately this is not especially recommended, because it may cause unit of analysis problems if the same group of subjects is included twice in the same meta-analysis (51).

We tried to control selection bias by including only randomized and controlled trials in the meta-analysis. Unfortunately this may not be enough to avoid selection bias, because inadequate allocation concealment existed in some of the studies. Blinding of subjects, care providers and outcome assessors is difficult in sports injury prevention interventions, which may have caused performance and detection biases in this meta-analysis. We were not able to avoid either the possibility of attrition bias, because intention-to-treat analysis was not included in all of the included studies. The possibility of publication bias by missing unpublished trials is always an issue of concern that cannot be avoided (50, 51). Because of publication bias, our review may also have provided too positive results.

An important limitation of this review is the general heterogeneity. Different designs and heterogeneity of interventions between studies were potential problems for meta-analysis. Also the follow-up times between 29 included studies varied markedly. These limitations may reduce the generalization of the pooled effects of different preventive interventions.

4.4 Conclusions

This systematic review showed evidence from 29 RCTs that different interventions may have a preventive effect on reducing sports injuries. Although studies of insoles, external supports and training programs indicated evidence for the use of preventive interventions, studies of stretching and warm-up provided non-preventive effect. Based on this review there is still insufficient evidence to draw firm conclusions about the effects of all assessed preventive methods on sports injuries. More high-quality RCTs in different sports and populations are needed to establish more precise implications.

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Table 1 Characteristics of randomized controlled trials included in the review

Authors	Intervention +	Subjects (% male)	Age (y)	No of subjects intervention/ control	Duration	Relative Risk (95% CI)	QS
Insoles							
Larsen et al 2002	Custom-made biomechanic shoe orthosis	Military conscripts (99. 3%)	18–24	77 / 69	3 months	RR 0.70 (0.50, 1.10)	7
Milgrom et al 1985	Shock-absorbing orthotic device	Military recruits (100%)	NR	143 / 152	14 weeks	OR 0.48 (0.29, 0.81)	2
Milgrom et al 1992	Modified basketball shoes	Infantry recruits (100%)	NR	187 / 203	14 weeks	OR 1.28 (0.80, 2.05)	3
Schwellnus et al 1990	Neoprene insoles	Military recruits (NR)	17–25	250 / 1261	9 weeks	RR 0.71 (0.56, 0.92)	3
Smith et al 1985	a) Poron insoles b) Spenco insoles c) Control	Coast guard recruits (both sexes, %NR)	17–25	a) 30 b) 30 c) 30	8 weeks	a) vs c) OR 0.21 (0.06, 0.74) b) vs c) OR 0.10 (0.02, 0.44)	1
External supports							
Amoroso et al 1998	Outside-the-boot braces	Military paratrooper students (100%)	Over 18	369 / 376	1 week	OR 0.50 (0.17, 1.49)	6
Barbic et al 2005 *$	WIPSS Brain-Pad mouth guard	University students (81%)	Mean age 20.9	322 / 324	3 months	OR 1.04 (0.56, 1.94)	4
Barrett et al 1993	a) High-top shoes b) High-top shoes with air chambers c) Low-top shoes	College basketball players (91.7%)	Mean age 20,6	a) 227 b) 212 c) 183	2 months	a) vs c) OR 1.34 (0.39, 4.66) b) vs c) OR 0.77 (0.19, 3.14)	4
Machold et al 2002	Wrist protector	Students (60%)	Mean age 14.8	342 / 379	1 week	OR 0.12 (0.02, 0.96)	5
Rønning et al 2001 $	Wrist protector	Snowboarders (64.2%)	10–68	2515 / 2514	3 months	OR 0.27 (0.12, 0.60)	7
Sitler et al 1990	Prophylactic knee brace	Military academy cadets (NR)	18–21	691 / 705	2 years	OR 0.43 (0.24, 0.78)	4
Sitler et al 1994	Semirigid ankle stabilizer	Military academy cadets (NR)	18–21	789 / 812	2 years	OR 0.31 (0.16, 0.62)	3
Surve et al 1994	Sport-Stirrup ankle orthosis	Senior soccer players (100%)	NR	244 / 260	1 playing season	OR 0.60 (0.40, 0.91)	3
Tropp et al 1985 *	a) Ankle orthosis b) Ankle disk training c) Control	Senior soccer players (100%)	NR	a) 124 b) 144 c) 180	6 months	a) vs c) OR 0.16 (0.04, 0.70) b) vs c) OR 0.24 (0.10, 0.57)	2
Training programs							
Ekstrand et al 1983 *	Prophylactic program	Senior soccer players (100%)	17–37	90 / 90	6 months	-	2
Emery et al 2005 *	Home-based balance-training program	Physical education students (50%)	14–19	66 / 61	6 months	OR 0.16 (0.03, 0.76)	6
Heidt et al 2000	Preseason training program	Soccer players (0%)	14–18	42 / 258	12 months	OR 0.33 (0.13, 0.81)	3
Holme et al 1999	Rehabilitation program	Recreational athletes (62%)	21–32	46 / 46	12 months	OR 0.18 (0.04, 0.90)	2
Olsen et al 2005 *	Structured warm-up program	Handball players (13.7%)	15–17	958 / 879	8 months	OR 0.53 (0.37, 0.78)	8

APPENDIX 1

Authors	Intervention	Subjects (% male)	Age (y)	No of subjects intervention/ control	Duration	Relative Risk (95% CI)	QS
Training programs							
Pope et al 1998 * #	Pre-exercise calf muscle stretching	Army recruits (100%)	17–35	549 / 544	12 weeks	OR 0.87 (0.49, 1.57)	5
Pope et al 2000 * #	Lower extremity stretching program	Army recruits (100%)	17–35	735 / 803	12 weeks	OR 0.98 (0.77, 1.25)	5
Söderman et al 2000 *	Balance board training program	Soccer players (0%)	15–25	121 / 100	7 months	OR 1.25 (0.62, 2.52)	2
Tropp et al 1985 *	a) Ankle orthosis b) Ankle disk training c) Control	Senior soccer players (100%)	NR	a) 124 b) 144 c) 180	6 months	a) vs c) OR 0.16 (0.04, 0.70) b) vs c) OR 0.24 (0.10, 0.57)	2
Van Mechelen et al 1993	Warm-up, cool-down and stretching program	Recreational runners (100%)	NR	210 / 211	16 weeks	OR 1.22 (0.67, 2.25)	2
Verhagen et al 2004 *	Balance board training program	Volleyball players (42.9 %)	21–27	641 / 486	36 weeks	OR 1.06 (0.78, 1.45)	4
Wedderkopp et al 1999 *	Ankle disc and functional warm-up training	Handball players (0%)	16–18	111 / 126	10 months	OR 0.20 (0.10, 0.41)	3
Wedderkopp et al 2003 *	Ankle disk and functional strength training	Handball players (0%)	14–16	86 / 77	9 months	OR 0.29 (0.11, 0.77)	4
Other interventions							
Arnason et al 2005 *	Video-based awareness program	Soccer players (100%)	NR	127 / 144	5 months	RR 1.11 (0.95, 1.30)	3
Jørgensen et al 1998	Instructional ski-video	Downhill skiers (58%)	5–61	243 / 520	1 week	OR 0.64 (0.43, 0.96)	3
Stasinopoulos 2004	a) Technical training program b) Proprioceptive program c) Ankle orthosis	Volleyball players (0%)	20–26	a) 18 b) 17 c) 17	1 season	-	3

+ = if not mentioned, comparison is made with control group which has not participated in any intervention
(y) = years
(95% CI) = confidence intervals
QS = quality score
* = cluster randomized
- = calculation of relative risk not possible
NR = not reported
# = quasi-randomized
$ = block randomized

Table 2 Methodological quality assessment of included studies

AUTHOR et al. / year	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**TOT**
EKSTRAND et al./1983	DK	DK	DK	DK	DK	DK	DK	YES	DK	YES	DK	**2**
MILGROM et al./1985	DK	DK	DK	DK	DK	DK	DK	DK	YES	YES	NO	**2**
SMITH et al./1985	DK	DK	DK	DK	DK	DK	DK	DK	NO	YES	NO	**1**
TROPP et al./1985	DK	DK	DK	DK	DK	DK	DK	DK	YES	YES	NO	**2**
SCHWELLNUS et al./1990	DK	DK	DK	DK	DK	DK	DK	YES	YES	YES	DK	**3**
SITLER et al./1990	YES	DK	YES	DK	DK	DK	DK	YES	DK	YES	DK	**4**
MILGROM et al./1992	DK	DK	DK	DK	DK	DK	DK	YES	DK	YES	YES	**3**
BARRETT et al./1993	YES	DK	YES	DK	DK	DK	DK	DK	YES	YES	NO	**4**
VAN MECHELEN et al./1993	DK	DK	YES	DK	DK	DK	DK	NO	NO	YES	NO	**2**
SITLER et al./1994	DK	DK	YES	DK	DK	DK	DK	YES	DK	YES	DK	**3**
SURVE et al./1994	DK	DK	DK	DK	DK	DK	DK	YES	DK	YES	YES	**3**
AMOROSO et al./1998	YES	DK	YES	DK	DK	YES	DK	YES	YES	YES	NO	**6**
JØRGENSEN et al./1998	DK	DK	YES	DK	DK	DK	DK	DK	DK	YES	YES	**3**
POPE et al./1998	DK	YES	DK	YES	DK	DK	DK	YES	YES	YES	DK	**5**
HOLME et al./1999	YES	DK	NO	DK	DK	DK	DK	DK	NO	YES	NO	**2**
WEDDERKOPP et al./1999	DK	DK	DK	DK	DK	DK	DK	YES	DK	YES	YES	**3**
HEIDT et al./2000	DK	DK	DK	DK	DK	YES	DK	DK	DK	YES	YES	**3**
POPE et al./2000	DK	YES	DK	DK	DK	YES	DK	YES	NO	YES	YES	**5**
SÖDERMAN et al./2000	DK	DK	YES	DK	DK	DK	DK	NO	NO	YES	NO	**2**
RØNNING et al./2001	YES	DK	YES	DK	DK	YES	DK	YES	YES	YES	YES	**7**
LARSEN et al./2002	YES	YES	DK	DK	YES	DK	DK	YES	YES	YES	YES	**7**
MACHOLD et al. /2002	YES	DK	YES	DK	DK	DK	DK	YES	DK	YES	YES	**5**
WEDDERKOPP et al./2003	DK	DK	DK	DK	DK	DK	DK	YES	YES	YES	YES	**4**
STASINOPOULOS /2004	YES	DK	DK	DK	DK	DK	DK	NO	DK	YES	YES	**3**
VERHAGEN et al./2004	DK	DK	YES	DK	DK	YES	DK	YES	NO	YES	DK	**4**
ARNASON et al./2005	DK	DK	DK	DK	DK	DK	DK	YES	YES	YES	NO	**3**
BARBIC et al./2005	DK	DK	YES	NO	NO	NO	DK	YES	YES	YES	NO	**4**
EMERY et al/2005	YES	YES	YES	DK	DK	DK	DK	YES	YES	YES	DK	**6**
OLSEN et al./2005	YES	YES	YES	DK	DK	YES	NO	YES	YES	YES	YES	**8**

A=adequate randomisation (yes=random assignment was made by using computer generated random number table, sealed opaque envelopes or other clearly described and acceptable random assignment method)
B=concealed allocation (yes=assignment was made by independent person, who had no information about study subjects)

C=groups similarity at baseline (yes=study groups were similar or comparable at baseline regarding demographic factors and other important prognostic factors)
D=study population blinding (yes=study population blinding was clearly described and acceptable)
E=care provider blinding (yes=medical staff or care providers involved in the study were blinded regarding the group assignment)
F=outcome assessor blinding (yes=doctors, radiologists, physiotherapist or other nursing staff who evaluated the injuries were blinded regarding the group assignment)
G=avoided or similar cointerventions (yes=all confounding cointerventions were either avoided or similar between study groups)
H=acceptable compliance (yes=compliance was regularly checked or otherwise strictly supervised by someone else than study subjects, and it was more than 70% in every study group)
I=described and acceptable drop-out rate (yes=drop-out rate was less than 20% for short-term follow-up (0–3 months) and less than 30% for long-term follow-up (3–24 months). drop-out reasons were given)
J=similar timing of the outcome assessment (yes=duration of the intervention was similar for all study groups)
K=intention-to-treat analysis (yes=intention-to-treat analysis was acceptable if all randomly assigned study subjects were included in analysis)
YES=criteria was described and acceptable (1 point)
NO=criteria was not acceptable (0 point)
DK=don't know; criteria was unclear or not described (0 point)
TOT=total points of quality assessment, max. 11 points