The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials

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ABSTRACT

Background Physical activity is important in both prevention and treatment of many common diseases, but sports injuries can pose serious problems.

Objective To determine whether physical activity exercises can reduce sports injuries and perform stratified analyses of strength training, stretching, proprioception and combinations of these, and provide separate acute and overuse injury estimates.

Material and methods PubMed, EMBASE, Web of Science and SPORTDiscus were searched and yielded 3462 results. Two independent authors selected relevant randomised, controlled trials and quality assessments were conducted by all authors of this paper using the Cochrane collaboration domain-based quality assessment tool. Twelve studies that neglected to account for clustering effects were adjusted. Quantitative analyses were performed in STATA V.12 and sensitivity analysed by intention-to-treat. Heterogeneity (I^2) and publication bias (Harbord's small-study effects) were formally tested.

Results 25 trials, including 26 610 participants with 3464 injuries, were analysed. The overall effect estimate on injury prevention was heterogeneous. Stratified exposure analyses proved no beneficial effect for stretching (RR 0.963 (0.846–1.095)), whereas studies with multiple exposures (RR 0.655 (0.520–0.826)), proprioception training (RR 0.550 (0.347–0.869)), and strength training (RR 0.315 (0.207–0.480)) showed a tendency towards increasing effect. Both acute injuries (RR 0.647 (0.502–0.836)) and overuse injuries (RR 0.527 (0.373–0.746)) could be reduced by physical activity programmes. Intention-to-treat sensitivity analyses consistently revealed even more robust effect estimates.

Conclusions Despite a few outlying studies, consistently favourable estimates were obtained for all injury prevention measures except for stretching. Strength training reduced sports injuries to less than 1/3 and overuse injuries could be almost halved.

INTRODUCTION

Increasing evidence exists, for all age groups, that physical activity is important in both prevention and treatment of some of the most sizable conditions of our time,[1–3] including cardiovascular disease, diabetes, cancer, hypertension, obesity, osteoporosis, and depression. Although overall population levels of physical activity is a general concern, increasing levels of leisure time physical activity and sports participation have been reported in some population groups.[4] Injuries are virtually the sole drawback of exercise, but may be a common consequence of physical activity and have been shown to pose substantial problems.[5–7] Management of sports injuries is difficult, time-consuming and expensive, both for the society and for the individual.[8–10] However, sports injury prevention by different kinds of strength training, proprioception exercises, stretching activities, and combinations of these, is accessible to essentially everyone and requires limited medical staff assistance. This adds several interesting aspects regarding the potential dispersion, applicability, and compliance to these programmes.

Most studies on musculoskeletal injuries have focused on one particular intervention, injury type/location, sport or studied other relatively narrowly defined research questions. This applies to most reviews and meta-analyses as well.[11–18] However, Parkkari *et al*[19] described 16 controlled trials in a narrative review. Central concepts of sports injury prevention such as extrinsic (including exposures, environment, equipment) and intrinsic (including physical characteristics, fitness, ability, age, gender, psychology) risk factors and the 'sequence of prevention' model of van Mechelen[20] were summarised. Aaltonen *et al*[21] presented an overview of all sports injury prevention measures, but as in the literature up until their search in January 2006, the focus of this review was primarily on extrinsic risk factors.[22] Recently, and with less restrictive exclusion criteria, Schiff *et al*[23] covered the same topic with additional studies. Aaltonen *et al* and Schiff *et al* were unable to obtain full quantification of intervention effect estimates. Steffen *et al*[24] presented a narrative review of acute sports injury prevention written by field experts for each location of injury, but an examination and quantification of specific training exposures and a differentiation of acute and overuse outcome effect estimates is still lacking.

This review and meta-analysis will broaden the scope of previous reviews and meta-analyses on sports injury prevention and focus on the preventive effect of several different forms of physical activity programmes and complement the existing summative literature on extrinsic risk factor reduction. Valuable summary literature exists for both neuromuscular proprioception[14 15] and stretching exercises.[17 18] However, aggregation of effect estimates and comparison with the effect of strength training and an intervention group with multiple exposures (combining ex strength, proprioception, stretch etc) could reveal new and interesting information, enabling proposals for future directions in the field of sports injury prevention. This study consequently aimed at performing stratified analyses of different injury prevention exercise programmes and additionally provides separate effect estimates for acute and overuse injuries.

MATERIAL AND METHODS

Search strategy and study selection

A review protocol was composed, comprising a priori specification of analyses, inclusion/exclusion criteria, injury definition and search strategy. Injury was defined according to the F-MARC consensus statement for football, merely broadened to fit all forms of physical activity.[25] See online supplements eMethods1–3 and eFigure 1 for full injury definition, detailed search entries, study selection description and flow chart. PubMed, EMBASE, Web of Science and SPORTDiscus databases were searched to October 2012 with no publication date restrictions. The search was performed by four blocks of keywords related to prevention, injury and diagnoses, sports, and randomised controlled trials. The searches were customised to accommodate the layout and search methods of each search engine and the application of additional free text words were based on the coverage of subject terms. Reference lists of retrieved articles were hand searched for trials of potential interest and the search was later updated to January 2013.

Search results yielded 3462 hits, which were screened by title to yield 90 titles. After exclusion by abstract, 40 were read in full text and 22 were included. Another three studies were included from reference lists and updated search. Study selection followed a priori-specified inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
▶ Primary prevention	▶ Influencing pathology
▶ Free of injury at inclusion	▶ Surrogate measures of injury
▶ Sports/physical activity injuries	▶ Any use of devices (kinesiotaping, insoles, etc)
▶ Randomised controlled trials	▶ Any means of transportation (bicycles, motor driven, skies, equestrian, etc)
▶ Appropriate intervention/control arms	▶ Inadequate follow-up
▶ Conducted in humans	
▶ Reported in English	
▶ Peer-reviewed publications	

Two reviewers (JBL and DMB) independently assessed the eligibility criteria with subsequent consensus by discussion. If unanimous consensus could not be reached, this was arbitrated by a third person (LBA).

In total, 25 studies were included.[26–50]

Data extraction

All included studies were assessed using the domain-based evaluation tool recommended by the Cochrane collaboration.[51] Two reviewers (JBL and DMB) independently collected the support for judgement and final judgements required consensus from all authors of this paper. If reporting was inadequate or unclear, efforts were made to contact the corresponding authors and ask by 'open questions' in order to reduce the risk of overly positive answers. Weighting of studies by quality assessment was considered but not performed, as such appraisals would inevitably involve subjective decisions and no evidence in support of this approach exists.[51]

Data extraction for total estimate and exposure subgroup estimates covered the primary outcome, defined by each study. Injuries were classified as acute or overuse according to definitions used by each study and proprioception was defined as exercises aiming at improving joint proprioception and/or joint stability. For the outcome subgroups, acute and overuse injuries, we additionally extracted appropriate secondary data from studies where information was available in order to optimise the power of these analyses. Overlapping entities were omitted so no injury was analysed more than once.

The stratification of studies into less heterogeneous exposure subgroups was, with the exception of Beijsterveldt *et al*,[27] performed after completion of the literature search. Beijsterveldt *et al* was added from the updated literature search and was unambiguously fitted into the multiple exposures group.

As compliance plays a central role in the robustness of results, sensitivity analyses without studies that neglected to analyse by intention-to-treat were conducted.

During the iterative process of hypothesis generation and preliminary searches the prespecified eligibility criteria were elaborated but not changed. All a priori-specified analyses were performed as planned.

Statistics

Whenever possible, only first-time injuries were taken into account as repeated outcomes are likely to be dependent of each other and therefore would introduce bias. Most studies have analysed by calculation of either RR, injury rate RR or Cox regression RR. When no appropriate effect estimates were reported or studies neglected to adjust for clustering effects, we adjusted for clustering effects and calculated a RR. Twelve included studies were not originally adjusted for cluster randomisation. As individuals in clusters potentially lack independence of each other, a regulation of sample size calculations is often required. The equation for cluster adjustment is

$$IF = 1 + (n-1)\rho$$

where ρ is the intracluster correlation coefficient, n the average cluster size and IF the inflation factor. Effective sample size is calculated by dividing sample size with IF.[52] The intracluster correlation coefficient was calculated by

$$\rho = s_c^2/(s_c^2 + s_w^2)$$

where s_w^2 is the within cluster variance of observations taken from individuals in the same cluster and s_c^2 the variance of true cluster means.[53] In the nine studies where the corresponding authors did not provide us with sufficient data for ρ calculation, we achieved this by calculating an average intracluster correlation coefficient based on p values from studies, which were appropriately adjusted for clustering effects.

In order to address reporting bias formally, we sought to test all analyses by the Harbord small-study effect test with a modified Galbraith plot.[54] This follows the recommendations by the Cochrane handbook for systematic reviews of interventions and is available in STATA V.12.[51 55] Effective sample sizes for intervention and control group populations were used for the required binary data input to achieve a cluster-adjusted result for this test.

The heterogeneity for all analyses was assessed by I^2 and the χ^2 (Q) p value. I^2 is calculated from the Stata given Q value and number of studies (n) by

$$I^2 = \frac{Q-(n-1)}{Q}$$

A rough interpretation guide of I^2 has been proposed by Higgins *et al*.[51]

All analyses were computed in STATA V.12 by user-written commands described by Egger *et al*[56] The random effects model was used for the weighting of studies. Statistically heterogeneous

estimates were graphically explored by the metainf command, displaying the influence of each individual study on the effect estimate. These analyses did not reveal conclusive information of particular studies primarily causing the heterogeneity and will not be reported throughout this article.

RESULTS

Study characteristics

Table 1 summarises the characteristics of 25 included studies. A full study characteristics table is available in the online supplements eTable 2. In total 26 610 individuals were included in the analysis and effect estimates were based on 3464 injuries. Thirteen studies were performed on adult participants, 11 studies on adolescents and one study included both.

We contacted nine authors and four supplied clarifying answers with subsequent change in their data or quality assessment. For detailed quality assessments and quality assessment summary see online supplementary eMethods 4, eTable 1 and eFigure 2.

Total estimate

The total effect estimate was RR 0.632 (95% CI 0.533 to 0.750, I^2=70% with a χ^2 p<0.001). Brushoj *et al*,[28] Eils *et al*,[30] Gilchrist *et al*,[34] Holmich *et al*[36] and Soderman *et al*[46] did not report intention-to-treat data. When performing a sensitivity analysis on the 20 studies with intention-to-treat data, an estimate of RR 0.608 (0.503–0.736, I^2=74%, χ^2 p<0.001) was found. A post hoc analysis stratified for age showed RR 0.577 (0.453–0.736, I^2=68%, χ^2 p<0.001) for adolescents and RR 0.683 (0.526–0.885, I^2=72%, p<0.001) for adults (figure 1).

Table 1 Study characteristics summary

Study	Intervention	Population	Completion	Follow-up	Injuries	Primary out
Askling *et al*[26]	Strength	Soccer, male, elite	Intervention 15 Control 15	10 weeks + 1 season	Intervention 3 Control 10	Hamstring injury
Beijsterveldt *et al*[27]	Multi	Soccer, 18–40, male amateur	Intervention 223 Control 233	9 months	Intervention 135 Control 139	All injuries
Brushoj *et al*[28]	Multi	Conscripts, 19–26 years	Intervention 487 Control 490	12 weeks	Intervention 50 Control 48	Overuse knee injury
Coppack *et al*[29]	Strength	Recruits, 17–30 years	Intervention 759 Control 743	14 weeks	Intervention 10 Control 36	Overuse ant. knee pain
Eils *et al*[30]	Proprioception	Basketball, 1st–7th league	Intervention 81 Control 91	1 season	Intervention 7 Control 21	Ankle injury
Emery *et al*[31]	Proprioception	Students, 14–19 years	Intervention 60 Control 54	6 weeks + 6 months	Intervention 2 Control 10	All injuries
Emery and Meeuwisse[32]	Multi	Soccer, 13–18 years	Intervention 380 Control 364	1 year	Intervention 50 Control 79	All injuries
Emery *et al*[33]	Proprioception	Basketball, 12–18 years	Intervention 494 Control 426	1 year	Intervention 130 Control 141	All injuries
Gilchrist *et al*[34]	Multi	Soccer, collegiate	Intervention 583 Control 852	12 weeks	Intervention 2 Control 10	Non-contact ACL
Heidt *et al*[35]	Proprioception	H. school, female, soccer	Intervention 42 Control 258	1 year	Intervention 6 Control 87	All injuries
Holmich *et al*[36]	Multi	Football, 2nd–5th level	Intervention 477 Control 430	42 weeks	Intervention 23 Control 30	Groin injuries
Jamtvedt *et al*[37]	Stretch	Internet, >18 years	Intervention 1079 Control 1046	12 weeks	Intervention 339 Control 348	Lower limb + trunk injury
LaBella *et al*[38]	Multi	Athletes, female	Intervention 737 Control 755	1 season	Intervention 50 Control 96	Lower extremity injury
Longo *et al*[39]	Multi	Basketball, male	Intervention 80 Control 41	9 months	Intervention 14 Control 17	All injuries
McGuine and Keene[40]	Proprioception	Basketball, adolescent	Intervention 373 Control 392	4 weeks + 1 season	Intervention 23 Control 39	Ankle sprain
Olsen *et al*[41]	Multi	Handball, 15–17 years	Intervention 958 Control 879	8 months	Intervention 48 Control 81	Knee and ankle injury
Pasanen *et al*[42]	Multi	Floorball, female, elite	Intervention 256 Control 201	6 months	Intervention 20 Control 52	Non-contact injuries
Petersen *et al*[43]	Strength	Soccer, male, elite	Intervention 461 Control 481	12 months	Intervention 12 Control 32	Hamstring injuries
Pope *et al*[44]	Stretch	Recruits, 17–35 years	Intervention 549 Control 544	12 weeks	Intervention 23 Control 25	4 specific LE injuries
Pope *et al* 2000[45]	Stretch	Recruits, male	Intervention 666 Control 702	12 weeks	Intervention 158 Control 175	Lower limb injuries
Soderman *et al*[46]	Proprioception	Soccer, female, elite	Intervention 62 Control 78	7 months	Intervention 28 Control 31	Lower extremity injury
Soligard *et al*[47]	Multi	Football, 13–17, female	Intervention 1055 Control 837	8 months	Intervention 121 Control 143	Lower extremity injury
Steffen *et al*[48]	Multi	Soccer, female	Intervention 1073 Control 947	8 weeks + 1 season	Intervention 242 Control 241	All injuries
Walden *et al*[49]	Strength	Soccer, 12–17, female	Intervention 2479 Control 2085	7 months	Intervention 7 Control 14	ACL injuries
Wedderkopp *et al*[50]	Proprioception	Handball, 16–18, female	Intervention 111 Control 126	10 months	Intervention 11 Control 45	All injuries

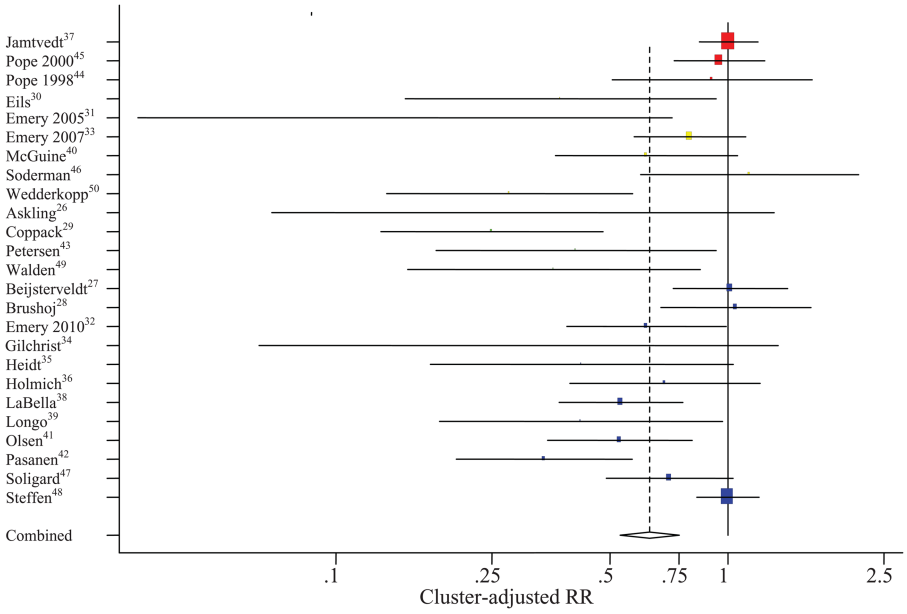

Figure 1 Total estimate Forest plot. Stretching studies are denoted by red, proprioception exercises yellow, strength training green, and multiple component studies blue.

Stratified exposure analyses

The strength training estimate including four studies was RR 0.315 (0.207–0.480, I^2=0%, χ^2 p=0.808). All studies in the strength training group were analysed by intention-to-treat. For stratified exposure Forest plots see online supplementary eFigure 4–7.

The pooled effect estimate for six studies with proprioception training as the primary exposure showed a RR of 0.550 (0.347–0.869, I^2=66%, χ^2 p=0.012). Sensitivity analysis of intention-to-treat ruled out Eils *et al*[30] and Soderman *et al*[46] and revealed RR 0.480 (0.268–0.862, I^2=71%, χ^2 p=0.017).

Unlike the above two exposures, the overall estimate for stretching did not prove significant with RR 0.963 (0.846–1.095, I^2=0%, χ^2 p=0.975) based on three studies. All studies in the stretching group were analysed by intention-to-treat.

The combined effect estimate for the 12 studies with multiple exposure interventions revealed a RR of 0.655 (0.520–0.826, I^2=69%, χ^2 p<0.001). Sensitivity analysis of intention-to-treat excluded Brushoj *et al*[28] Gilchrist *et al*[34] and Holmich *et al*[36] and revealed RR 0.625 (0.477–0.820, I^2=75%, χ^2 p<0.001; figure 2).

Stratified outcome analyses

On the basis of primary or secondary data from nine studies, the RR for all types of exposures against acute injury was 0.647 (0.502–0.836, I^2=73%, χ^2 p<0.001). One study had strength training as exposure, two studies did proprioception training and the remaining six studies were from the group of multiple exposure studies. Sensitivity analysis of eight intention-to-treat analysed studies (Soderman *et al*[46] was excluded) showed a RR 0.615 (0.470–0.803, I^2=75%, χ^2 p<0.001).

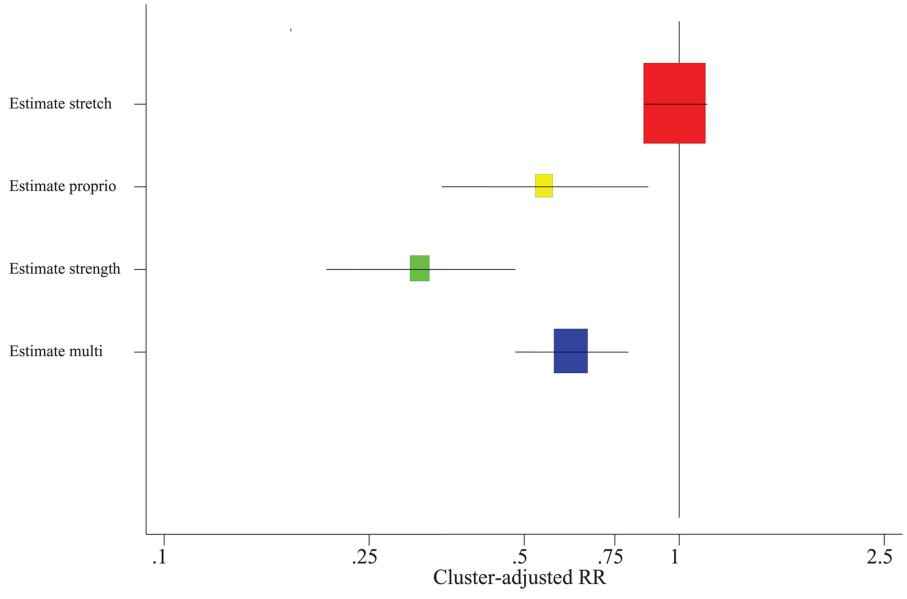

Figure 2 Exposure estimates Forest plot. Stretching studies are denoted by red, proprioception exercises yellow, strength training green, and multiple component studies blue.

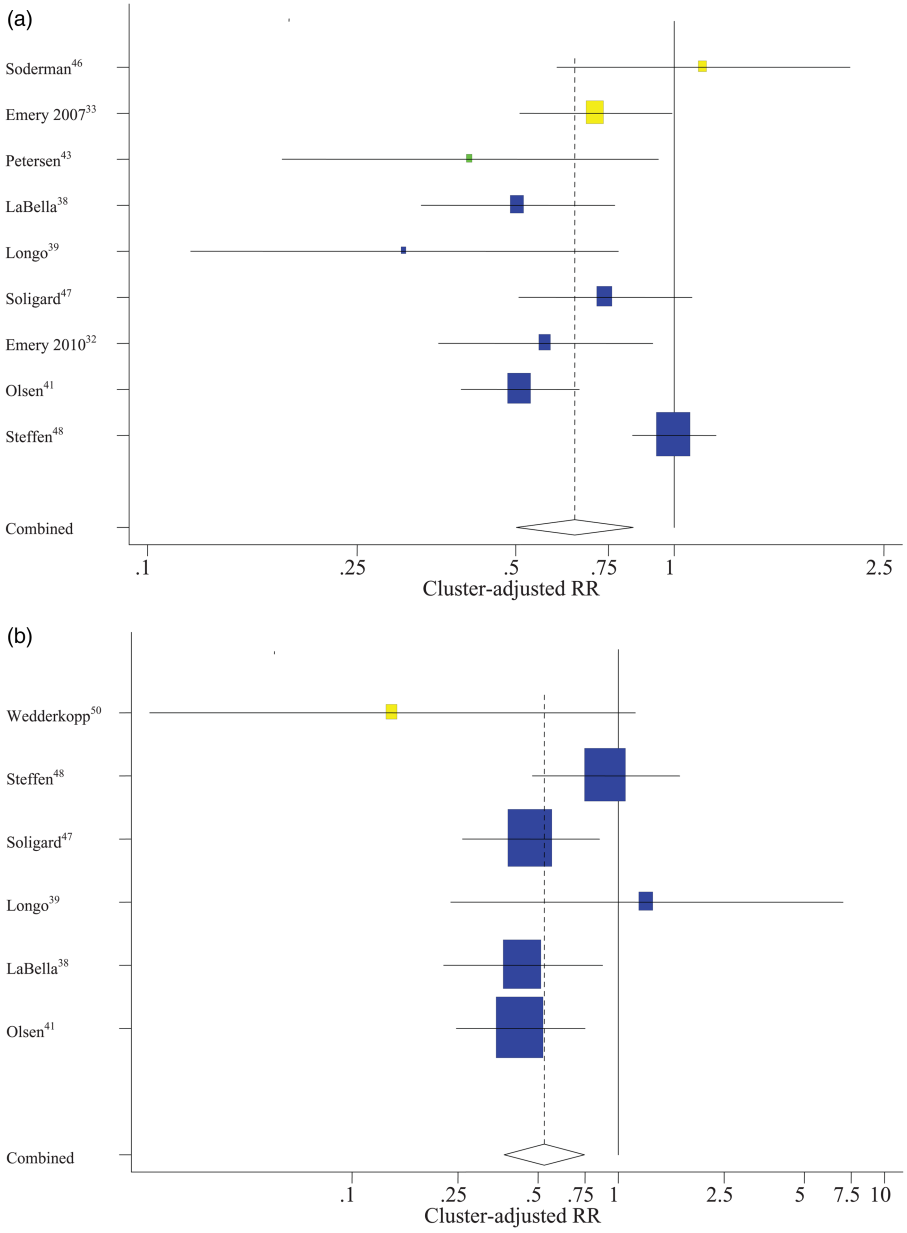

Figure 3 (A) Acute outcomes estimate Forest plot. Proprioception studies are denoted by yellow, strength training green, and multiple component studies blue. (B) Overuse outcomes estimate Forest plot. Proprioception studies are denoted by yellow and multiple component studies blue.

Six studies provided data on overuse injuries. RR from these six studies was 0.527 (0.373–0.746, I^2=19%, χ^2 p=0.287). All studies in this analysis, except one proprioception training study, were multiple exposure studies. All analysed studies reported intention-to-treat data (figure 3A,B).

Small-study effect

The Harbord test for the total estimate of all 25 studies showed a highly significant small-study effect test. Exposure and outcome subgroups revealed significant test for only the multiple exposures group. See online supplementary eFigure 7 for modified-Galbraith plot and online supplementary eTable 3 for Harbord tests.

DISCUSSION

An overall RR estimate for physical activity for injury prevention, adjusted for clustering effects, was 0.632 (0.532–0.750), and slightly lower when sensitivity analysed by intention-to-treat (RR 0.607 (0.501–0.735)). A preventive effect of this size should be considered convincing, but the analysis was heterogeneous and the result is, therefore, clinically useless. However, it also suggests that some types of interventions may prove better than others.

Stretching did not show any protective effect (RR=0.961 (0.836–1.106)), while strength training proved highly significant (RR 0.315 (0.207–0.480)). Results from stretching and strength training studies were not heterogeneous despite different programmes were used and outcomes of interest were different. This points towards a strong generalisability of results. Proprioception training and multiple exposure programmes were also effective (RR=0.480 (0.266–0.864) and 0.625 (0.477–0.820), respectively), but results were relatively heterogeneous.

The effect estimate of stretching and proprioception training analyses in this article corresponds to earlier reviews.[14 15 17 18] Our data do not support the use of stretching for injury prevention purposes, neither before or after exercise, however it

should be noted that this analysis only included two studies on army recruits and one internet-based study on the general population. Strength training showed a trend towards better preventive effect than proprioception training and proved significantly better than multiple exposure studies, even though all multiple exposure studies included a strength training component. Further research of strength training for a wider range of injuries is still needed, as our analyses suggest great sports injury prevention potential for this type of intervention. With a growing number of randomised controlled trials containing numerous exposure types, it was of interest to assess intervention studies with multiple exposures separately, although, as expected, still being a heterogeneous subgroup. Though it makes intuitive sense to design an array of exposures for prevention of all injuries, it is important to note that each component may be reduced quantitatively and/or qualitatively by doing so. Multiple exposure programmes may therefore reduce the proportion of proven beneficial exposures and consequently reduce the overall preventive effect on sports injury. Additionally, the risk of designing too extensive prevention programmes will unavoidably be enhanced with growing amounts of applied exposures and compliance may suffer as a consequence. Although most multiple intervention studies in this analysis were well designed and carried out in a satisfactory way, this subgroup did not exhibit an unambiguous preventive effect on sports injuries. Our findings suggest that designs of multiple exposure interventions should at least be built from well-proven single exposures and that further research into single exposures remains pivotal.

When analyses were stratified by outcome, both acute (RR 0.615 (0.470–0.803)) and overuse (RR 0.527 (0.373–0.746)) injuries were effectively reduced by preventive physical activity, although overuse injuries fared slightly better.

Five of six studies analysing overuse injuries were multiple exposure studies, and estimates were not particularly heterogeneous. Six of nine studies analysing acute injuries were multiple exposure studies with heterogeneous effect sizes. It is not possible to derive which parts of these interventions manifested the preventive effect. Future studies should report acute and overuse injuries separately and test specific exposures against these in order to acquire further knowledge in this import area.

Strengths and limitations

The aim of this meta-analysis was to aggregate a wide array of populations, exposures and outcomes to augment the external validity while maintaining the suitability of combining studies. Physical activity is broadly defined and populations include army recruits, recreational and professional athletes. In this regard, it should be pointed out that the diversity of included studies should not be interchanged with the I^2 measure of statistical heterogeneity, which exclusively concerns inconsistency in effect sizes. The statistically homogeneous analyses of strength training and stretching studies differing in population, intervention, and outcome, prove the generalisability of results. The statistically heterogeneous analyses of this meta-analysis should be interpreted with caution as this heterogeneity could arise from true variation (diversity in design) and/or artefactual variation (bias by conduct, attrition, etc).

Omission of intention-to-treat analysis and cluster adjustment are two sources of potentially serious bias. As compliance to intervention programmes appears to vary and remains a disputed phenomenon, the analysis by intention-to-treat plays a central role in the robustness of results.[57–61] In the present meta-analysis we extracted data from intention-to-treat analyses whenever possible and performed sensitivity analysis by exclusion of five studies with no report of intention-to-treat analysis. Contrary to the expected more conservative effect estimate, the intention-to-treat sensitivity analyses revealed even more beneficial effect estimates. As a result we can conclude that physical activity as primary prevention against sports injuries is effective, even if it has been argued that compliance issues could diminish the implementation and effect of these programmes. We speculate the above to result from an association between using intention-to-treat analysis and study conduct in general. For example, Brushoj *et al*[28] added concurrent training in the critical high risk period of military training initiation, which intuitively appears detrimental to overuse injuries. Soderman *et al*[46] exhibited several methodological issues and reported adverse effects of major injuries that have not been reproduced by other studies. None of them analysed by intention-to-treat and exclusion of such studies improved the quality of included studies and subsequently the effect estimate.

Cluster adjustment is similarly important in order not to overestimate the power of the study. A strength of this meta-analysis is the adjustment of these studies that report the same effect estimate but underestimate the width of CIs. Corresponding authors of studies without cluster adjustment were contacted and three provided data for ρ calculation. For the remaining nine studies we calculated an average p value extracted from 12 reported values of 10 studies that performed correct adjustment methods. This caused, in some cases, a dramatic, down-regulation of effective sample size which affected the study weight in the quantitative analyses.

A short discussion of the allocation concealment and participant blinding quality assessments is advocated. As true participant blinding is frequently argued to be impossible in sports injury prevention and allocation, concealment makes less sense in non-pharmacological interventions, these quality assessment items should be interpreted with caution. In spite of this, some of the included studies made qualified efforts to alleviate these, which, in this review, resulted in a lower risk of bias judgement. The domain-based tool was chosen as evaluation tool of this review as recommended by the Cochrane collaboration with the most convincing validation evidence in this area. Although not being perfectly suited for assessment of sports injury prevention studies, assessment of these parameters still holds relevance as these factors can greatly influence analyses.[62 63]

A Harbord's small-study effect test and a modified Galbraith's plot were performed for this meta-analysis to assess publication bias. The small-study effect test for the total estimate was highly significant, while the multiple exposures subgroup was the only subgroup showing a statistically significant test. According to Egger *et al*[64 65] significant small-study effects may arise from a number of reasons, including true publication bias, heterogeneity, chance, and methodological differences between smaller and larger studies. As the p value of the small-study effects increased when the total estimate test was divided into less heterogeneous subgroups, it is likely that a substantial part of the total estimate small-study effect originates in heterogeneity. Owing to the relatively heavy burden of implementing physical activity interventions, it should be noted that smaller studies often would be able to pay greater attention to the intervention for each team/individual, thereby enabling them to obtain more thorough intervention quality. Hence, a methodological difference may exist as well.

CONCLUSION

In general, physical activity was shown to effectively reduce sports injuries. Stretching proved no beneficial effect, whereas

multiple exposure programmes, proprioception training, and strength training, in that order, showed a tendency towards increasing effect. Strength training reduced sports injuries to less than one-third. We advocate that multiple exposure interventions should be constructed on the basis of well-proven single exposures and that further research into single exposures, particularly strength training, remains crucial. Both acute and overuse injuries could be significantly reduced, overuse injuries by almost a half. Apart from a few outlying studies, consistently favourable estimates were obtained for all injury prevention measures except for stretching.

What this study adds

This meta-analysis provides quantitative effect estimates of different exercise programmes on sports injury prevention. Comparison of exposures reveals a highly effective strength training estimate, significantly better than multicomponent studies.

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Competing interests None.

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Online-only supplements

eMethods1, Definition of sports injury

This article will define an injury as;
"Any physical complaint sustained by an individual that result from sports-related physical activity, irrespective of the need for medical attention or time loss from sports-related physical activities. An injury that results in an individual receiving medical attention is referred to as a "medical attention" injury, and an injury that results in an individual being unable to take a full part in sports-related activities as a "time loss" injury."
This definition originates in the F-MARC consensus group concerning soccer injuries and has merely been fitted to the scope of this analysis.

eMethods2, Complete searches

PubMed (Mesh terms are exploded): 1023 results, performed 3/10-2012, updated 7/1-2013

("prevention"[All Fields] OR "preventive"[All Fields] OR "decrease"[All Fields] OR "reduce"[All Fields] OR "reduction"[All Fields] OR "prophylaxis"[All Fields] OR "risk"[All Fields] OR "incidence"[All Fields] OR "prevention program"[All fields] OR "prevention and control"[Subheading] OR "primary prevention"[Mesh] OR "accident prevention"[Mesh] OR "risk management"[Mesh] OR "risk assessment"[Mesh] OR "risk reduction behavior"[Mesh] OR "program evaluation"[Mesh] OR "exercise therapy"[Mesh])
AND
("injury"[All Fields] OR "injuries"[All Fields] OR "accident?"[All Fields] OR "trauma"[All Fields] OR "cumulative trauma disorders"[Mesh] OR "soft tissue injuries"[Mesh] OR "sprains and strains"[Mesh] OR "tendons/pathology"[Mesh] OR "tendon injuries"[Mesh] OR "fractures, bone"[Mesh] OR "fractures, cartilage"[Mesh] OR "musculoskeletal system/injuries"[Mesh] OR "musculoskeletal system/pathology"[Mesh] OR "musculoskeletal system/physiopathology"[Mesh] OR "arm injuries"[Mesh] OR "hand injuries"[Mesh] OR "neck injuries"[Mesh] OR "back injuries"[Mesh] OR "hip injuries"[Mesh] OR "leg injuries"[Mesh] OR "sports medicine"[Mesh] OR "athletic injuries"[Mesh])
AND
("sport?"[All Fields] OR "athletic?"[All Fields] OR "exercise"[All Fields] OR "physical activity"[All Fields] OR "game"[All Fields] OR "recreation"[All Fields] OR "train"[All Fields] OR "training"[All Fields] OR "workout"[All Fields] OR "competition"[All Fields] OR "contest"[All Fields] "handball"[All Fields] OR "baseball"[Mesh] OR "basketball"[Mesh] OR "football"[Mesh] OR "soccer"[Mesh] OR "golf"[Mesh] OR "gymnastics"[Mesh] OR "hockey"[Mesh] OR "racquet sports"[Mesh] OR "running"[Mesh] OR "swimming"[Mesh] OR "volleyball"[Mesh] OR "athletic performance"[Mesh] OR "physical fitness"[Mesh] OR "motor activity"[Mesh] OR "exercise"[Mesh] OR "Motion"[Mesh] OR "Movement"[Mesh] OR "Exercise Movement Techniques"[Mesh])
AND
("randomized controlled trial"[All fields] OR RCT OR "randomized controlled trial"[Publication Type])

EMBASE (advanced search, searches limited to human, English language, and randomized controlled trial + multicenter studies): 1314 results, performed 3/10-2012, updated 7/1-2013

Search 1	prevention or prevention/ or exp accident prevention/ or exp primary prevention/ or exp prevention study/ or decrease or reduce or reduction or risk or exp risk management/ or exp risk reduction/ or exp risk assessment/ or prophylaxis or exp prophylaxis/ or exp "primary prevention"/
Search 2	injury or injuries or exp injury/ or exp accidental injury/ or exp musculoskeletal injury/ or exp soft tissue injury/ or exp sport injury/ or accident? or trauma or exp "cumulative trauma disorder"/ or exp "sports medicine"/
Search 3	sport? or athletic? or exercise or "physical activity" or exp "physical activity"/ or train* or workout or competition or train or exp sport/ or handball or exp team sport/ or exp exercise tolerance/ or exp exercise/ or exp "physical performance"/ or exp training/ or "motor activity"/
Search 4	exp randomized controlled trial/ or RCT or "randomized controlled trial?"

Combine 1, 2, 3 and 4 with AND

Web of science (advanced search, English, articles, lemmatization on, combining sets with AND, and a sensitive scope of category refining): 728 results, performed 3/10-2012, updated 7/1-2013

Set 1	TS=(prevention OR preventive OR decrease OR reduce OR reduction OR incidence OR "primary prevention" OR "accident prevention" OR "prevention study" OR prophylaxis OR "risk reduction" OR "risk management" OR "program evaluation")
AND	
Set 2	TS=(injury OR injuries OR accident OR trauma OR strain OR sprain OR tendinopathy OR tendinosis OR "tendon injury" OR "overuse injury" OR fracture OR "bone injury" OR "cartilage injury" OR "cumulative trauma" OR muscle injury OR muscular injury OR myopathy OR "musculoskeletal injury" OR "soft tissue injuries" OR "cartilage injury" OR "sports medicine" OR "athletic injuries")
AND	
Set 3	TS=(sport? OR athletic? OR exercise OR "physical activity" OR "motor activity" OR movement OR game OR recreation OR train OR training OR workout OR contest OR competition OR handball OR baseball OR basketball OR football OR soccer OR rugby OR golf OR gymnastics OR hockey OR "racquet sports" OR running OR swimming OR volleyball)
AND	
Set 4	TS=(randomized controlled trial OR RCT)

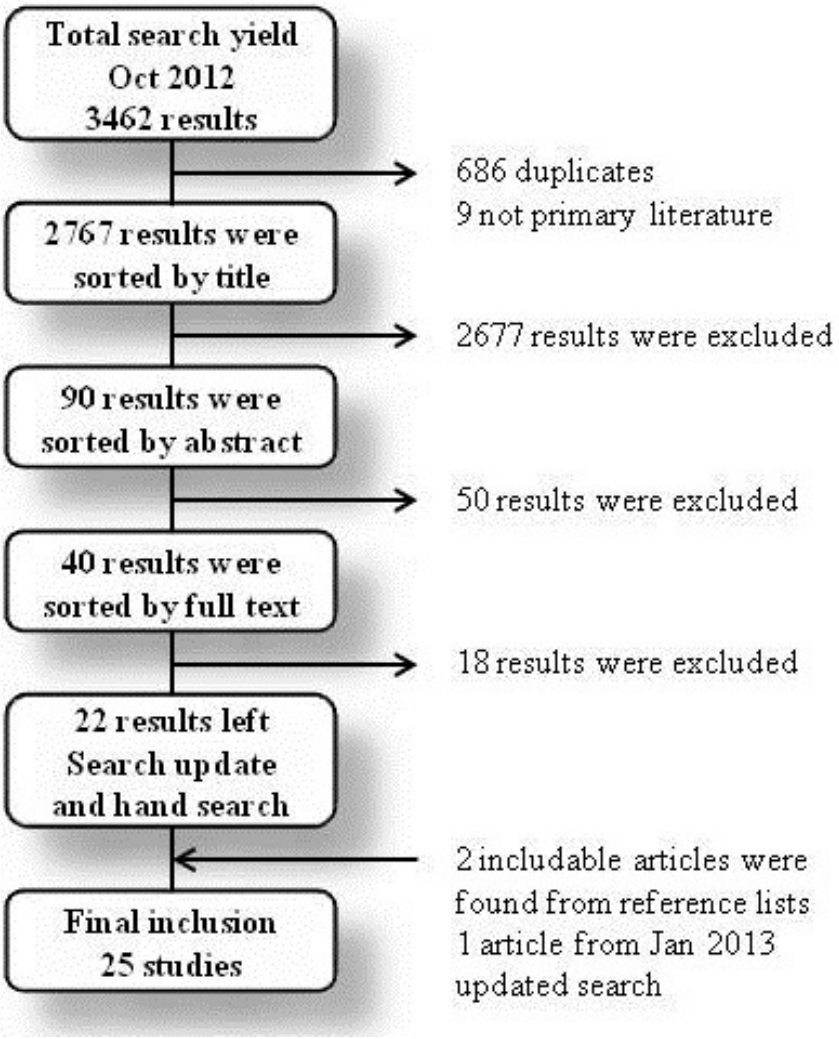
Search refined by: Language = (English), Document Types =(Article)

Categories included: SPORT SCIENCES (299), ORTHOPEDICS (201), MEDICINE GENERAL INTERNAL (147), GERIATRICS GERONTOLOGY (94), GERONTOLOGY (65), RHEUMATOLOGY (59), MEDICINE RESEARCH EXPERIMENTAL (33), HEALTH CARE SCIENCES SERVICES (24), PRIMARY HEALTH CARE (21), WOMEN'S STUDIES (4), BEHAVIORAL SCIENCES (2), HOSPITALITY LEISURE SPORT TOURISM (2), TRANSPORTATION (2)

"SPORTSDiscus" (including "SPORTDiscus", "SPORTDiscus with full text" and "academic search complete", advanced search, applying related words, subject terms (SU) exploded when possible, and English): 397 results, performed 3/10-2012, updated 7/1-2013

Search 1	preventive OR prevention OR decrease OR inhibit OR avoid OR prophylaxis OR risk OR SU ACCIDENT prevention OR SU MEDICINE, Preventive OR SU risk
AND	
Search 2	injury OR injuries OR accident? OR trauma OR musculoskeletal OR SU MUSCULOSKELETAL system -- Wounds & injuries OR SU SOFT tissue injuries OR SU OVERUSE injuries OR SU OVEREXERTION injuries OR SU RUPTURE of organs, tissues, etc. OR SU FRACTURES OR SU SPORTS injuries OR SU SPORTS physical therapy OR SU SPORTS accidents
AND	
Search 3	sport? OR athletic? OR exercise OR physical activity OR train OR SU TRAINING OR SU PHYSICAL activity OR SU PHYSICAL training & conditioning OR SU ATHLETES OR SU ATHLETICS OR SU RECREATIONAL sports OR SU SPORTS OR SU SPORT for All OR SU SPORTS tournaments
AND	
Search 4	randomized controlled trial OR RCT OR SU RANDOMIZED controlled trials

eFigure1, Study selection flowchart



eMethods3, Detailed study selection description

The above searches revealed 3462 results

3462 sorted for duplicates (if identical title and first author) and reference type

- 686 referenceduplicates (2776 left)
- 2 book sections, 1 case, 5 newspaper articles, and 1 blank reference (2767 left)

2767 sorted by title

- 2677 excluded

90 sorted by abstract

- 43 studies sorted by screening for exclusion criteria
- 2 studies had inappropriate control group
  ("Buist, I., No effect of a graded training program on the number of running-related injuries in novice runners"/"Childs, J.D., Effects of Traditional Sit-up Training Versus Core Stabilization Exercises on Short-Term Musculoskeletal Injuries in US Army Soldiers: A Cluster Randomized Trial")
- 1 report duplicate
  ("Canham-Chervak, M., Does stretching before exercise prevent lower-limb injury?" same as *"Pope, R. P., A randomized trial of preexercise stretching for prevention of lower-limb injury")*

- 1 study had prevalence as outcome
  ("Cumps, E., Effect of a preventive intervention programme on the prevalence of anterior knee pain in volleyball players")
- 1 study included "healthy" participants regarded by the authors of this meta-analysis as having a "medical attention injury"

  ("Fredberg, U., Prophylactic training in asymptomatic soccer players with ultrasonographic abnormalities in Achilles and patellar tendons - The Danish super league study")
- 1 study had information/safety equipment as intervention
  ("Kendrick, D., Preventing injuries in children: cluster randomised controlled trial in primary care")
- 1 study was a review
  ("Oneill, T., Can we prevent fractures?")

40 sorted by full text

- 4 references were conference abstracts or course lectures
  ("Emery C., The efectivenes of a combined sport injury and obesity prevention program in junior high school"/"Richmond S., Examining a sport injury and obesity intervention program in junior high school"/"Sinaki M., Stronger back muscles reduce the incidence of vertebral fractures: A prospective 10 year follow-up of postmenopausal women"/"Myklebust G., Prevention of noncontact anterior cruciate ligament injuries in elite and adolescent female team handball athletes")
- 3 references were study protocols
  ("van Beijsterveldt A., Effectiveness and cost-effectiveness of an injury prevention programme for adult male amateur soccer players: design of a cluster-randomised controlled trial"/"Finch C. The Preventing Australian Football Injuries with Exercise (PAFIX) Study: a group randomised controlled trial"/"Bredeweg S., The GRONORUN 2 study: effectiveness of a preconditioning program on preventing running related injuries in novice runners. The design of a randomized controlled trial")
- 3 studies weren't randomized
  ("Gatterer H., Effects of the performance level and the FIFA "11" injury prevention program on the injury rate in Italian male amateur soccer players"/"Kiani A., Prevention of Soccer-Related Knee Injuries in Teenaged Girls", "Caraffa A., Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training")
- 2 study had control group defined as physical activity by this study
  ("Bello M., Rhythmic stabilization versus conventional passive stretching to prevent injuries in indoor soccer athletes: A controlled clinical trial "/"Gabbe B., A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian football")
- 2 studies with cluster randomization of 4 clusters and no adjustment for cluster effect were considered inadequate

  ("Parkkari J., Neuromuscular training with injury prevention counselling to decrease the risk of acute musculoskeletal injury in young men during military service: a population-based, randomised study"/"Verhagen E., Acute physical activity and sports injuries in children")
- 2 studies had physical activity intervention regarded insufficient for this analysis
  ("Collard D., Effectiveness of a school-based physical activity injury prevention program: a cluster randomized controlled trial"/"van Mechelen W., Prevention of running injuries by warm-up, cool-down, and stretching exercises")
- 2 report duplicates

2 articles included from article references were added to 22 articles

- *"Askling C., Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload"*
- *"Heidt R., Avoidance of soccer injuries with preseason conditioning"*

1 article included by the literature search update Jan 2013 was added to 24 articles

- *"van Beijsterveldt A., Effectiveness of an injury prevention programme for adult male amateur soccer players: a cluster-randomised controlled trial"*

25 articles for final inclusion

eMethods4, Quality assessments of included studies

Askling et al., Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload

Random sequence generation	Reported	*"were randomly assigned to either"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Blinding of participants/personnel	Reported	*"Before the start of the study, the players, coaches and medical personnel of the two teams were informed about the purpose and the design of the study"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"Before the start of the study, the players, coaches and medical personnel of the two teams were informed about the purpose and the design of the study"* *"medical personnel of each team were not part of the study, thus avoiding bias"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: No reported dropout or missing data*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Intention-to-treat analysis performed* *Comment: Possible contamination between study arms may underestimate intervention effect*
	Judgement	**Low** risk of bias

Beijsterveldt et al., effect Effectiveness of an injury prevention programme for adult male amateur soccer players: a cluster-randomised controlled trial

Random sequence generation	Reported	*Published study protocol reference: "Randomisation was done independently by drawing lots"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Blinding of participants/personnel	Reported	*Published study protocol reference: "The research team gave the clubs and their first team coaches information about the aims of the trial. The control group was asked to participate in a study on injury incidence and characteristics of practice sessions"*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Incomplete outcome data	Reported	*"Shortly after randomisation, the coach of one team from the intervention group refused to use The11 during the practice sessions"* *Comment: The above should count as dropout as the team were randomized at this point. This means a dropout of 39 from the intervention group and 13 players from the control group according to the study flow chart*
	Judgement	**High** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study was available but the published article don't report the pre-specified Cox regression or any satisfactory measures of first-time injury*
	Judgement	**High** risk of bias

Other bias	Reported	*Comment: Intention-to-treat analysis performed. Sample size calculations based in inflation factor estimate but no report of actual cluster adjustments in either study protocol or published report*
	Judgement	**High** risk of bias

Brushoj et al., Prevention of overuse injuries by a concurrent exercise program in subjects exposed to an increase in training load - A randomized controlled trial of 1020 army recruits

Random sequence generation	Reported	*"The conscripts were randomly divided (by personal registration number) into 8 companies each consisting of 3 platoons"* *Comment: True cluster-randomization was achieved as personal registration numbers are randomly generated in Denmark*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"randomization was performed by the head nurse, who otherwise did not participate in the study"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"the recruits did not know which of the training programs was being tested"* *"before their examination, the patients were informed by the head nurse not to reveal what exercise group they were allocated to"*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*"before their examination, the patients were informed by the head nurse not to reveal what exercise group they were allocated to"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"Attrition reasons not related to the present study"* *Comment: Attrition of 20 and 23 in intervention and control group, respectively.*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: No clinical trials registry study protocol available and no pooled estimate for pre-specified primary outcomes*
	Judgement	**High** risk of bias
Other bias	Reported	*Comment: No intention-to-treat analysis or cluster adjustments* *Comment: Concurrent training in high risk period may be detrimental for overuse injuries and may lead to an increased injury risk in the intervention group.*
	Judgement	**High** risk of bias

Coppack et al., The Effects of Exercise for the Prevention of Overuse Anterior Knee Pain A Randomized Controlled Trial

Random sequence generation	Reported	*"A simple randomization procedure based on a computer-generated table of random numbers"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"An external administrator provided the group assignment"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"An attempt was made to blind participants, but given the physical nature of the intervention, we refrain from calling this a double-blinded study"* *Comment: participant blinding attempt through the application of dummy warm- up exercises for control group participants*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*"Participants... were instructed not to reveal information about sessions to the AKP outcome assessor (physiotherapist)"*
	Judgement	**Low** risk of bias
Incomplete	Reported	*"Because of the military setting, no individuals were lost to follow-up"*

outcome data		*"there was no evidence to suggest a difference in voluntary discharge rate between groups (P>0,05)"*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Adjustment for clustering effect and intention-to-treat performed*
	Judgement	**Low** risk of bias

Eils et al., Multistation proprioceptive exercise program prevents ankle injuries in basketball

Random sequence generation	Reported	*"198 subjects were randomly assigned to the control or the training group using a stratified randomization design, with the strata defined by performance (high, middle, or low) and sex"* *Comment: Performed by computer*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*Comment: No blinding*
	Judgement	**High** risk of bias
Blinding of participants/personnel	Reported	*Comment: Description of injury assessment and reporting indicate that blinding haven't been performed*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*Comment: Description of injury assessment and reporting indicate that blinding haven't been performed*
	Judgement	**High** risk of bias
Incomplete outcome data	Reported	*Comment: Figure 1 shows 15 and 11 lost to follow-up for training and control, respectively. Attrition is fairly balanced between the two groups with similar reasons for missing data reported.*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: No mention of intention-to-treat or adjustment for clustering effects*
	Judgement	**High** risk of bias

Emery et al. 2005, Effectiveness of a home-based balance-training program in reducing sports-related injuries among healthy adolescents: a cluster randomized controlled trial

Random sequence generation	Reported	*"Computer generated random numbers were used to recruit schools and students and to allocate the schools to the intervention or control group"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"Computer generated random numbers"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"The study was blinded in that we randomly allocated schools to the intervention or control group following initial subject recruitment"* *Comment: This doesn't in itself ensure blinding but given the nature of interventions in most of the included studies in this paper an effort is considered to at least minimize the risk of bias in comparison to studies that provide full info to all participants*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*N/A*
	Judgement	**Unclear** risk of bias

Incomplete outcome data	Reported	*Comment: Participation flow chart states 6 and 7 exclusions from the intervention and control group, respectively. Exclusion reasons are stated and there are no indices that these shouldn't be balanced between groups or being of dissimilar reasons.*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Adjustment for clustering effects performed. Rate of collected data on compliance was low (43,3%) but as intention-to-treat analysis was performed this would lead to an underestimation of the effect of the intervention effect and the conclusions of this study therefore seems robust*
	Judgement	**Low** risk of bias

Emery et al. 2010, The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer: a cluster-randomised controlled trial

Random sequence generation	Reported	*"Teams were randomised by club"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"Randomisation was revealed following recruitment of teams to ensure allocation concealment"*
	Judgement	**High** risk of bias
Blinding of participants/personnel	Reported	*"Teams were blinded to the details of the other study-group programmes"* *Comment: Control group did a standard warm-up which made it possible to blind participants*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*"A study therapist (physiotherapist or athletic therapist) blinded to study group allocation was on site"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: Participant flow chart shows an attrition of 89 individuals in the training group and 52 from the control group. Team dropout after randomization was considered uneven*
	Judgement	**High** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Adjusted for clustering effects.* *Comment: Rate of collected data on compliance was poor (<15%) but as intention-to-treat analysis was performed this would lead to an underestimation of the effect of the intervention effect and the conclusions of this study therefore seems robust* *Comment: Statistically significant difference in gender distribution at baseline*
	Judgement	**Low** risk of bias

Emery et al. 2007, A prevention strategy to reduce the incidence of injury in high school basketball: a cluster randomized controlled trial

Random sequence generation	Reported	*"Random selection of schools was done by computer generation of random numbers"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"following subject recruitment to ensure allocation concealment"*
	Judgement	**Unclear** risk of bias

Blinding of participants/personnel	Reported	*Comment: Subject blinding haven't been mentioned but design make true blinding possible*
	Judgement	**Unclear** risk of bias
Blinding of outcome assessment	Reported	*"The team therapist was blinded to training group allocation"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: Participation flow chart report a dropout of one team (n = 11 subjects) from intervention group.*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Adjusted for clustering effects and analysed by intention-to-treat*
	Judgement	**Low** risk of bias

Gilchrist et al., A Randomized Controlled Trial to Prevent Non contact Anterior Cruciate Ligament Injury in Female Collegiate Soccer Players

Random sequence generation	Reported	*"Intervention and control teams were paired by proximity"* *"Pairs were clustered geographically by region... and one pair from each region was selected randomly for observation"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"Participation and injury reports were submitted weekly by facsimile to study staff using codes for both teams and individual athletes for confidentiality"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"Each team's ATC provided the athletes an overview of the study"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"an ACL injury was counted only if the ATC reported confirmation by magnetic resonance imaging, arthroscopy, or direct visualization at the time of repair"* *Comment: The above methods ensure a high level of objectiveness but, MR especially, can still contain a component of assessment.*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"Eight intervention teams were excluded from the analysis because they did not use the program 12 or more times"* *Comment: Twelve teams dropped out after randomization from intervention group and two from control group*
	Judgement	**High** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: No intention-to-treat analysis or adjustment attempts for clustering effects*
	Judgement	**High** risk of bias

Heidt et al., Avoidance of soccer injuries with preseason conditioning

Random sequence generation	Reported	*"Before the start of the select season, 42 of these players were randomly selected to participate in the Frapier Acceleration Training Program"*
	Judgement	**Low** risk of bias
Allocation	Reported	*N/A*

concealment	Judgement	**Unclear** risk of bias
Blinding of participants/personnel	Reported	*Comment: Customized athlete training makes blinding impossible*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"The athletic trainers were blinded as to which athletes participated in the preseason training program"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: All 300 participants was included in analysis*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Intention-to-treat analysis were performed and no serious sources of bias were found*
	Judgement	**Low** risk of bias

Holmich et al., Exercise program for prevention of groin pain in football players: a cluster-randomized trial

Random sequence generation	Reported	*"randomized to the prevention group (PG) or the CG by block randomization (block size two). The randomization was computer generated"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The individual physiotherapists and coaches were informed about the allocation of their club by a letter in a sealed and opaque envelope mailed by a secretary not involved in the analysis of the data"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"Because of the nature of the intervention, blinding of the participants and observers (physiotherapist and coach) was not possible"* *"The data manager, the statistician, and the authors were all blinded to the result of the randomization"*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*"Because of the nature of the intervention, blinding of the participants and observers (physiotherapist and coach) was not possible"*
	Judgement	**High** risk of bias
Incomplete outcome data	Reported	*"Because this ... was evenly distributed between the two allocations, we do not find this alarming from a trial quality point of view but very unfortunate from a sample size point of view."*
	Judgement	**High** risk of bias
Selective reporting	Reported	*Comment: No clinical trials registry study protocol available and results of the claimed intention-to-treat analysis wasn't reported*
	Judgement	**High** risk of bias
Other bias	Reported	*Comment: Adjusted for intracluster correlation and intention-to-treat analysis was performed but was not reported* *Comment: With 907 injuries in 977 individuals repeated injuries must have been included.*
	Judgement	**High** risk of bias

Jamtvedt et al., A pragmatic randomised trial of stretching before and after physical activity to prevent injury and soreness

Random sequence generation	Reported	*"The randomisation schedule was unrestricted (no stratification or blocking) and was administered by computer"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The allocation code was not broken until the analyses were compared and found to yield the same results"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*Comment: No attempts to blind participants were described. The recruitment methods make it unlikely that participants have been blinded*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"Participants who experienced an injury of the lower limb or back in the past week were asked to provide details about the injury."* *Comment: No mention of injury-confirmation procedures*
	Judgement	**High** risk of bias
Incomplete outcome data	Reported	*"Completeness of reporting was similar in the two groups"*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias

Other bias	Reported	*Comment: In the stretching group only 38,4% and 7,7%, respectively, complied fully or almost fully with target frequency and target duration. This could lead to an underestimation of the effect and may originate in the limitations on participant motivation over the internet*
	Judgement	**High** risk of bias

LaBella et al., Effect of neuromuscular warm-up on injuries in female soccer and basketball athletes in urban public high schools: cluster randomized controlled trial

Random sequence generation	Reported	*"The statistician generated the randomization sequence using an online random number generator program"* *Comment: A minimization was conducted*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The research coordinator (J.G.) informed coaches of their allocation"*
	Judgement	**High** risk of bias
Blinding of participants/personnel	Reported	*"The research coordinator (J.G.) informed coaches of their allocation"* *"The research assistants (RAs) were not blinded to group assignments"* *"We minimized this potential bias by objectively defining injury as one causing missed time from practice or game, and when a physician's diagnosis was unavailable, RA's consulted the principal investigator, who was blinded"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"The principal investigator and coinvestigators were blinded until data collection was complete"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"Drop-out rates were 6% for control coaches and 4% for intervention coaches"*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports lack a total estimate for primary outcome*
	Judgement	**High** risk of bias
Other bias	Reported	*Comment: Intention-to-treat analysis was performed but adjustments for clustering effects wasn't accounted for on primary outcome*
	Judgement	**High** risk of bias

Longo et al., The FIFA 11+ Program Is Effective in Preventing Injuries in Elite Male Basketball Players A Cluster Randomized Controlled Trial

Random sequence generation	Reported	*"Randomization was done independently by drawing lots"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The statistician who conducted the randomization did not take part in the study"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"Another limitation of this study is that teams were not blinded to the exercise program"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*Comment: Team medical staff reported to blinded orthopaedic personnel*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: Participants flow chart reveal 0 lost to final follow-up*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias

Other bias	Reported	*Comment: Analyzed by intention-to-treat but no adjustments for clustering effects*
	Judgement	**High** risk of bias

McGuine et al., The effect of a balance training program on the risk of ankle sprains in high school athletes

Random sequence generation	Reported	*"Randomization into intervention and controls was performed using groups of two based on a schedule provided by the statistician"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Blinding of participants/personnel	Reported	*"Subjects performing the intervention knew they were doing so to prevent ankle sprains"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"the ATCs at the schools knew which teams were in the control and intervention groups"*
	Judgement	**High** risk of bias
Incomplete outcome data	Reported	*"(n = 11) of athletes dropped out of the study when they stopped participating on their interscholastic team and were included in the analysis through the last day of their team membership"*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Intention-to-treat analysis performed but no adjustments for clustering effects*
	Judgement	**High** risk of bias

Olsen et al., Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial

Random sequence generation	Reported	*"block randomised these, with four clubs in each block to an intervention or control group"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The statistician who conducted the randomisation was not involved in the intervention"* *"Data on injury and exposure were reported by the physiotherapist using a web based database in which all the data were coded anonymously"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*Comment: teams were informed of allocation*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"Ten research physiotherapists who were blinded to group allocation recorded injuries in both groups"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"Data on players who dropped out during the study period were included for the entire period of their participation"* *Comment: Participants flow chart show 30 dropouts from intervention and 19 from control group and no difference in dropout rates*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*"We undertook all statistical analyses according to a pre-specified plan"* *Comment: A clinical trials registry study protocol wasn't available*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Well powered and design/analyses appears strong*
	Judgement	**Low** risk of bias

Pasanen et al., Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study

Random sequence generation	Reported	*"computer-generated randomisation"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The statistician (MP) who carried out the computer-generated randomisation was not involved in the intervention"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"We informed the teams allocated to the intervention group about the upcoming training programme for preventing injuries"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*Comment: study doctor was "not involved in the intervention"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: Participant flow chart showed 9 dropouts in each group, all were players with no contract*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: Clinical trials registry study protocol was available and inclusion criteria, intervention, and outcomes corresponded to the reported study*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Sufficiently powered and design/analyses appears strong with both intention-to-treat analysis and adjustments for clustering effects*
	Judgement	**Low** risk of bias

Petersen et al., Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial

Random sequence generation	Reported	*"An independent research assistant did the randomization procedure by drawing a sealed, opaque envelope containing a team name followed by drawing another sealed, opaque envelope containing the allocation group"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"An independent research assistant did the randomization procedure by drawing a sealed, opaque envelope containing a team name followed by drawing another sealed, opaque envelope containing the allocation group"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"the person responsible for the day-to- day running of the project, medical staff within the teams, and all players were aware of group allocation"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"Reasons for dropping out were transfer or stop of active career"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: Dropout rates were 8% and 9% for intervention and control groups, respectively*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Adjusted for clustering effects but no intention-to-treat analysis*
	Judgement	**Low** risk of bias

Pope et al. 1998, Effects of ankle dorsiflexion range and pre-exercise calf muscle stretching on injury risk in Army recruits

Random sequence generation	Reported	*"Recruits with surnames commencing with the same letter were equally split between the two platoons"* *"Pairs of platoons were then randomly allocated to control and stretch groups for this study"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Blinding of participants/personnel	Reported	*"They were not told which muscle group and injuries the researchers were investigating"* *Comment: Control stretching of upper- limb muscles is likely the best possible way to achieve true blinding of subjects*
	Judgement	**Low** risk of bias
Blinding of outcome assessment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Incomplete outcome data	Reported	*Comment: 98 from the intervention group and 112 from the control group were either discharged, backsquadded or withdrawn from the study*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: No mention of either adjustment for clustering effects or intention-to-treat analysis*
	Judgement	**High** risk of bias

Pope et al. 2000, A randomized trial of preexercise stretching for prevention of lower-limb injury

Random sequence generation	Reported	*"were allocated to strecth or control groups using a blocked, stratified, random allocation procedure"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"All allocation procedures to this point were conducted by administrative staff at Kapooka, without regard for the research to be conducted"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*Comment: Participants/personnel haven't likely been effectively blinded*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"The RMO, who was masked to patient allocation, categorized all injuries by area and type"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"170 (11%; 69 from stretch group, and 101 from the control group) were discharged or transferred to officer training before the end of the training program and without suffering a lower- limb injury"* *Comment: Survival analysis was conducted with subject results weighted by number of days of participation*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*

	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Intention-to-treat analysis but no adjustments for clustering effects*
	Judgement	**High** risk of bias

Soderman et al., Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? A prospective randomized intervention study

Random sequence generation	Reported	*"Seven teams (n=121) were randomized to an intervention group and six teams (n=100) to a control group"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Blinding of participants/personnel	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Blinding of outcome assessment	Reported	*N/A*
	Judgement	**Unclear** risk of bias
Incomplete outcome data	Reported	*"Drop-out in the intervention group (59/121) and control group (22/100)"*
	Judgement	**High** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available and the published reports do not report a total estimate for primary outcomes*
	Judgement	**High** risk of bias
Other bias	Reported	*Comment: Exclusion of 1/3 intervention group on the basis of compliance and not because of lack of data* *Comment: Analysis of recurrent injuries* *Comment: RR of 10.96 (2.10-57.3) regarding major injuries indicate that intervention may be detrimental*
	Judgement	**High** risk of bias

Soligard et al., Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial

Random sequence generation	Reported	*"We randomised"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The statistician (IH) who conducted the randomisation did not take part in the intervention"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*Comment: Both groups were informed of allocation*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"At the research centre one physical therapist and one medical student, who were blinded to group allocation, recorded injuries"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"13 clubs in the intervention group did not start the warm-up programme nor did they deliver any data on injury or exposure"* *"Nineteen clubs in the control group did not provide any data"* *"The dropout rate was similar between the groups (23 (2,1%) vs. 24 (2,9%))"*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*

	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Adjusted by intracluster coefficient and analyzed by intention-to-treat*
	Judgement	**Low** risk of bias

Steffen et al., Preventing injuries in female youth football – a cluster-randomized controlled trial

Random sequence generation	Reported	*Comment: Stratified block randomization was described*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"The statistician (IH) who conducted the randomisation did not take part in the intervention"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*Comment: Both groups were informed of allocation*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"The injury recorders were blinded to which group the teams and injured players belonged to"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*Comment: 18 and 54 players dropped out from the intervention and control group, respectively. The reports on attrition is ambiguous*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*"The program was used at 52% of all trainings for the intervention group and the average attendance for these were 60% for each player"* *Comment: Both intention-to-treat analysis and clustering effect adjustments were performed*
	Judgement	**Low** risk of bias

Waldén et al., Prevention of acute knee injuries in adolescent female football players: cluster randomised controlled trial

Random sequence generation	Reported	*"We used a computer generated list of random numbers to randomise clubs stratified by district, whereby all teams from the same club were assigned to the same group"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*"One author (IA) who was blinded to the identity of the clubs did the randomisation"*
	Judgement	**Low** risk of bias
Blinding of participants/personnel	Reported	*"The coaches, players, and study therapists were not blinded to group allocation"*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*"The coaches, players, and study therapists were not blinded to group allocation, but the study physicians who assessed the primary outcome were"*
	Judgement	**Low** risk of bias
Incomplete outcome data	Reported	*"the dropout frequency was 21% (intervention 16% (23/144 clubs), control 26% (38/147))"* *"no missing data for analysed clubs"*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: Clinical trials registry study protocol was available and inclusion criteria, intervention, and outcomes corresponded to the reported study of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Both adjustment of clustering effects and intention-to-treat were performed.*
	Judgement	**Low** risk of bias

Wedderkopp et al., Prevention of injuries in young female players in European team handball. A prospective intervention study

Random sequence generation	Reported	*"Eleven teams with 11 players were randomised to the intervention group and 11 teams with 126 players to the control group"*
	Judgement	**Low** risk of bias
Allocation concealment	Reported	*Author correspondance: No blinding*
	Judgement	**High** risk of bias
Blinding of participants/personnel	Reported	*Author correspondance: No blinding*
	Judgement	**High** risk of bias
Blinding of outcome assessment	Reported	*Author correspondance: No blinding*
	Judgement	**High** risk of bias
Incomplete outcome data	Reported	*Comment: Analysis performed on same no. of players as reported were randomized*
	Judgement	**Low** risk of bias
Selective reporting	Reported	*Comment: A clinical trials registry study protocol wasn't available but the published reports appear to include all expected outcomes, including those that were pre-specified in the method section of this article*
	Judgement	**Low** risk of bias
Other bias	Reported	*Comment: Intention to treat but no mention of adjustment for cluster effects*
	Judgement	**High** risk of bias

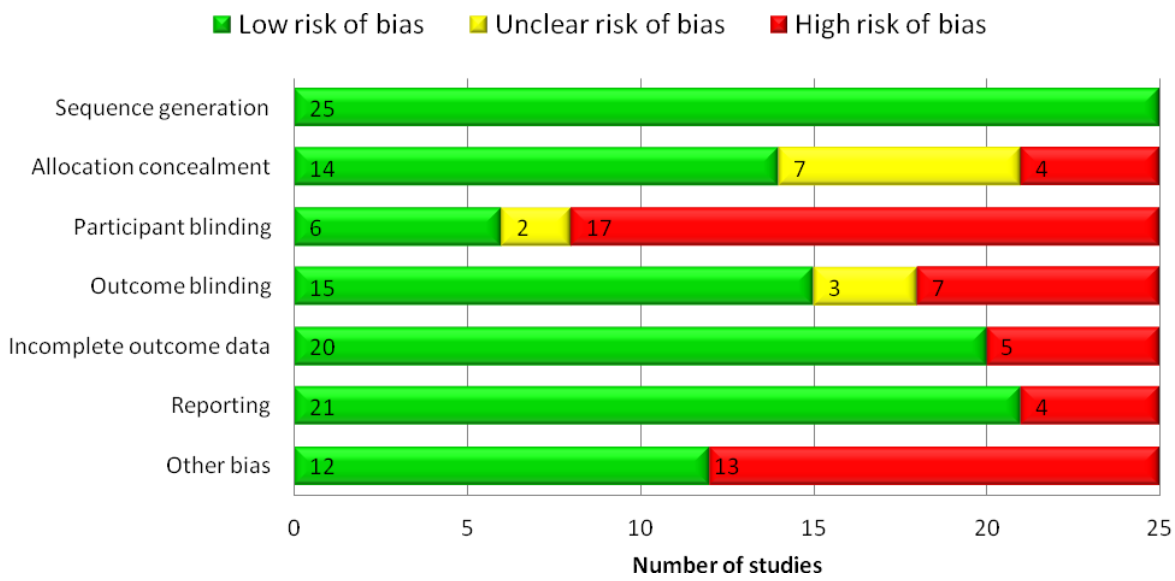
eTable1, Quality assessment summary

Total quality assessment 0-14 scale obtained by assigning studies 1 point for unclear and 2 for low

	Sequence generation	Allocation concealment	Participant blinding	Outcome blinding	Incomplete outcome data	Reporting	Other bias	Total quality assessment
Askling	Low	Unclear	High	Low	Low	Low	Low	11
Beijsterveldt	Low	Unclear	Low	High	High	High	High	5
Brushoj	Low	Low	Low	Low	Low	High	High	10
Coppack	Low	Low	Low	Low	Low	Low	Low	14
Eils	Low	High	High	High	Low	Low	High	6
Emery 05	Low	Low	Low	Unclear	Low	Low	Low	13
Emery 07	Low	Unclear	Unclear	Low	Low	Low	Low	12
Emery 10	Low	High	Low	Low	High	Low	Low	10
Gilchrist	Low	Low	High	Low	High	Low	High	8
Heidt	Low	Unclear	High	Low	Low	Low	Low	11
Holmich	Low	Low	Low	High	High	High	High	6
Jamtvedt	Low	Low	High	High	Low	Low	High	8
LaBella	Low	High	High	Low	Low	High	High	6
Longo	Low	Low	High	Low	Low	Low	High	10
McGuine	Low	Unclear	High	High	Low	Low	High	7
Olsen	Low	Low	High	Low	Low	Low	Low	12
Pasanen	Low	Low	High	Low	Low	Low	Low	12
Petersen	Low	Low	High	High	Low	Low	Low	10
Pope 00	Low	Low	High	Low	Low	Low	High	10
Pope 98	Low	Unclear	Low	Unclear	Low	Low	High	10
Soderman	Low	Unclear	Unclear	Unclear	High	Low	High	7
Soligard	Low	Low	High	Low	Low	Low	Low	12
Steffen	Low	Low	High	Low	Low	Low	Low	12
Walden	Low	Low	High	Low	Low	Low	Low	12

Wedderkopp	Low	High	High	High	Low	Low	High	6

eFigure2, Quality assessment summary figure



eTable2, Characteristics of included studies

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Askling et al. Sweden 2003	- 10-week (16 sessions) preseason hamstring concentric/eccentric strength training. - Performed additional to standardized warm-up programme also performed by controls.	- 30 elite, male soccer players, except goalkeepers, in two teams from the Swedish premier-league division.	- 15 individuals in intervention group with a distribution of eight and seven subjects, from each team respectively. - 15 controls with seven individuals from one team and eight from the other. - No attrition	- Ten weeks preconditioning + one season of eight months.	- 3 injuries in intervention group. - 10 injuries in control group.	- Hamstring injury: Pain by use/palpation + time loss. - Evaluation by therapist and physician. - Injured players were excluded.	- True individual-randomized study, but potential contamination problems could exist - Intention-to-treat analysis. - All players reported having completed all sessions.
Beijsterveldt et al. Netherlands 2013	- 10-15min with ten exercises focusing on core stability, eccentric training of the thighs, proprioception training, dynamic stabilization, and plyometrics with straight leg alignment. - 5 week pre-season familiarisation and full implementation by the start of the season. - Control group did the practice as usual.	- 487 male amateur players, aged 18-40 years.	- 223 players in eleven intervention teams. - 233 players in twelve control teams. - Dropout of one team (21 players) plus 18 individuals in the intervention group and 13 from control group.	- One season of nine months.	- 135 injuries in intervention group. - 139 injuries in the control group.	- All-injury: F-MARC consensus statement definition - Team paramedic or sports trainer recorded injuries.	- Intention-to-treat. - Sample size calculation based on inflation factor estimate but no report of actual cluster adjustments in either study protocol or published report. - 73% compliance.

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Brushoj et al. Denmark 2008	- 12-week program (three sessions, 15min each, per week) concurrent with start of basic military training. One session composed two strength exercises, three stabilization/ coordination exercises, and one stretching exercise. - Controls did placebo core/upper body exercises with stretch of the pectoral muscles.	- 1020 conscripts, aged 19-26.	- 487 individuals in twelve intervention platoons – attrition of 20 - 490 in twelve control teams - attrition 23	- Twelve weeks.	- 50 primary outcome injuries in prevention group. - 48 outcome injuries in control group.	- Knee overuse injury: Pain + unrelated to trauma + specific criteria. - Medical officer and doctor. - Injuries within last month were excluded. - Repeated outcomes not taken into account. - Secondary: Total lower extremity injuries	- 75% training compliance. - True individualized randomization - No intention-to-treat analysis. - True blinding have likely been achieved. - Concurrent training intervention in high risk period for overuse injuries may be detrimental
Coppack et al. United kingdom 2011	- 14 week program concurrent with military training. Seven training lessons/week with four strength exercises + four stretching exercises per training. - Control performed syllabus military warm-up and warm-down for parts of the body irrelevant for anterior knee pain.	- 44 male and female troops (clusters) with 1502 recruits. Aged 17-30y. - 100% of eligible recruits participated.	- 759 individuals in 21 intervention troops. - 743 in 23 control troops. - No attrition.	- 14 weeks	- 10 injuries in intervention group. - 36 injuries in control group. - Cox HR 0,25 (0,13-0,48).	- Overuse anterior knee pain injury: Pain criteria and other knee injuries excludable. - Military medical center and physiotherapist. - Recruits with signs or symptoms of pathologic conditions of the leg	- Study suspended early because of military operational commitments. - Within-cluster correlation was accounted for. - Mean individual compliance rate for the 2 programs was 91%. - Intention-to-treat

						were excluded. - Secondary: Total, acute, and overuse injuries	analysis.

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Eils et al. Germany 2010	- Six proprioception exercises for 20min once per week concurrent with basketball training. - Controls continued normal workout routine.	- 198 basketball players in 35 teams from 7th highest to highest league.	- 81 individuals in intervention group. - 91 controls. - 35 teams.	- One season	-Seven injuries in intervention group. - 21 injuries in control group.	- Ankle injury: time loss. - Coach/ physiotherapist/ player registration by questionnaire, followed by interview in case of injury. - Subjects were free of injuries at the start of study.	- No mention of compliance - No adjustments for clustering effects. - No mention of intention-to-treat.
Emery et al. Canada 2005	- Proprioception, balance, and core training 20min/day for six weeks and weekly for six more months. - Students in the control group received only testing.	- 127 students from 10 high schools, aged 14-19. - 76% of eligible participants consented to participate.	- 60 students in 5 intervention schools. - 54 students in 5 control schools.	- Six weeks plus six months.	- 2 injuries in intervention group. - 10 injuries in control group. - RR 0,20 (0,05-0,88).	- All injuries: Medical attention and/or time loss. - Physiotherapist - Injuries within last 6 weeks prior to the study were excluded.	- Intention-to-treat analysis. - Adjusted for clustering effects. - Collected data on compliance was low (43,3%) but actual training compliance is unknown.
Emery et al. Canada 2010	- 5min warm-up + 10min strength, stretch, balance warm-up substitution + additional 15min wobble board. - Controls 15min	- 885 soccer players in 60 clubs. Both boys and girls, aged 13-18. - 73% of eligible teams were	- 380 players in 32 intervention teams. - 364 players in 28 control teams.	- One year follow-up, season was 20 weeks.	- 50 injuries in training group. - 79 injuries in control group. - RR 0,62	- All injuries: Medical attention and/or time loss. - Physiotherapist or athletic therapist. - Injuries within 6	- Intention to treat analysis used. - Adjusted for clustering. - Teams completing exposure data performed all

	standart warm-up.	enrolled.			(0,39-0,99).	weeks were excluded. Secondary outcome: Total acute injuries.	intervention warm-ups but reporting was poor (<15%).

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Emery et al. Canada 2007	- 5min sport-specific balance training and 20min wobble board additional to control warm-up. - Control group performed "current standart practice" warm-up five times/week.	- 931 male and female high school basketball players, 12-18y in 89 teams.	- 494 players in 47 intervention teams. - 426 players in 41 control teams.	- One year follow-up. Season was 18 weeks.	- 130 injuries in intervention group - 141 injuries in control group - RR 0,8 (0,57-1,11).	- All injuries: Medical attention and/or time loss - Injury surveillance system from Canadian Intercollegiate Sports Injury Registry (CISIR) and therapist. - Injuries within 6 weeks were excluded.	- Self-recorded wobble-board compliance 60,3%. - Analysed by intention-to-treat. - Adjusted for cluster effect.
Gilchrist et al. Switzerland 2008	- Warm-up, stretch, strength, plyometric, and sport-specific agility three times per week consisting of 3-5 exercises for each discipline. - Controls normal warm-up.	- Female collegiate soccer players in 75 teams.	- 26 intervention teams with 583 individuals. - Control 35 teams with 852 individuals.	- One season of twelve weeks.	- 2 injuries in intervention group. - 10 injuries in control group.	- Noncontact ACL injury: time loss. - Athletic trainers, confirmed by either MR, arthroscopy, or visualization at the time of repair. - Previous injuries were included.	- As-treated analysis. - No adjustments for clustering effects. - Average compliance with training regime was 26 times per team.
Heidt et al. USA	- 20 individualized preseason conditioning sessions for seven weeks. Two sessions per week were sport-specific cardiovascular conditioning	- 300 female high school soccer players, 14-18y.	- 42 players in intervention group. - 258	- One year, including two separate	- 6 first-time injuries in 42 athletes of the intervention	- All-injury: time loss. - School athletic	- Intention-to-treat analysis. - True individual-

2000	exercises with increasingly inclining treadmill to enforce forceful knee drive. One plyometric session per week. - Sport cord drills, strength training, and flexibility training mentioned but not described. - Control group not described.		controls.	seasons.	group. - 87 first-time injuries in 258 athletes in the control group.	trainers. - No mention of previous injuries.	allocation to groups. - No mention of player recruitment. - No mention of compliance rates.

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Holmich et al. Denmark 2010	- Sit-ups, one-leg coordination, iliopsoas stretching, and three concentric, eccentric, and isometric adduction exercises for 13min as integrated part of warm-up. - Control group performed traditional warm-up	- Amateur football players, 2-5th level. - 46% of invited teams accepted participation.	- 477 players in 22 intervention clubs. - 430 players in 22 control clubs - 12 + 11 clubs withdrew immediately after randomization and further 5 + 6 during the study.	- 42 weeks.	- Corresponding author reported 23 injuries in intervention group and 30 injuries in control group. - Cox HR 0,69 (0,40-1,19).	- Groin injury: any physical complaint or medical attention. - Physiotherapist and coach. - Previous groin injuries included.	- 11 year report delay due to high number of competing tasks. - Adjusted for intracluster estimate. - 93% of players presented with full data. - The intention-to-treat analysis were claimed not to show any differences but weren't reported.
Jamtvedt et al. Norway/ Australia 2010	- Seven muscle groups in the lower limb and trunk were stretched for at least 14min before and after vigorous activity. Instructions were accessible at website and subjects were asked to stretch for at least 30 sec and until felt strong but not painful stretch. - Controls were asked not to stretch any lower limb or trunk muscle	2377 participants worldwide, >18 years, English/ Norwegian speaking, vigorous activity ≥1 day(s) a week, and internet access.	- 1079 participants in intervention group. - 1046 controls.	- Twelve weeks.	- 339 injuries in intervention group and 348 in the control group. - Cox HR 0,97 (0,84-1,13).	- Lower limb and trunk injuries: internet-based self-reporting. - Current injuries were excluded.	- Entirely internet-based study design. - Intention to treat analysis. - According to self-reports 38,4% and 43,9% of the intervention group complied fully or almost fully to target frequency and duration, respectively.

	groups						

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
LaBella et al. USA 2011	- 20min full strength, plyometric, balance, and agility warm-up program before practice and dynamic motion warm-up before games. - Controls did usual warm-up.	- 95 coaches of 111 teams with 1558 female athletes in a mixed-ethnicity, pre-dominantly low-income, urban population.	- 45 intervention coaches (53 teams) with 737 athletes. - 45 control coaches (53 teams) coaches with 755 athletes.	- One season.	- 50 injuries in intervention group. - 96 injuries in the control group.	- Lower extremity injury: Time loss. - Physical therapy/ medicine/ advanced practice nursing students with diagnosis confirmation. - No specific exclusion criteria.	- Self-reported compliance to prescribed warm-up was 80% but most coaches did not use all the prescribed exercises. - No adjustments for clustering effects. - Intention-to-treat analysis.
Longo et al. Italy/England 2012	- 20min, three component warm-up program, 1: Slow running exercises with stretch/controlled partner contact, 2: strength/balance/jump exercises, 3: speed running with basketball-specific movements. Full warm-up before each training and running exercises before matches - Control usual warm-up	- 11 teams composed of 121 players from one club. Male players from U12, league to 3rd national league.	- Seven intervention teams with 80 players. - Four control teams with 41 players. - No attrition.	- Nine months.	- 14 injuries in intervention group. - 17 injuries in control group.	- All-injury: No mention of diagnosis criteria - Team medical staff and orthopeadic research center. - No mention of previous injuries.	- Analyzed by intention-to-treat. - Authors report 100% compliance. - No adjustments for clustering effects.
McGuine et	- Four progressive phases with five sessions per week. Balance	- 765 adolescent	- 27 intervention	- Four weeks conditioning	- 23 injuries in	- Ankle sprain: disruption of	- Intention-to-

al. USA 2006	board preconditioning in four weeks followed by a maintenance phase during the season, three sessions per week - Controls did normal conditioning.	basketball and soccer players, 523 girls and 242 boys, high schools from twelve areas.	teams consisting of 373 participants. - 28 control teams with 392 participants.	plus one season of follow-up.	intervention group. - 39 injuries in control group. - Cox RR 0.56 (0.33-0.95).	ligaments + time loss. - Athletic trainer assessment. - Previous injuries (24%) were included in the study.	treat analysis. - 9% were defined as non-compliant. - No adjustments for clustering effects.

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Olsen et al. Norway 2005	- 15 consecutive sessions of four exercises for a total of 15-20min every training session and then once a week for the remainder of the season. Comprised of warm-up, technique, balance and strength/power. - Controls trained as usual.	- 1886, 15-17 year-old, players in 123 handball clubs. - 85% of eligible were recruited.	- 61 intervention clubs of 958 players. - 59 control clubs of 879 players.	- One season of eigth months.	- 48 injuries in the intervention group. - 81 injuries in the control group. - Cox RR 0,53 (0.35-0.81).	- Knee and ankle injury: Time loss. - Physiotherapists. - No major injuries at inclusion.	- Intention-to-treat analysis. - Adjusted for clustering effect. - 87% compliance to programme.
Pasanen et al. Finland 2008	- 20-30min of running techniques, balance/body control, plyometric, and strength exercises. Players with lower back control difficulties or flexibility limitation were asked to stretch in addition. Two week introduction and thereafter the players were advised to carry out in own time. - Control usual warm-up	- 28 teams with 475 female floorball players of elite league, 1st, and 2nd division. - 86% of eligible players were recruited.	- 14 intervention teams of 256 players. - 14 control teams of 201 players.	- One season of six months.	- 20 injuries in the intervention group. - 52 injuries in the control group. - RR 0,34 (0.20-0.57).	- Non-contact injury: time loss. - Study doctor followed up on questionnaire reports. - Previous injuries were included and didn't differ between the two groups.	- Intention-to-treat analysis. - A mean of 74% of sessions were completed. - Cluster adjusted by estimation of intracluster correlation

							coefficients. - On average 69% of players attended training.
Petersen et al. Denmark 2011	- Additional ten week progressive Nordic hamstring exercise and maintenance of three sets once a week. - Controls trained as usual.	- 54 men's soccer teams from the five best leagues in Denmark.	- 23 intervention teams with 461 players. - 27 control teams with 481 players. - No dropout.	- Twelve months.	- 12 injuries in intervention group. - 32 injuries in control group. - RR 0,41 (0,18-0,93).	- Acute hamstring injury: any physical complaint. - Medical staff or physiotherapist. - Previous injuries were included and didn't differ between the two groups.	- 91% compliance to intended training. - Adjusted for intracluster coefficient. - Intention-to-treat analysis.

eTable2, Characteristics of included studies (continued)

Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Pope et al. Australia 1998	- Two 20sec stretches for gastrocnemius and soleus before strenuous exercise, on average every second day. - Controls stretched wrist flexors and triceps.	- 1093 male recruits between 17-35 years.	- 549 subjects in 26 intervention platoons. - 544 subjects in 26 control platoons. - No attrition.	- Twelve weeks.	- 23 injuries in intervention group. - 25 injuries in control group. - Cox HR 0,92 (0,52-1,61).	- Injury definition: >3 days before taking up full duty without symptoms because of tendo-achilles lesion, ankle sprain, stress fracture, periostitis, or anterior tibial compartment pressure syndrome. - Reporting to medical assistants or nursing staff and diagnosis by medical officer or research physiotherapists. - Excluded if significant pre-	- 96,7% of eligible recruits consented. - Analysed by survival analysis. - No mention of adjustment for clustering effects. - Intention-to-treat as there

						existing injury.	was no dropout.
Pope et al. Australia 2000	- 40 sessions in twelve weeks with a 5min program with 20sec stretches interspersed with 4min warm-up. Six muscle groups of the leg were stretched. - Controls didn't stretch during warm-up.	- 1538 male army recruits in 39 platoons.	- 19 intervention platoons of 666 subjects. - 20 control platoons of 702 subjects.	- Twelve weeks.	- 158 injuries in intervention group. - 175 injuries in control group. - Cox HR 0,95 (0,77-1,18).	- Lower-limb injury: >3 days before taking up full duty without symptoms. - Reporting by medical assistants or nursing staff and diagnosis by medical officer. - Significant injuries were excluded.	- Intention-to-treat analysis. - No mention of adjustments for clustering effects. - No analysis of compliance other than reported training days.

eTable2, Characteristics of included studies (continued)

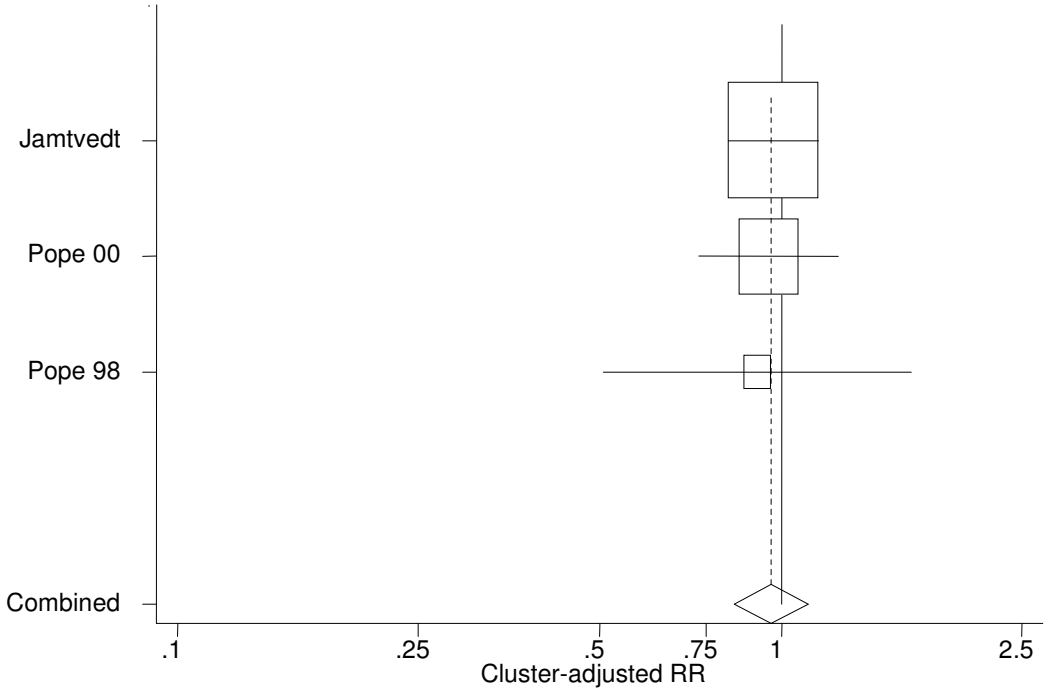
Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Soderman et al. Sweden 2000	- 10-15min additional balance board exercises consisting of five progressions of difficulty. Each exercise was carried out three times 15sec for each leg. Initially training each day for 30 days and after this three times per week the rest of the season. - No description of control group instructions.	- 221 female soccer players from 13 teams in the 2nd and 3rd Swedish division.	- 62 players in seven intervention teams. - Control 78 players in six teams. - 27 individuals who didn't complete more than 35 sessions were excluded.	- One season of seven months.	- 28 injuries in intervention group. - 31 injuries in control group. - Cox RR 1,24 (0,74-2,06).	- Lower extremity injury: time loss. Reported by players and coaches and diagnosed by authors. - Recurrent injuries analyzed.	- No cluster adjustment. - Not analyzed by intention-to-treat. - Intervention group performed 77% of the planned sessions. - Cox RR of major injuries 10.96 (2.10-57.3).
Soligard et al. Norway 2008	- 8min running exercises, 10min of strength/balance/jump exercises, and 2min of football-specific movements before each training and the running exercises before each match. - Controls performed usual warm-up.	- 2540 female football players in 125 clubs, aged 13-17 years. - 69% of eligible clubs participated.	- 52 intervention clubs with 1055 players. - 41 control clubs with 837 players.	- One season of eigth months.	- 121 injuries in intervention group. - 143 injuries in control group. - Cox RR 0,71 (0,49-1,03).	- Lower extremity injury: time loss. - Physical therapist and medical student. - Unknown whether previous injuries were included in analysis.	- Adjusted by intracluster coefficient. - Intention-to-treat analyses. - 77% compliance. - No injury occurred during the execution of the warm-up programme.

eTable2, Characteristics of included studies (continued)

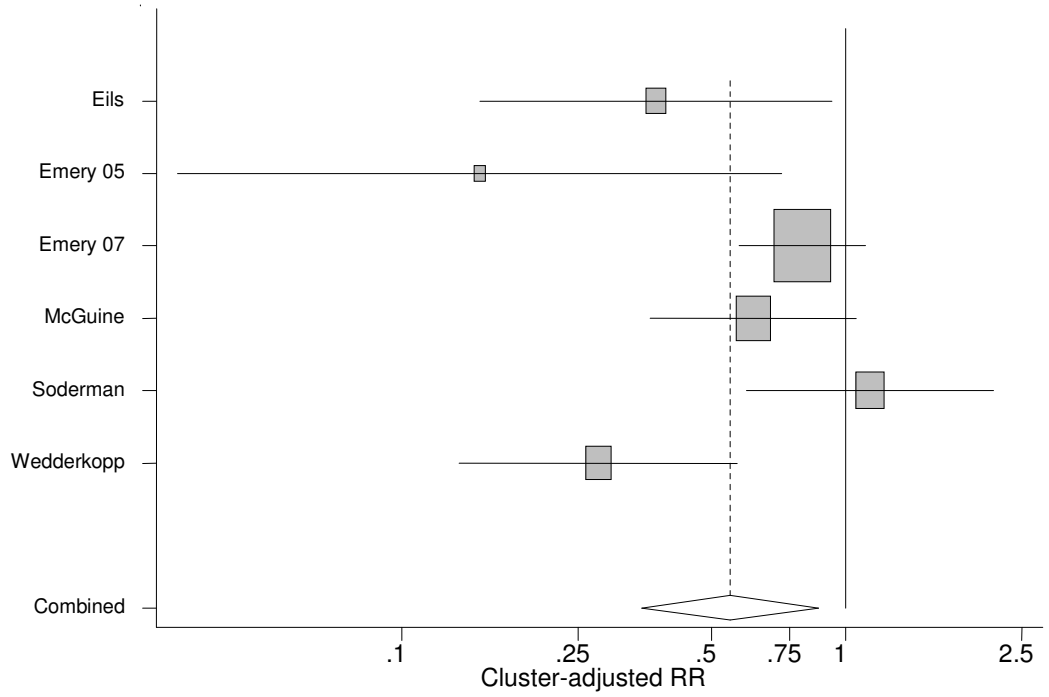
Source/ location	Intervention	Population	Study completion	Follow-up	Outcome	Primary outcome	Remarks
Steffen et al. Norway 2008	- 5min jogging followed by ten exercises focusing on core stability, balance, joint stabilization, and eccentric hamstring strength for about 15min. Performed for 15 consecutive sessions and after that, once a week for the rest of the season. - Controls trained and warmed-up as usual.	- About 2100 female soccer players in 113 teams from Norwegian U17 league. - 72% of eligible clubs participated.	- 1073 players in 58 intervention teams. - 947 players in 51 control teams.	- Two months pre-season + one season of eight months.	- 242 injuries in intervention group. - 241 injuries in control group. - RR 1,0 (0,8-1,2).	- All-injury: time loss. - Physical therapists. - Unknown whether previous injuries were included in analysis.	- Intention-to-treat analyses. - Adjusted for clustering effects. - The program was used at 52% of all trainings for the intervention group and the average attendance for these were 60% for each player.
Waldén et al. Sweden 2012	- 5min low intensity running warm-up and 15min for six neuromuscular exercises program. The six exercises were one legged knee squat, pelvic lift, two legged knee squat, the bench, the lunge, and jump/landing technique two times a week. - Controls trained as usual and teams already did injury prevention were excluded.	- 309 clubs with 4564 female soccer players, 12-17 years. - 75% of eligible clubs participated.	- 121 intervention clubs with 2479 players. - 109 control clubs with 2085 players.	- One season of seven months.	- Intervention group: 7 injuries. - Controls: 14 injuries. - Cox RR 0,36 (0,15-0,85).	- ACL injury: sudden onset time loss. - Study therapists and physicians with access to diagnostic imaging. - Unknown whether previous injuries were excluded.	- Intention-to-treat analysis. - Adjustment for clustering effects performed. - No report of compliance.
Wedderkopp et al.	- 10-15min of ankle disc exercises and a minimum of two functional activities for all	- 22 teams with 237 players, aged 16-18	- 11 intervention teams with	- One season of	- 11 injuries in intervention	- All-injury: time loss.	- Controlled for playing level.

Denmark 1999	major upper and lower extremity muscle groups. - Controls were asked to practice as usual.	years, in three tournaments.	111 players. - 11 control teams with 126 players.	ten months	group. - 45 injuries in intervention group. - OR 0.17 (0.089-0.324).	- Therapists and physicians. - Unknown whether previous injuries were excluded.	- Intention-to-treat analysis was performed. - No mention of adjustments for clustering effects.

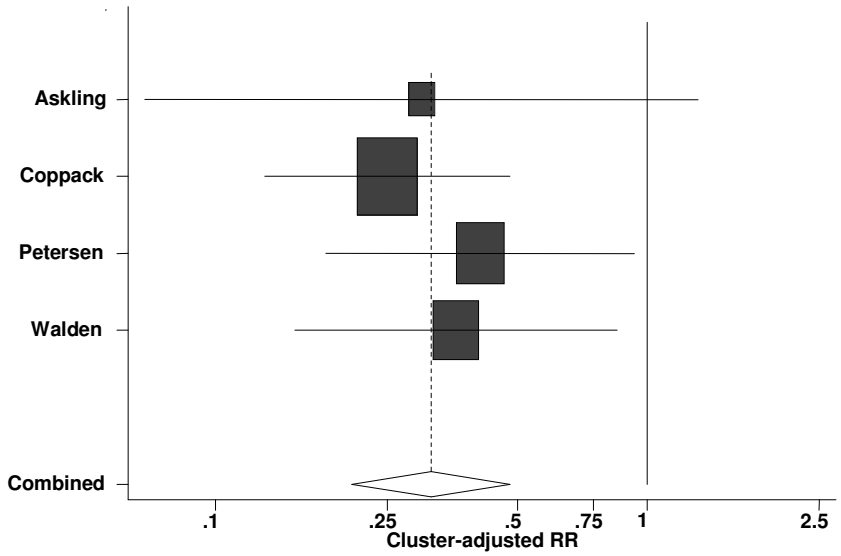
eFigure3, Stretch estimate Forest plot



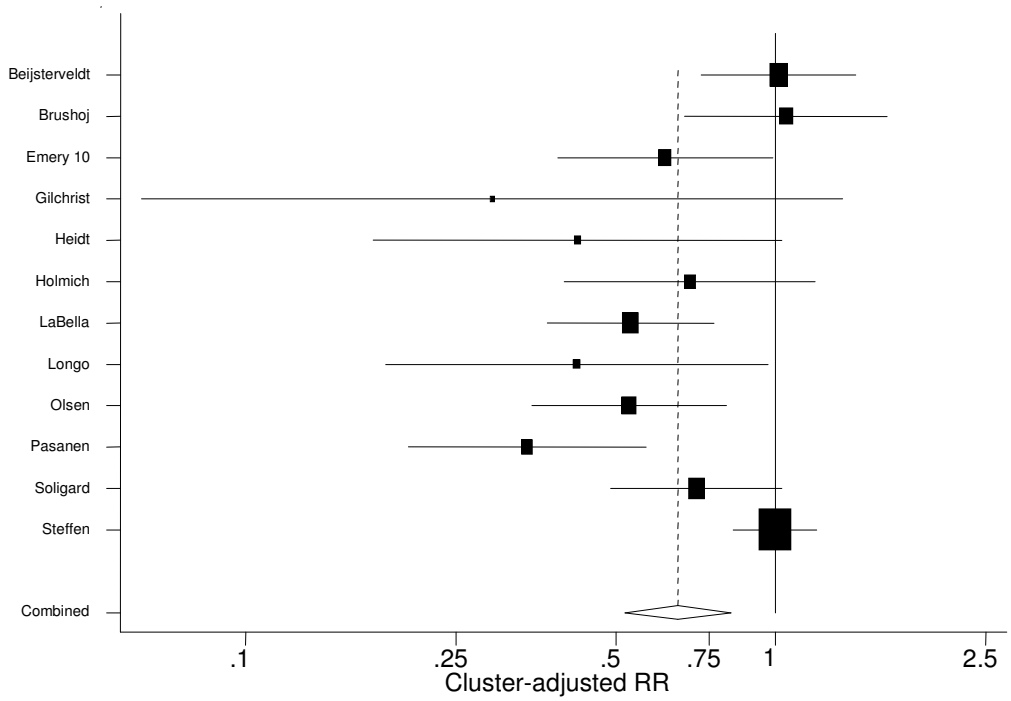
eFigure4, Proprioception training estimate Forest plot



eFigure5, Strength training estimate Forest plot

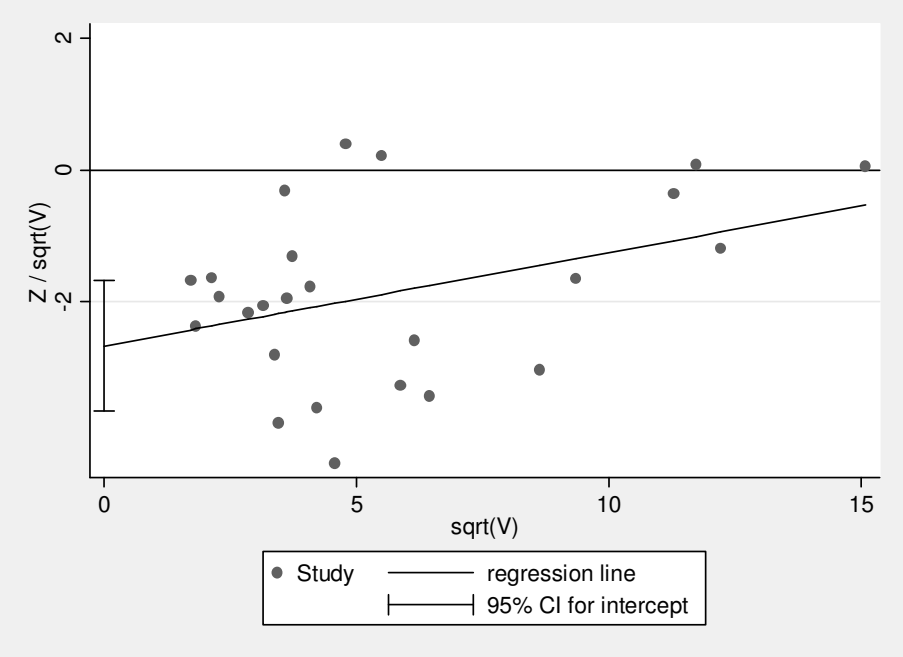


eFigure6, Multiple exposure studies estimate Forest plot



eFigure7, Modified Galbraith plot

Regress Z/sqrt(V) on sqrt(V) where Z is efficient score and V is score variance



eTable3, Harbord's tests for the total estimate and subgroups

Estimate	P-value for Harbord's test
Total estimate	< 0.001
Strength training	0.440
Proprioception training	0.128
Stretching	0.384
Multi interventions	0.012
Acute outcomes	0.129
Overuse outcomes	0.975