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Review

The effectiveness of proprioceptive training in preventing ankle sprains in sporting populations: A systematic review and meta-analysis

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ABSTRACT

Objectives: To systematically summarise the evidence on the effectiveness of proprioceptive training in reducing the incidence and recurrence rates of ankle sprains in the sporting population.
Design: A systematic review and meta-analysis of randomised controlled trials.
Methods: A computer-based literature search of MEDLINE, EMBASE, CINAHL, SPORTDiscus and PEDro (to October 2013) was conducted. Methodological quality of individual studies was assessed using the PEDro scale. Meta-analysis was performed on eligible studies to produce a pooled estimate of the effectiveness of the intervention.
Results: Seven moderate-to-high quality randomised controlled trials involving 3726 participants were included. Results of the meta-analysis combining all participants, irrespective of ankle injury history status, revealed a significant reduction of ankle sprain incidence when proprioceptive training was performed compared to a range of control interventions (relative risk = 0.65, 95% CI 0.55–0.77). Results favouring the intervention remained significant for participants with a history of ankle sprain (relative risk = 0.64, 95% CI 0.51–0.81). Results looking exclusively at primary prevention in those without a history were also statistically significant (relative risk = 0.57, 95% CI 0.34 to 0.97), although the pooled effect was obtained from two non-significant trials.
Conclusions: Proprioceptive training programmes are effective at reducing the rate of ankle sprains in sporting participants, particularly those with a history of ankle sprain. Current evidence remains inconclusive on the benefits for primary prevention of ankle sprains.

1. Introduction

Ankle sprains are the most common sports-related injury.[1] They are especially prevalent in sports requiring frequent jumping, directional changes and pivoting such as basketball, football, soccer, handball, netball, and volleyball.[1] Ankle sprains often result in pain, disability, dysfunction, time lost from activity, the requirement for treatment, and economic burden.[2–4] Furthermore, athletes who sprain their ankle are prone to reinjure the same ankle,[3,5,6] with recurrent ankle sprains commonly leading to ongoing impairment and chronic instability.[4,5,7]

Popular interventions for preventing ankle sprains include tape, ankle braces, evertor muscle strengthening and proprioceptive training.[5,8] Braces and tape have been shown to be effective preventive methods against ankle sprains,[5,8,9] however, they do have disadvantages. For example, there is some evidence that braces may hinder elements of athletic performance,[9,10] while taping needs to be skilfully applied, loosens with activity, and can irritate the skin.[9,11] Exercise programmes may avoid those disadvantages, although compliance is a potential barrier.[5,12] Athletes may also choose to utilise several preventative measures in conjunction, such as taping and an exercise programme.[5]

Proprioception is a complex neuromuscular process concerned with the internal kinaesthetic awareness of body position and movement.[13,14] It is reliant on appropriate afferent and efferent signalling and plays an important role in joint stability and injury prevention.[13,15] Proprioceptive training involves exercises that challenge the ability of the targeted joint to detect and react to afferent input regarding joint position.[13,15,16] Examples of proprioceptive exercises include balancing on a wobble board or ankle disc, throwing and catching or dribbling a ball whilst in single leg stance, or balancing with eyes closed.[11,17,18] There is evidence showing that one's risk of suffering an ankle sprain is doubled in

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the year following initial injury.[6,19] It is theorised that impaired proprioception in the injured joint pre-disposes it to re-injury.[20,21] Proprioceptive training aims to improve the capabilities of this system in order to prevent primary and secondary ankle injuries.

Several systematic reviews have explored the effectiveness of exercise programmes for the prevention and management of ankle sprains.[5,12,15,22–26] Components of these exercise programmes have included proprioceptive training, strengthening, agility, plyometrics, sport-specific exercises or a combination of several components (with the later often called neuromuscular training).[5,26] While most existing reviews have concluded that exercise programmes reduce ankle sprain injuries,[5,12,23,24,26] no reviews have focussed exclusively on the effects of proprioceptive training alone without the addition of co-interventions such as strengthening, plyometrics or agility training. It has been hypothesised that proprioceptive exercises may be the most important component of ankle rehabilitation programmes,[5] but to date the isolated effect of proprioceptive training has not been evaluated in a systematic review.

The purpose of this systematic review was to determine whether proprioceptive training as a sole intervention is effective for reducing the incidence or recurrence rate of ankle sprains among sporting populations.

2. Methods

A systematic review was performed using the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[27] and the Cochrane handbook.[28] Ethical approval was not required for this review.

A computerised literature search was performed in October 2013 using MEDLINE, EMBASE, CINAHL, SPORTDiscus and the Physiotherapy Evidence Database (PEDro). Search terms were developed in order to identify proprioceptive training programmes for the ankle joint in sporting populations. Full search terms for MEDLINE are presented in Supplemental File 1. Filters were utilised to limit results to human participants and studies published in English. No limitations were imposed on the date of publication. Additionally, the reference lists of all the selected publications and relevant systematic reviews were screened to retrieve any additional studies. As terminology for balance, proprioceptive and neuromuscular training is often used interchangeably,[24,26] we searched for all terms but only included studies that focussed solely on proprioceptive training (exercises to challenge the detection and maintenance of ankle joint position) without the addition of adjunct interventions such as muscle strengthening exercises.

Studies were included if they met the following criteria: (1) the study design was a moderate-to-high quality randomised controlled trial with a PEDro score of at least 4/10,[29] (2) participants were involved in recreational or professional sport, with or without a history of ankle sprain, (3) the intervention group received exclusively a proprioceptive training programme with no other adjunct interventions and was compared to a control group who did not receive proprioceptive training and (4) incidence or recurrence rate of ankle sprain was reported as an outcome measure.

Search results were stored and organised using the EndNote X6 computer software (Thomson-Reuters). Duplicates were removed and two authors (GSS & AJH) independently reviewed the studies for eligibility based on title and abstract. Studies deemed potentially eligible by at least one reviewer were then assessed independently by both reviewers for eligibility based on the full text. Any disagreements were to be resolved by consensus with the third author (LAR), however, this was not required.

The methodological quality of the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale. The scale is used to rate studies from 0–10 according to 10 methodological criteria (Supplemental File 2). This appraisal tool was chosen because it has been shown to provide sufficient reliability and validity for use in systematic reviews of physiotherapy related RCTs.[30,31] The scale was applied independently by two reviewers (GSS & AJH), with any differences in an article's assigned score being resolved by consensus.[28] For this review, it was considered unlikely that participants, therapists or assessors would be blinded to the intervention; therefore, a maximum score of 7 was predicted. With this in mind, studies scoring 6 or 7 were considered to be of 'excellent' quality, those scoring 5 were deemed 'good' quality and a score of 4 was felt to be of 'moderate' quality. Studies scoring less than 4 were considered to be of 'poor' quality and were excluded from the review.[29]

Two reviewers (GSS & LAR) independently extracted data from each included study. The data extracted included the number of participants, the nature, frequency and duration of the intervention received, details of the control group, follow-up periods and incidence rates of ankle sprain injuries. Relative risks (RR) and numbers needed to treat (NNT) were calculated using the PEDro confidence interval calculator (www.pedro.org.au). Data were assessed for statistical heterogeneity, which was considered likely if p-values of <0.1 were obtained on the X^2 test, or if the I^2 statistic was >25%.[32,33] Trials that were deemed to be statistically homogenous were subjected to meta-analysis. Meta-analyses were undertaken with RevMan 5.2 using a random-effects model. It was planned to undertake a pre-specified subgroup analysis that divided effects into those relating to participants with a history of ankle sprain and those without a history. Additional data were sought from authors of eligible studies for this purpose if it was not available within the article.

3. Results

Electronic database searches yielded 345 studies after the removal of duplicates (Fig. 1). Eighteen articles underwent full-text review. Eleven of these studies were excluded for the following reasons: they were not completed randomised controlled trials,[34–38] the proprioceptive training administered consisted of adjunct interventions (e.g. evertor strengthening),[39,40] the control group also received proprioceptive exercises,[41] or the study scored less than 4/10 on the PEDro scale.[42–44] This left seven total studies (involving 3726 participants) for inclusion in the final analysis.[11,18,45–49] One author provided additional data for the purposes of the planned subgroup analysis.[11] Characteristics of the included studies are presented in Table 1.

The PEDro scores of the included studies ranged from 4 to 7, with an average score of 5.4/10 (see Supplemental File 2 for individual scores). Using our PEDro score grading system, three articles were considered to be of "excellent" quality (scoring 6 or 7),[18,46,47] two were considered good quality (scoring 5),[11,48] and two were rated as moderate quality (scoring 4).[45,49]

The seven trials were found to be statistically homogenous, allowing for meta-analysis to be undertaken. Results of the meta-analysis revealed a statistically significant reduction in ankle sprains favouring the proprioceptive training group (7 trials, RR = 0.65, 95% CI 0.55–0.77) (Fig. 2 – top). This represented a pooled number needed to treat (NNT) of 17 (95% CI 33–11), indicating that 17 athletes would need to undertake proprioceptive training in order for one ankle sprain to be prevented. Comparison interventions included usual care/warm-up routines, strength training and an orthosis. When results were sub-divided to look at the secondary preventative effects of proprioceptive training on those exclusively with a history of ankle sprain, results were similarly in favour of the intervention (4 trials, RR = 0.64, 95% CI 0.51–0.81; NNT = 13,

Table 1
Characteristics of studies included for review.

Study details		Participants		Intervention				Outcome (ankle sprain rate)
Study	Quality	Characteristics	*n*	Intervention	Frequency/dosage	Duration	Control	Follow-up
Hupperets et al.[47]	Excellent PEDro = 7	Female (48%) and male athletes aged 12–70 (mean age 28) who had sustained an ankle sprain in the preceding two months	522	Usual care immediately post injury plus home based unsupervised proprioceptive training programme	3× 30 min sessions a week	8 weeks	Usual care immediately post injury only	One year
Emery et al.[46]	Excellent PEDro = 7	Female (50%) and male high school (12–18 years, median age 16) basketball players without (85%) and with (15%) history of ankle sprain	920	Sport-specific balance training programme and a home-based balance training programme using wobble board	5 min at each practice sessions (5× weekly) plus 20 min at home (unspecified frequency)	18 weeks	Standardised warm-up programme only	Baseline, 18 weeks. Phone follow up until 12 months post study for sustained but unresolved injuries obtained during the study
McGuine and Keene[18]	Excellent PEDro = 6	Female (68%) and male high school (12–18 years, mean age 16) basketball and soccer players without (76%) and with (24%) history of ankle sprain	765	5-phase balance training programme using single-leg stance exercises and wobble board	5× 5 min of balance training per week for 4 weeks preseason. 3× 10 min of balance training per week throughout the season	4 weeks pre-season and throughout season (unspecified duration)	Standard conditioning exercises as part of usual training	Baseline and conclusion of season (exact duration not specified)
Mohammadi[48]	Good PEDro = 5	Professional male soccer players aged 22–26 (mean age 25) years with a past history of ankle inversion sprain	80	Home-based proprioceptive training programme using ankle disc	30 min daily	120 sessions	Ankle evertor muscle strength training OR orthosis OR no intervention	Baseline and conclusion of season (approx 120 sessions of play. 1 session is equal to a training session or match)
Verhagen et al.[11]	Good PEDro = 5	Community-based female (57%) and male volleyball players (mean age of 24 years) without (33%) and with (67%) a past history of ankle sprain	1127	Balance board training programme performed as part of team warm-up	4× weekly for 5 min	36 weeks	Usual training routine only	Baseline and 36 weeks
Soderman et al.[49]	Moderate PEDro = 4	Female soccer players without (and with a history of ankle sprain (unspecified percentages)	140	Specific training programme consisting of balance board training in addition to their standard soccer practice and games	10–15 min, daily for first 30 days, and then 3× per week for rest of the season	7 months	Standard soccer practice and games only	7 months (one season)
Eils et al.[45]	Moderate (PEDro = 4)	Professional basketball players (14–43 years) without (53%) and with (47%) a history of ankle sprain who had never previously worn ankle brace or performed proprioceptive training	172	Multistation proprioceptive exercise programme	Once a week for 20 min	One season (unspecified duration)	Standard workout routines only	Baseline and conclusion of season (unspecified duration)

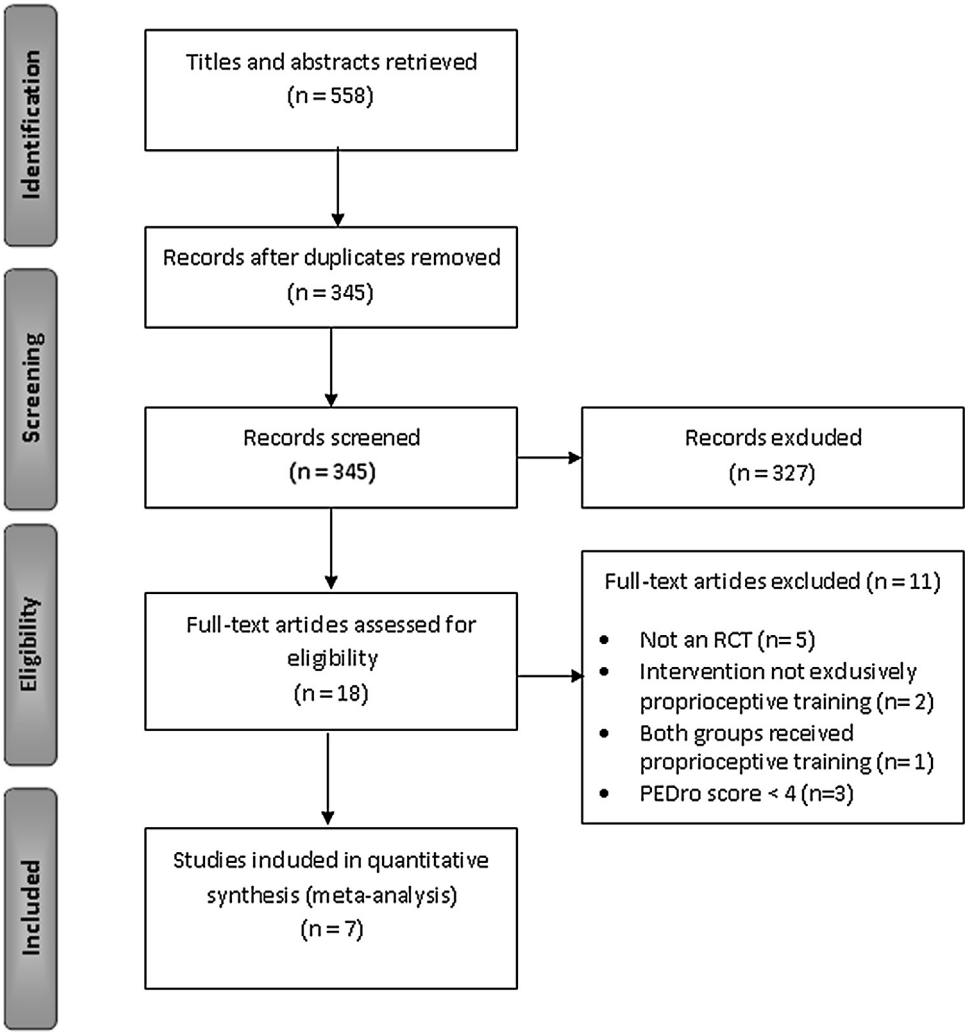


Fig. 1. Flow diagram for study inclusion.

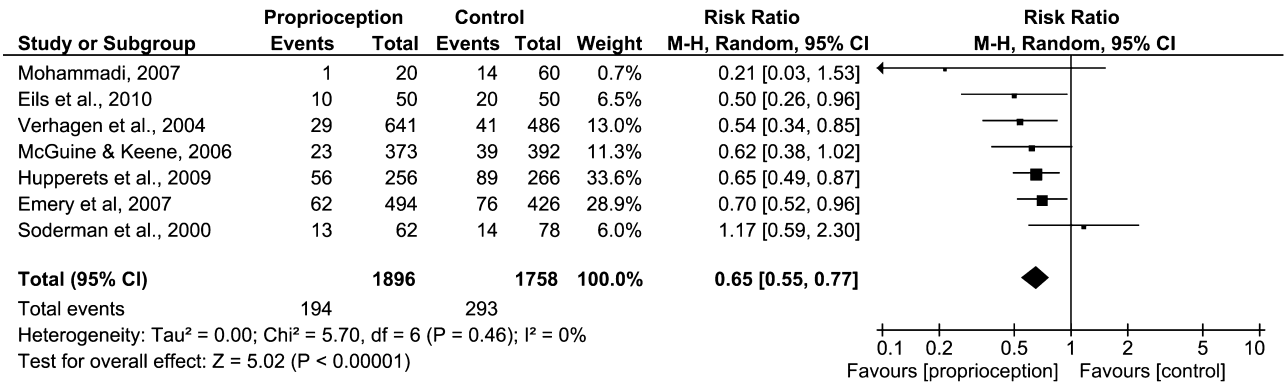
95% CI 100–7) (Fig. 2 – middle). When looking at proprioceptive training's effect as a form of primary prevention amongst sporting participants with no history of ankle injury, the pooled results were statistically significant (RR = 0.57, 95% CI 0.34 to 0.97; NNT = 33, 95% CI 1000 to 16), although only two non-significant trials were included in this comparison and the confidence interval was wide. (Fig. 2 – bottom).

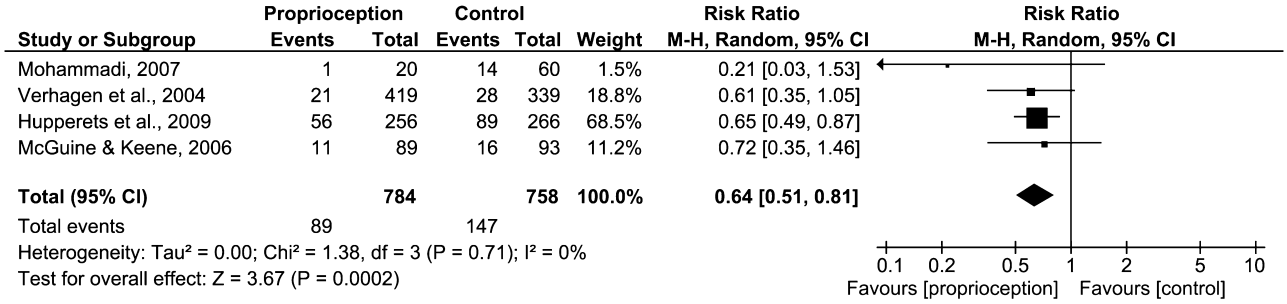
4. Discussion

Overall results of this systematic review and meta-analyses indicate that when considering all sporting participants, irrespective of their ankle injury history status, there was a preventative effect of proprioceptive training on ankle sprains (Fig. 2 – top). The pooled NNT values of 17 (95% CI 33–11) for all participants and 13 (95% CI 100–7) for those with a history of ankle sprain appear clinically relevant, as this equates to approximately one ankle sprain being prevented per sporting team by proprioceptive training. Subgroup analyses revealed that proprioceptive training programmes are effective as a form of secondary prevention for reducing the recurrence rate of ankle sprains in athletes with a history of injury (Fig. 2 – middle). The effectiveness of proprioceptive training as a form of primary prevention amongst athletes with no history of ankle sprain remains inconclusive, as the pooled point estimate was significant but should be interpreted with caution since it was derived from only two non-significant trials. (Fig. 2 – bottom).

The effectiveness of proprioceptive training for athletes with a history of ankle injury suggests that a rehabilitative effect may be an underlying mechanism. It has been proposed that proprioceptive training may address underlying impairments that predispose athletes to recurrent ankle sprains following an initial injury, such as restoring disrupted afferent pathways and protective reflexes around the ankle joint.[50,51] Applying this to a clinical context, the importance of this intervention should therefore be emphasised amongst those sporting participants with a history of ankle sprain.

Neither of the two trials with data relating to participants with no history of ankle sprain showed a primary preventative effect of proprioceptive training. However, there was a statistically significant pooled effect obtained via meta-analysis for this comparison in favour of proprioceptive training. (Fig. 2 – bottom). It is important to note that there were only two studies included in this pooled estimate investigating primary prevention.[11,18] Another study that did not differentiate between primary and secondary ankle injury in their results showed overall significant effects in favour of proprioceptive training despite 47% of their sample reporting no prior history of ankle injury (RR = 0.50, 95% CI 0.26–0.96).[45] If future studies report outcomes relating specifically to participants with no history of ankle sprain then estimates of the primary preventative effects of proprioceptive training should become more accurate.





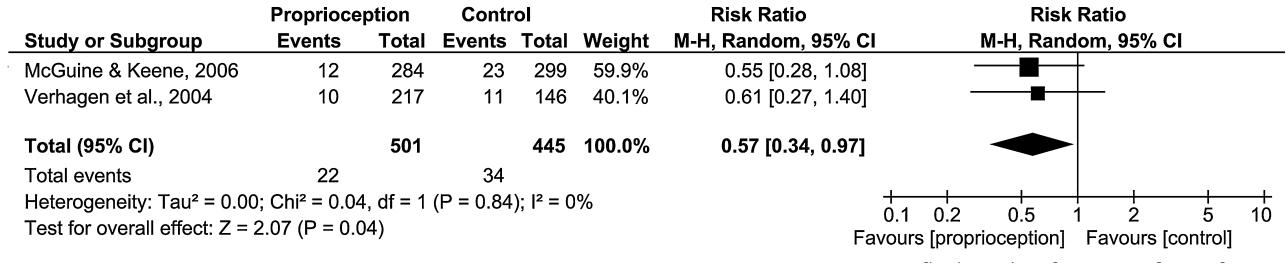


Fig. 2. Meta-analysis forest plots showing relative risk of ankle sprain (proprioceptive training versus control) in: (top) all participants regardless of injury history; (middle) participants with a history of ankle sprain, and; (bottom) participants without history of ankle sprain.

A limitation of the studies included in this review is the substantial variability and lack of detail reported in training parameters of the included studies. For example, the training frequency of the programmes ranged from 20 min a week[11,45] to 30 min daily,[48] while the duration of the programmes ranged from 8 weeks[47] to 36 weeks.[11] Furthermore, three of the studies failed to provide specific programme durations.[18,45,48] Despite this variability in training parameters, an overall effect was still detected in this review.

While the optimal dose-response ratio to achieve the prophylactic effects of proprioceptive training is not known, a cumulative effect may exist whereby longer programmes have a greater preventative effect.[52] Given the lack of detail in many of the included studies relating to intervention dosage and duration, it is difficult to determine whether the training programmes were implemented with sufficient training parameters to enable the intervention's prophylactic potential to truly take effect. Future studies should report training parameters fully to enable such considerations to be made.

Compliance levels must be taken into account when considering the impact of the proprioceptive training programme, as this will alter the intervention's apparent effect.[5] There was substantial variability in both the level of discussion of compliance in the studies, as well as in the levels of compliance reported in those studies that did monitor it. One study failed to mention compliance levels,[45] three studies acknowledged the lack of monitoring of compliance as limitations in their study designs,[11,48,49] while the three studies of excellent methodological quality reported non-compliance levels of 10%[18], 35%[47] and 40%[46] respectively. It is therefore possible, that had there been greater levels of compliance, the preventive effects of the proprioceptive training programme would have been larger.[5,12] However, compliance issues are a reality of the clinical setting with any exercise intervention, so the studies in this review reflect this clinical reality.

There are inherent study limitations relating to this area of research that influence methodological quality.[18] Owing to the nature of the intervention, subject, therapist and assessor blinding were not possible in any of the included studies. This lack of blinding may introduce an element of performance and detection bias which could potentially lead to an overestimation of the effect of intervention.[53] However, as active or usual routine controls were used in all of the included studies, the impact of this on results is likely to be minimal.[53] A common strength of the included studies was the minimisation of attrition bias.[18,45–48] This was due to the minimal drop-out rates and/or intention-to-treat analysis being used, thereby preserving group randomisation and maintaining validity of the results.[53]

Due to a number of similarities between the clinical context and that of the included studies, the results in this study can be applied clinically. Subjects included in the studies are representative of the population likely to be treated in practice, as they cover a wide range of age groups (12–70 years), include a relatively even representation of both genders, and range from community-based to professional athletes participating in high-risk ankle injury sports. The intervention and outcome measure are highly applicable as they are already widely used,[48] are inexpensive,[2,18] safe,[11,18,39,45,47–49] and can be independently self-administered once initially taught.[18]

This review has several strengths that differentiate it from previous reviews relating to the topic. Firstly, our review focuses very specifically on the effectiveness of proprioceptive training programmes as a sole intervention. Unlike other reviews in this field,[5,12,15,22–26] our review excluded studies allowing co-interventions (such as strengthening, agility training or plyometrics) that may confound the effects of the proprioceptive training element of the intervention. Results of other reviews may also be confounded by the inclusion of lower quality studies,[5,15,22,23,25,26] wheras our review focussed exclusively on moderate-to-high quality studies thereby increasing validity of the results and conclusions drawn. Another strength of our review is that it differentiates between the effectiveness of the intervention for those with and without history of ankle sprain. This enables more specific conclusions relating to functional outcomes in different populations. A further strength of our review that differentiates it from most others is that we used meta-analysis in order to establish pooled estimates of the effect of the intervention. Two previous reviews have utilised meta-analysis [12,15], but they included only three[12] and two[15] studies respectfully (with one study from each not qualifying for our review), whereas ours included seven.

Limitations of our review include the potential for publication bias as we did not search for unpublished trials. Furthermore, studies published in languages other than English were excluded. However, there is some evidence to suggest that excluding non-English articles does not typically have a large impact on systematic review results.[54]

Further research is likely to make additional contributions to knowledge in this field. In particular, there is a need for more high quality trials relating to the preventative effects of proprioceptive training for those without a history of injury, given that only two such studies were included in our review. Even in participants with a history of ankle sprain, proprioceptive training has not been compared to a wide range of comparisons, providing scope for future trials to add to existing knowledge. For example, a new RCT that was published after the completion of our review reported that a proprioceptive programme was less effective than bracing, however, compliance with exercises and bracing was poor and the confidence intervals were wide[55]. Further evaluation of the relative effects of proprioceptive training programmes in comparison to commonly used alternatives (such as bracing and taping) appear warranted, as does the evaluation of methods for increasing compliance to interventions.

5. Conclusion

This review found that proprioceptive training reduces the risk of sustaining an ankle sprain among sporting populations. Preventive effects have been established in mixed populations and in those with a history of ankle injury. The effectiveness of this intervention for participants without a history of ankle sprain was found to be inconclusive.

Practical implications

- Proprioceptive training is effective at reducing the rate of ankle sprains in sporting participants.
- Approximately 17 sporting participants, or 13 participants with a history of ankle sprain, need to undergo proprioceptive training in order to prevent one future ankle sprain.
- The preventative benefits of proprioceptive training have been well established in sporting participants with a history of ankle sprain (prevention of recurrence), but there is still insufficient evidence to be sure that it prevents initial injuries in those without a history of ankle sprain.

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Conflict of interests

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2014.04.005.

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