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Research

Injury prevention programs that include balance training exercises reduce ankle injury rates among soccer players: a systematic review

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KEY WORDS

Injury prevention programs
Balance exercises
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FIFA
Soccer
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ABSTRACT

Question: What is the effect of injury prevention programs that include balance training exercises on the incidence of ankle injuries among soccer players? **Design**: Systematic review of randomised trials with meta-analysis. **Participants**: Soccer players of any age, sex or competition level. **Interventions**: The experimental intervention was an injury prevention program that included balance training exercises. The control intervention was the soccer team's usual warm-up program. **Outcome measures**: Exposure-based ankle injury rates. **Results**: Nine articles met the inclusion criteria. The pooled results of injury prevention programs that included balance training exercises among 4,959 soccer players showed a 36% reduction in ankle injury per 1,000 hours of exposure compared to the control group with an injury risk ratio (IRR) of 0.64 (95% CI 0.54 to 0.77). The pooled results of the Fédération Internationale de Football Association (FIFA) injury prevention programs caused a 37% reduction in ankle injury (IRR 0.63, 95% CI 0.48 to 0.84) and balance-training exercises alone cause a 42% reduction in ankle injury (IRR 0.58, 95% CI 0.41 to 0.84). **Conclusions**: This meta-analysis demonstrates that balance exercises alone or as part of an injury prevention program decrease the risk of ankle injuries. PROSPERO CRD42017054450. **[Al Attar WSA, Khaledi EH, Bakhsh JM, Faude O, Ghulam H, Sanders RH (2022) Injury prevention programs that include balance training exercises reduce ankle injury rates among soccer players: a systematic review. *Journal of Physiotherapy* 68:165–173]**

Introduction

Ankle injuries represent the second most common category of injuries after knee injuries in sports such as rugby, soccer, volleyball, handball and basketball.[1] They can occur at training and at all levels of competition, representing nearly 15% of high school and university athletics injuries.[2,3] In soccer, the most popular world sport,[4] players are exposed to many types of injuries such as sprains, strains, contusions and fractures,[5] and the ankle is one of the most common sites of injury.[5] Furthermore, a history of ankle injury is associated with increased risk of developing osteoarthritis, joint instability and a low physical activity level.[6] People who have had an ankle injury are more than three times more likely to have an ankle injury in the future than those with no previous ankle injury.[3] Ankle injuries incur healthcare-related expenses and time lost due to injury.[7] In a typical soccer club of around 28 players, there is an average of seven ankle injuries per season.[8] Additionally, almost 87% of ankle injuries lead to time off due to injury and the mean time off per ankle sprain is around 15 days.[8] Therefore, prevention of ankle injuries among soccer players has the potential to make large reductions in complications and healthcare and social costs;[9] for example, Marshall et al[10] found that a neuromuscular training prevention program can reduce ankle injuries by 43% and healthcare costs by Canadian $2.7 million among the Calgary soccer clubs during the season.

Non-contact ankle injuries represent 33% to 64% of all ankle injuries in soccer players.[11–14] Balance, neuromuscular control and proprioception have been proposed as intrinsic risk factors for non-contact ankle injuries.[15] Among professional basketball and soccer players, poor single leg balance, laxity of the ankle joint and decreased ankle plantar flexion were more prevalent in players with a history of an acute or recurrent lateral ankle sprain,[16] but in that study it was not possible to know whether these deficits preceded the injury. Stronger evidence comes from a prospective cohort study,[17] which showed that amateur soccer players with poor balance and lower limb strength are at increased risk of sustaining non-contact ankle injuries.

Some individual studies have reported that balance training is an effective method of improving ankle stability and reducing ankle injuries.[18,19] Furthermore, balance exercises greatly contribute to the improvement in proprioception and balance,[20,21] and may also

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improve performance and prevent lower limb injuries.[21] In a randomised controlled trial with professional soccer players, 20 minutes of balance training for at least 18 training sessions increased proprioceptive ability and improved body control, although specific balance measures improved similarly in both groups.[22]

Several systematic reviews have provided some indication of the effect of balance training on ankle injury prevention in sport generally and in soccer specifically.[23–27] In sport generally, Hübscher et al[24] assessed the effect of neuromuscular training programs on injury incidence. The pooled result of multi-intervention programs that included balance training showed reductions in lower limb injuries by 39% (RR 0.61, 95% CI 0.49 to 0.77) and ankle sprain injuries by 50% (RR 0.50, 95% CI 0.31 to 0.79).[24] Furthermore, the pooled result of balance training alone reduced the risk of ankle sprain injuries (RR 0.64, 95% CI 0.46 to 0.90).[24] However, these meta-analyses were each based on only two studies. A later systematic review[25] confirmed that balance training reduced ankle sprains across various sports (RR 0.62, 95% CI 0.43 to 0.90, five studies) and also improved joint position sense, postural sway and dynamic neuromuscular control.

In soccer specifically, the systematic review by Ojeda et al[26] investigated which interventions are used to prevent lower limb injuries in soccer players; the interventions included proprioceptive training, neuromuscular training, balance training and postural control training.[26] Al Attar et al[23] published a systematic overview of the systematic reviews and meta-analyses that have investigated the preventive effect of the Fédération Internationale de Football Association (FIFA) injury prevention programs in soccer. The FIFA programs, which include the FIFA11 and the FIFA11+, include balance exercise, among other components. That overview found four systematic reviews with meta-analyses that examined the effect of the FIFA programs; there were consistently positive results among these reviews when they examined the effect of the FIFA11+ or mixed FIFA injury prevention programs on overall injury risk or lower limb injury risk. The effects on ankle injuries specifically were not reported.

Several randomised controlled trials have evaluated the effectiveness of balance exercises on the incidence and severity of ankle injuries in soccer players.[27–29] One study indicated that the incidence of ankle injuries was reduced in the experimental group compared with the control group (RR 0.5, 95% CI 0.26 to 0.97),[28] while two studies showed the possibility of clinically relevant effects in either direction for the incidence rate (RR 0.63, 95% CI 0.31 to 1.27)[27] and (RR 0.59, 95% CI 0.21 to 1.67).[29]

Given the inconsistent findings among these studies, there is a need to evaluate the role of injury preventon programs that include balance training exercises in preventing soccer-related ankle injury. However, none of the previous reviews assessed in isolation the effect of injury prevention programs that include balance training on reducing ankle injuries.

The aim of this systematic review was to investigate how much ankle injury rates (pooling initial ankle injuries and re-injuries) are influenced by injury prevention programs that include balance training in soccer players.

Therefore, the research question for this systematic review was:

What is the effect of injury prevention programs that include balance training exercises on the incidence of ankle injuries among soccer players?

Methods

The systematic review was prospectively registered and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[30]

Identification and selection of studies

Search strategy

Two researchers independently searched for relevant articles. The full search strategy is presented in Appendix 1 on the eAddenda. The systematic search covered publications from 1985 to 2020 using electronic databases: the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, Web of Science and the Physiotherapy Evidence Database (PEDro). The following keywords combination was used to perform electronic searches: (balance training) OR (proprioceptive training) OR (neuromuscular training) OR (injury prevention programs) OR (FIFA 11+) OR (sensorimotor) OR (stability training) AND (ankle sprain) OR (ankle injury) OR (inversion injury) OR (ankle instability) AND (soccer) OR (football) OR (athlete).

Eligibility criteria

The inclusion criteria are shown in Box 1. There were no restrictions on the age, sex or skill level of the soccer players in the eligible studies. Studies were excluded if the compliance of the participants with the randomised interventions was not reported. Studies were excluded if they had insufficient information and the corresponding author did not respond when contacted for missing data.

The records retrieved by the searches were pooled and duplicates were removed. The titles and abstracts of the remaining articles were screened for potential eligibility by two investigators working independently. The full texts of all potentially eligible studies were then obtained. Articles that did not meet the eligibility criteria were excluded. In the event of any discrepancies, a third reviewer was consulted to reach a consensus. The remaining list of included studies underwent reference tracking. Previous literature reviews were also screened for any further eligible studies. Commercial reference management software[a] was used for collecting studies, screening, eliminating duplicates and managing references.

Assessment of characteristics of studies

Risk of bias

The internal validity of all included studies was assessed by two reviewers working independently using the revised Cochrane Risk of Bias tool (RoB 2) for randomised trials,[31] as recommended by Armijo-Olivo et al.[32] Any discrepancy was resolved by a third reviewer.

Participants

The age and sex of the participants and their compliance with the study interventions were extracted for each included trial to characterise the experimental and control groups. The level of soccer competition was also extracted.

Intervention

The content of the injury prevention program was extracted from each included trial, along with the frequency of use prescribed and the total duration of the intervention period.

Box 1. Inclusion criteria.

Design
- (Cluster) randomised controlled trials
- Published in English

Participants
- Soccer players

Intervention
- Injury prevention programs that included balance training exercises

Outcome measures
- Reported at least two of: number of ankle injuries, ankle injury rate and exposure hours

Comparisons
- An injury prevention program that included balance training exercises versus usual/standard warm-up program

Outcome measures

Number of ankle injuries, ankle injury rates, exposure hours, follow-up duration and compliance rate were the outcome data elements that were extracted from the included trials.

Data analysis

Two researchers independently extracted data from the full-text versions of the eligible articles using a data extraction form. The main outcome results were extracted for each included study and collected in commercial spreadsheet software[b] prior to analysing them by commercial meta-analysis software.[c]

The meta-analysis software was used to enter and analyse extracted data for the meta-analyses, including subgroup analyses. The main meta-analysis was performed based on the total exposure hours. Subgroup meta-analysis was conducted for prespecified subsets of studies based on specific types of injury prevention program (balance exercise only, and the FIFA11+ program) and sex (male and female). The random-effects model was used, assuming that the studies incorporated a variety of populations and contexts as well as variation in the delivered balance training doses and procedures. The incidence of injuries represents the injury rate; it is favoured in sports research for estimating injury incidence, because it adjusts for the variation in athletes' exposure hours among the included studies.[33] This injury rate is determined by dividing the injury incidence number by the total risk time and multiplying by 1,000. Injury risk ratio (IRR) was the injury rate of the experimental group divided by the injury rate of the control group. A positive intervention effect is indicated by an IRR < 1; for example, an IRR of 0.80 indicates a 20% reduction in the injury rate relative to the control group. Each IRR was reported with a 95% CI. The heterogeneity was measured by conducting an I^2 test for each meta-analysis; I^2 values of 25%, 50% and 75% were interpreted as low, moderate and high heterogeneity, respectively.[34]

If 10 studies were available, it was intended to create a funnel plot to assess the risk of potential publication bias. Egger's test[35] and Begg's test[36] would then be performed to assess the funnel plot asymmetry. The Duval and Tweedie's Trim and Fill method[37] would be applied to determine whether the overall IRR estimate required any adjustments for the publication bias based on the filled studies.

Definitions of injury and athlete workload

According to the consensus statement of sports epidemiologists, ankle injuries in the included trials were required to meet the definition that the injury caused the player to be completely incapable of participating in the following game or training session.[38] Athlete workload was defined as the number of active hours spent by athletes in either training or competition during the study period.[39]

Results

Flow of studies through the review

The initial database searches retrieved 5,372 records. After removal of duplicates, 3,689 records were screened based on assessment of the titles and abstracts, leaving 57 full-text articles to be assessed. Forty-eight articles did not meet the eligibility criteria. Thus, nine articles were included in this meta-analysis. Figure 1 shows the flow of articles through the search, screening and inclusion processes.

Characteristics of studies

Eight studies were cluster randomised controlled trials[28,29,40–45] and one was an individual randomised controlled trial.[27] Three studies were conducted in the USA,[29,40,43] two in Norway,[27,41] one in Canada,[28] one in Australia[44] and one in Nigeria,[42] with one multicentre study conducted in four countries (Germany, Switzerland, the Netherlands and Czech Republic).[45]

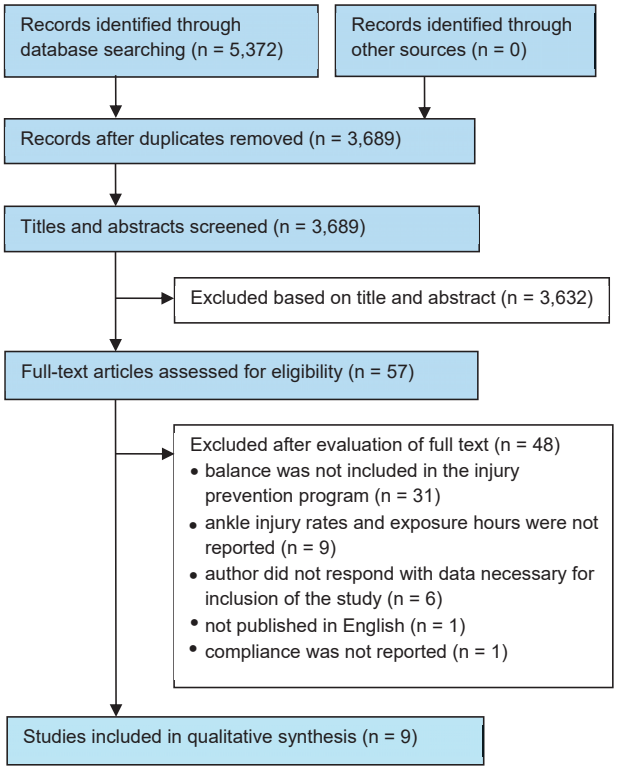

Figure 1. Flow of trials through the review.

Risk of bias

The results of the risk of bias assessment are presented in Figure 2 and Appendix 2 (see eAddenda for Appendix 2). The randomisation process was assessed as low risk of bias in eight of the included studies,[28,29,40–45] with some concerns of bias in the other study.[27] Eight studies were at low risk of bias from deviations from intended interventions,[27,28,40–45] with some concerns of bias in the other study.[29] The risk of bias due to missing outcome data was classified as low in seven studies[27-29,40-42,44] and high in two studies.[43,45] Bias in the measurement of the outcome was assessed as low in three studies[28,41,44] and high in five studies,[27,40,42,43,45] with some concerns of bias in one study.[29] Risk of bias in the selection of the reported result was low in all of the included studies.[27-29,40–45]

Participants

Four studies included males only,[27,42–44] two included females only[29,41] and three included both male and female participants.[28,40,45] Four studies included soccer players aged 13 to 19 years;[28,40–42] one study included collegiate soccer players aged 18 to 25 years;[43] one study included amateur soccer players aged 14 to 35 years;[44] one study included soccer players participating in the Norwegian First, Second, and Third Division, aged 17 to 35 years;[27] one study included middle and high school soccer players aged 12 to 16 years;[29] and one study included child soccer players aged 7 to 13 years.[45]

Interventions

Four studies used the FIFA 11+ injury prevention program as a warm-up for the experimental groups,[41–44] of which one study performed the FIFA 11+ program before and after training.[44] The '11+' program includes three levels of single-leg stance exercise (level one: hold the ball; level two: throwing the ball with a partner; level three: test your partner), two sets for each, 30 seconds for each leg. One study used the FIFA 11+ program for kids,[45] including five levels of single-leg stance exercise (level one: throwing the ball, one set on each leg, five throws per player; level two: throwing the ball and move it around the free leg, one set on each leg, five throws per player; level three: passing game, one set on each leg, five passes per player; level four: throwing the ball and passing back without touching the ground, one set on each leg, five throws per player; and

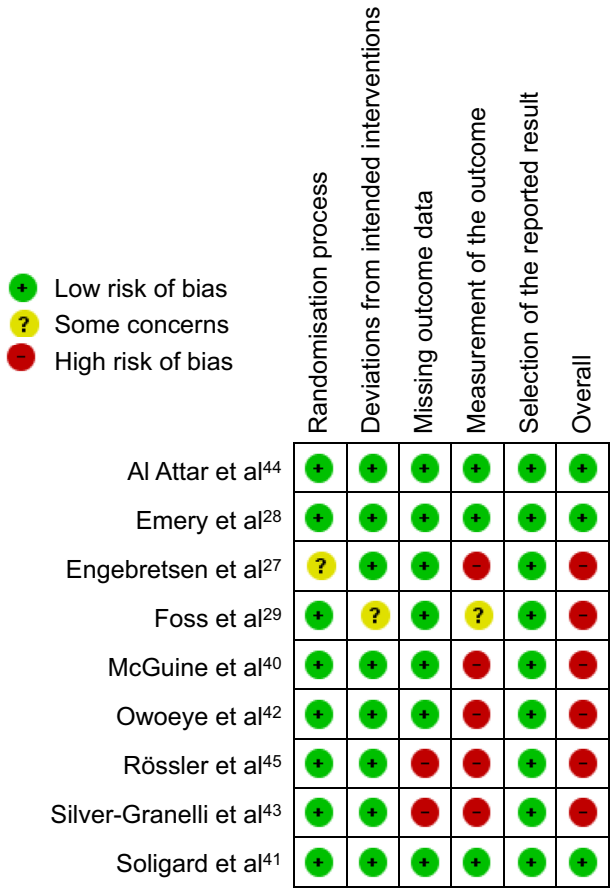

Figure 2. Risk of bias assessment of the included studies.

level five: testing the partner's balance, one set on each leg, 20 seconds for each). One study used 5 minutes of warm-up routine, which included aerobic exercise and dynamic stretching in addition to 10 minutes of a specific neuromuscular training program including strength, balance and agility, with a further 15-minute home-based balance training program using a balance board.[28] One study applied 20 to 25 minutes of neuromuscular training including strength, plyometric and balance exercises such as single-leg Romanian deadlift.[29] Two studies used only balance training programs but in different ways:[27,40] the experimental group of one study participated in a balance training program for the ankle joint using a balance board and balance pad,[27] whereas the experimental group of the other study performed a balance training program comprising five phases on different surfaces, performed with open and closed eyes.[40] The duration of the injury prevention programs in the included studies ranged from 10 weeks to 12 months.

For the control intervention, five studies used usual warm-up programs,[27,41-43,45] one study used pre-training of the FIFA 11+ injury prevention program only (where the experimental group had used it before and after training),[44] one study used a protocol consisting of resisted running using elastic bands,[29] one study used standard conditioning exercises only,[40] and one study used a standardised warm-up (include static and dynamic stretching, and aerobic components) and a home-based stretching program for control groups.[28] Table 1 summarises the characteristics of the nine included studies.

Effect of the intervention

Pooled injury estimates

Table 2 presents the rates of ankle injury and exposure hours for intervention and control groups. From the nine included studies, pooled data from 9,633 participants with 775,606 exposure hours identified 529 ankle injuries.

Reduction of ankle injuries based on total exposure hours

The pooled results showed a 36% reduction in overall ankle injuries per 1,000 hours of exposure in the group using injury prevention programs that included balance training exercises compared with control (IRR 0.64, 95% CI 0.54 to 0.77). The inconsistency statistic indicated no heterogeneity between studies (I^2 = 0%) (Figure 3a). See Figure 4a on the eAddenda for a detailed forest plot.

Subgroup analyses

The pooled estimate of the effect of the FIFA 11+ injury prevention program was a 36% reduction in ankle injuries per 1,000 hours of exposure (IRR 0.64, 95% CI 0.48 to 0.84) compared with control (Figure 3b). The inconsistency statistic indicated moderate heterogeneity among FIFA 11+ injury prevention program's studies (I^2 = 36%). See Figure 4b on the eAddenda for a detailed forest plot.

The pooled estimate of the effect of balance training exercises alone was a 41% reduction in ankle injuries per 1,000 hours of exposure (IRR 0.59, 95% CI 0.41 to 0.84) when compared with control (Figure 3c). The inconsistency statistic indicated that these studies were homogeneous (I^2 = 0%). See Figure 4c on the eAddenda for a detailed forest plot.

Injury prevention programs that include balance training exercises reduced the rate of ankle injuries per 1,000 hours of exposure by 42% in the trials with male participants (IRR 0.58, 95% CI 0.45 to 0.76), by 15% in the trials with female participants (IRR 0.85, 95% CI 0.59 to 1.22) and by 41% in the trials with some male and some female participants (IRR 0.59, 95% CI 0.42 to 0.83). The inconsistency statistic indicated negligible or no heterogeneity in these analyses (Figure 5). See Figure 6 on the eAddenda for a detailed forest plot.

Publication bias

No analysis of publication bias was undertaken because this review was unable to include a minimum of 10 trials in the review and meta-analysis.

Discussion

This is the first systematic review and meta-analysis that has evaluated the effectiveness of injury prevention programs that included balance training exercises for reducing the incidence of ankle injuries among soccer players. The nine included randomised controlled trials[27-29,40-45] yielded strong evidence that balance exercises undertaken alone or as part of an injury prevention program are very effective in reducing the risk of ankle injuries in soccer players. The main outcome of the current meta-analysis was the exposure-based ankle incidence rates, and the analysis revealed that injury prevention programs that include balance training exercises reduced the risk of ankle injuries in soccer players by 36% based on total exposure hours.

The trials of injury prevention programs that include balance training exercises were divided into two subgroups: the trials of the FIFA 11+ injury prevention program formed one group, while the studies that included neuromuscular training or balance training alone were included in the specific balance training subgroup. The FIFA 11+ injury prevention program and the specific balance training programs demonstrated ankle injury reductions of 36% and 41%, respectively. This is consistent with the meta-analysis conducted by Al Attar et al[46] in 2015, which investigated the effectiveness of the FIFA injury prevention programs in reducing soccer-related injuries. The findings of that review demonstrated a reduction in overall injuries by 23% (IRR 0.77, 95% CI 0.65 to 0.92) and a 24% reduction in lower extremity injuries (IRR 0.76, 95% CI 0.62 to 0.94).[46]

Several meta-analyses have investigated the effectiveness of proprioceptive and balance training exercises in reducing the incidence of ankle injuries among different sports, not only soccer.[25,47,48] A systematic review with meta-analysis by Bellows et al[48] included eight randomised controlled trials to assess the effect of ankle bracing and balance training in reducing the incidence of ankle injuries in competitive athletes across different sports. Bellows et al[48] reported that athletes who performed balance training showed a reduction in

Table 1
Characteristics of the included trials (n = 9).

Study Design Country	Participants	Intervention		Outcome measures
		Exp	Con	
Al Attar 2017 [44] Cluster RCT Australia	N = 280 Age *(yr)* = 14 to 35 Sex = M Compliance *(%)* = 83 Amateur soccer	FIFA 11+ program performed before and after training 2 to 3/week × 6 months	FIFA 11+ program performed before training only 2 to 3/week × 6 months	Ankle injuries
Emery 2010 [28] Cluster RCT Canada	N = 744 Age *(yr)* = 13 to 18 Sex = M, F Compliance *(%)* = 85 Youth soccer	Soccer-specific neuromuscular training program including dynamic stretching, eccentric strengthening, agility, jumping and balance exercises (including home-based balance training using a wobble board) 3/week × 12 months	Standardised warm-up (static and dynamic stretching and aerobic components) and a home-based stretching program 3/week × 12 months	Ankle injuries
Engebretsen 2008 [27] RCT Norway	N = 209 Age *(yr)* = 17 to 35 Sex = M Compliance *(%)* = 28 First, Second and Third Division soccer	Targeted exercise program including balance exercise using a balance board and balance pad, and bouncing with both legs and single leg 2 to 3/week × 2.5 months	Neuromuscular training, Nordic hamstring lowers and groin strength training 2 to 3/week × 2.5 months	Ankle injuries
Foss 2018 [29] RCT USA	N = 142 Age *(yr)* = 12 to 16 Sex = F Compliance *(%)* = 95 Middle school and high school soccer	Neuromuscular training program including strengthening, plyometric exercises and balance exercises (eg, variations in jumping techniques, single-leg exercises, balance on an inflated hemisphere and Romanian deadlift) 2 to 3/week × 6 months	Resisted running using elastic bands 2 to 3/week × 6 months	Ankle injuries
McGuine 2006 [40] RCT USA	N = 530 Age *(yr)* = 15 to 18 Sex = M, F Compliance *(%)* = 85 Youth soccer	Balance training program comprising five phases on different surfaces, performed with eyes open and closed 3 to 5/week × 5 months	Standard conditioning exercises, without any balance training exercises 3 to 5/week × 5 months	Ankle injuries
Owoeye 2014 [42] Cluster RCT Nigeria	N = 416 Age *(yr)* = 14 to 19 Sex = M Compliance *(%)* = 60 Youth soccer	FIFA 11+ program including three levels of balance exercises in single-leg stance: L.1 hold the ball, L.2 throwing the ball with a partner and L.3 test your partner 2/week × 6 months	Aerobic warm-up (eg, jogging), static stretches and soccer skills practice (eg, running/cutting drills) 2/week × 6 months	Ankle injuries
Rössler 2017 [45] Cluster RCT Switzerland, Germany, Czech Republic, Netherlands	N = 3,895 Age *(yr)* = 7 to 13 Sex = M, F Compliance *(%)* = 50 to 100 Children's soccer	FIFA 11+ Kids program including five levels of balance exercise in single-leg stance: L.1 throw the ball, L.2 throw the ball and move it around the free leg, L.3 passing game, L.4 throw the ball and pass back without touching the ground, L.5 testing your partner 2/week × 12 months	Standard warm-up, typically including aerobic exercise (eg, running laps of the pitch), static and dynamic stretching, soccer skills practice (eg, dribbling and passing) and small-sided games 2/week × 12 months	Ankle injuries
Silvers-Granelli 2015 [43] Cluster RCT USA	N = 1,525 Age *(yr)* = 18 to 25 Sex = M Compliance *(%)* = 73 Collegiate soccer	FIFA 11+ program including three levels of balance exercises in single-leg stance: L.1 hold the ball, L.2 throwing the ball with a partner and L.3 test your partner 3/week × 6 months	Aerobic warm-up (eg, running exercises), static and/or dynamic stretching and soccer skills practice (eg, cutting and short passing drills) 3/week × 6 months	Ankle injuries
Soligard 2008 [41] Cluster RCT Norway	N = 1,892 Age *(yr)* = 13 to 17 Sex = F Compliance *(%)* = 77 Youth soccer	FIFA 11+ program including three levels of balance exercises in single-leg stance: L.1 hold the ball, L.2 throwing the ball with a partner and L.3 test your partner 3/week × 8 months	Standard warm-up, typically including running exercises to warm-up and static stretches 3/week × 8 months	Ankle injuries

Con = control group, Exp = experimental group, F = female, FIFA 11+ = Fédération Internationale de Football Association 11+ injury prevention program, L = level, M = male, RCT = randomised controlled trial.

ankle sprains of 46% compared with control groups that did not receive any intervention (RR 0.54, 95% CI 0.29 to 0.90), based on the analysis of 3,577 participants. Furthermore, de Vasconcelos et al[25] conducted a systematic review and meta-analysis that included 12 randomised controlled trials in different languages, five of which were included in the quantitative analysis to investigate the effectiveness of balance training in reducing ankle sprains among athletes. They found that balance training increased the reduction of ankle sprain incidence by 38% compared with the control group (RR 0.62, 95% CI 0.43 to 0.90), based on the analysis of 1,606 participants.[25] Another meta-analysis by Schiftan et al[47] of seven randomised controlled trials investigated the effectiveness of proprioceptive training in reducing the incidence of ankle sprains in different sports populations, with or without ankle injury history. They found that regardless of the previous history of ankle injury, athletes who participated in proprioceptive training had a 35% reduction in the incidence of ankle sprains (RR 0.65, 95% CI 0.55 to 0.77); results were similar in a subgroup analysis of participants with and without ankle sprain history: RR 0.64 (95% CI 0.51 to 0.81) and RR 0.57 (95% CI 0.34 to 0.97), respectively.[47]

All of the other systematic reviews on similar topics relied on the number of ankle injuries rather than incidence rates,[25,47,48] with analyses based on the number of participants who became injured, without considering the athletes' exposure time. The incidence rate is the preferable and more meaningful measure of injury incidence in sports research studies because it can accommodate the variations in the athletes' exposure time and provide an estimate of the injury risk;[33,49,50] moreover, it provides an important foundation to study possible predictive factors and the efficacy of preventive measures.[33] Soomro et al[51] and Al Attar et al[46] proposed in their meta-analyses,

Table 2
Injury rates per 1,000 hours of exposure in the experimental and control groups of the included studies.

Study	Exp				Con				Injury risk ratio (95% CI)
	N	Ankle injuries	Exposure hours	Ankle injuries/1,000 hours	N	Ankle injuries	Exposure hours	Ankle injuries/1,000 hours	
Al Attar 2017 [44]	144	4	35,802	0.112	136	12	31,616	0.380	0.29 (0.10 to 0.91)
Emery 2010 [28]	380	14	24,051	0.582	364	27	23,597	1.144	0.51 (0.27 to 0.97)
Engebretsen 2008 [27]	102	13	21,666	0.600	107	20	22,222	0.900	0.67 (0.33 to 1.34)
Foss 2018 [29]	74	6	6,060	0.990	68	9	5,409	1.664	0.60 (0.21 to 1.67)
McGuine 2006 [40]	251	13	12,173	1.068	279	24	13,434	1.787	0.60 (0.31 to 1.17)
Owoeye 2014 [42]	212	10	51,017	0.196	204	30	61,045	0.491	0.40 (0.20 to 0.82)
Rössler 2017 [45]	2,066	26	140,716	0.185	1829	44	152,033	0.289	0.64 (0.39 to 1.04)
Silvers-Granelli 2015 [43]	675	59	35,226	1.675	850	115	44,212	2.601	0.64 (0.47 to 0.88)
Soligard 2008 [41]	1,055	51	49,899	1.022	837	52	45,428	1.145	0.89 (0.61 to 1.31)
Pooled data	4,959	196	376,610		4,674	333	398,996		0.64 (0.54 to 0.77)

which investigated the effectiveness of several injury prevention programs, that the athlete's injury risk can be influenced by the exposure time of the player. It has been found that the athletes' risk of injury was associated with an increase in the amount of exposure to sports.[52,53] Therefore, using athletes' exposure-based incidence rate in evaluating the efficacy of injury prevention programs is more accurate and powerful.

The subgroup analyses suggested that injury prevention programs that include balance training exercises might be more effective at reducing ankle injuries in male soccer players than female soccer players. When comparing studies including only male participants[27,42–44] with studies including only female participants,[29,41] the pooled IRRs were 0.58 (ie, a 42% reduction) and 0.85 (ie, a 15% reduction), respectively. However, these subgroup analyses were based on few trials, so there is considerable uncertainty in their estimates: IRR 0.58 (95% CI 0.45 to 0.75) and IRR 0.85 (95% CI 0.59 to 1.22), respectively. The 15% reduction in ankle injuries detected in the pooled studies with only female participants should be interpreted with caution because the confidence interval does not exclude the possibility that the intervention is ineffective. At any rate, the pooled results of the three studies that included both males and females showed a 41% reduction in the risk of ankle injury.[28,40,45] Consequently, further research studies are required to investigate the effect of injury prevention programs that include balance training exercises for reducing ankle injuries in female soccer players, especially because female athletes are at higher risk of sustaining ankle injuries than males.[50]

It was difficult to comment on the most appropriate balance training protocol, as the programs varied in multiple ways including duration, frequency and the specific exercises used. Therefore, more trials are needed to determine the dose-response relationship and the optimal strategy of the balance training program to prevent ankle injuries. However, it is assumed that a valuable outcome is achieved

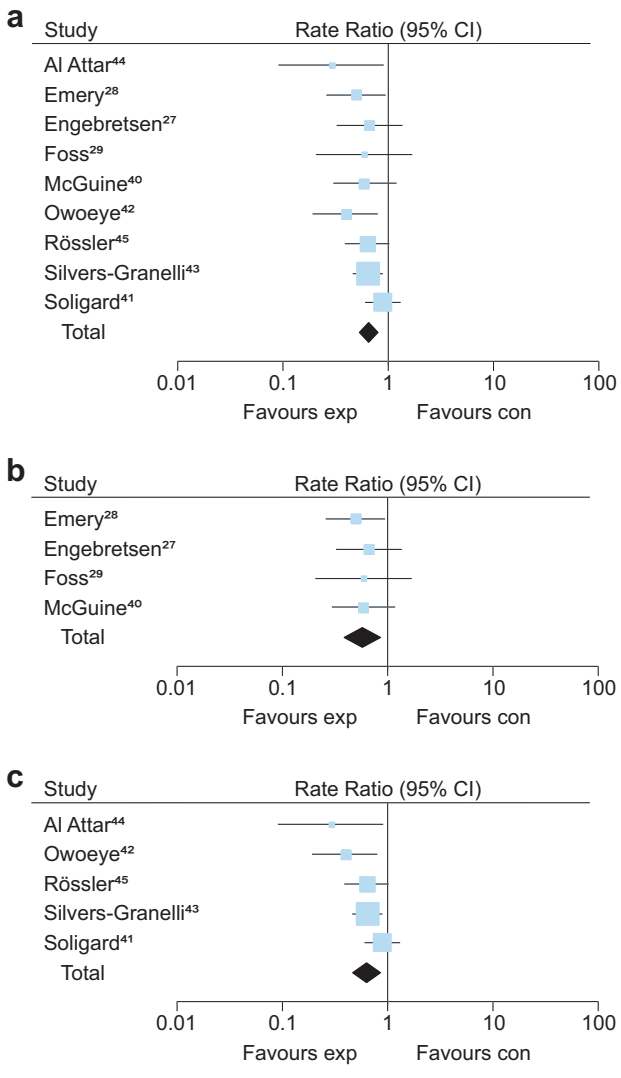

Figure 3. Forest plot of the effect on ankle injury rate ratio of (a) injury prevention programs that included balance training versus control; (b) balance training exercises alone versus control; and (c) Fédération Internationale de Football Association 11+ (FIFA 11+) injury prevention program versus control.

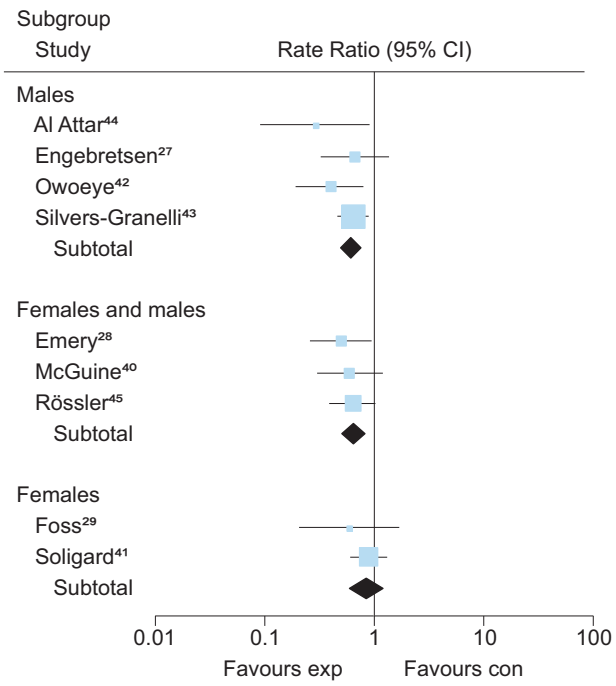

Figure 5. Detailed forest plot of the effect of injury prevention programs that included balance training versus control on ankle injury rate ratio, subgrouped according to the sex of the study participants.

when performing training sessions two to three times per week for 6 to 12 months.[28,42–44] It has been hypothesised that to achieve a preventive effect it is necessary to carry out the training session for at least 10 minutes,[24] more than once per week for 3 to 12 months,[24,54] taking into account that a higher number of sessions will result in extra benefits.[46]

The level of compliance with injury prevention programs affects injury rates.[55] The findings of two studies indicated that when compliance increased, the risk of injury decreased;[56,57] so compliance can influence the efficacy of the prevention program.[58] Therefore, one study was excluded from this review because the authors mentioned that they had no information about participants' compliance with the injury prevention programs that they used;[18] however, their findings showed that proprioceptive training reduced the ankle incidence rate (RR 0.13, 95% CI 0.003 to 0.93). The studies included in the current meta-analysis reported a moderate to excellent degree of compliance (60% to 100%) with the preventive programs used,[28,29,40–45] except for one study, which reported low participant compliance of 28% with the targeted prevention program.[27] All studies with moderate to high compliance revealed a higher reduction in injuries in the experimental group than the control, regardless of the prevention program used.[28,29,40–45] Nevertheless, only four included studies with moderate to high compliance of 60% to 85% showed a substantial reduction in ankle injuries in soccer players.[28,42-44] Therefore, due to the differences between previous literature and the current findings regarding the relationship between athletes' compliance and the reduction in injury risk, further studies are needed to determine how the compliance influences the efficacy of injury prevention programs that include balance training exercises for reducing ankle injury risk among soccer players.

It was difficult to run an additional analysis based on the history of ankle injury, as most of the studies did not distinguish between whether participants had a history of ankle injury or not. However, one included study examined the preventive effect of balance exercises on soccer players with a history of ankle injury, and the results showed a reduction in ankle injuries by 33% (IRR 0.67, 95% CI 0.33 to 1.34).[27] Another study investigated the effectiveness of a balance training program in reducing the risk of ankle injuries among soccer and basketball players, and the second objective of that study was to compare the effectiveness of balance training between athletes with and without a history of a previous ankle injury.[40] The findings showed no clear reduction in ankle injuries among athletes without a prior ankle injury, while a strong effect was identified among those with a history of ankle injury (RR 2.14, 95% CI 1.25 to 3.65).[40] Furthermore, previous clinical trials showed a reduction in ankle injuries when performing a proprioceptive training program in athletes with a history of ankle injury only.[59–61] Moreover, the previously mentioned meta-analysis by Schiftan et al[47] revealed a marked reduction in ankle sprains in sporting populations with and without a history of ankle injury: RR 0.64 (95% CI 0.51 to 0.81) and RR 0.57 (95% CI 0.34 to 0.97), respectively. This indicates that proprioceptive training is an effective element in preventing secondary ankle sprains in different sporting populations. Furthermore, a meta-analysis by Vriend et al[62] assessed the preventive effect of neuromuscular training that included balance exercises on the primary and secondary ankle injury among different sports. The findings demonstrated that neuromuscular training is an effective strategy for reducing ankle injuries in athletes with a history of ankle sprain (RR 0.69, 95% CI 0.49 to 0.98), but the evidence remained inconclusive for preventing primary ankle sprains.[62] Therefore, there is a need for more cluster-randomised controlled trials comparing the prophylactic effect of balance training in soccer players with and without a history of ankle injury.

This review included subgroup analyses of sex (male, female) and type of intervention (FIFA 11+ injury prevention program, specific balance training) to provide a better understanding of the factors that would influence the ankle injury risk. The uniqueness of this meta-analysis lay in the high methodological standards used in this review, including using exposure-based incidence rates. In addition, all eligible studies with missing data were initially included, as their authors were contacted to provide specific data of soccer players if they reported only general results such as ankle injury rate for multiple sports.

This review also had some limitations. First, only studies published in English language were included; however, language restrictions do not necessarily influence or bias the systematic review results.[63] Second, there were no specific criteria for the level of competition, and so the analysis included data across ages, sex, and playing grades; however, this variety does improve the external validity of the review. Third, a reduction in the rate of ankle injuries could be influenced by other training elements of the preventive program and this might confound the preventive effect of the balance training exercises; to address this, this review analysed the subgroup of trials that evaluated the preventive effect of balance exercises in isolation.

Further research evaluating the implementation of balance training exercises as a preventive strategy for ankle injuries in soccer players is recommended: to investigate the effectiveness of balance exercises among players with and without a history of an ankle injury; and to assess whether balance training exercises are effective in reducing ankle injuries among athletic populations other than soccer, especially those who are at high risk of sustaining ankle injuries in sports such as basketball, rugby, volleyball and handball.[1]

In conclusion, this is the first level 1 meta-analysis to show that balance exercises alone or combined with an injury prevention program lead to a significant reduction in ankle injuries in soccer players. In addition, it is the first meta-analysis to set out the effectiveness of injury prevention programs that included balance training exercises in preventing ankle injuries among male and female soccer players. The results showed that performing injury prevention programs that include balance training exercises could reduce ankle injury rates by 36% compared with teams that did not apply. These findings can help stakeholders regarding the implementation of balance training as a preventive measure of ankle injuries for soccer players.

What was already known on this topic: Soccer players commonly sustain ankle injuries, leading to healthcare expenses and lost playing time.

What this study adds: Among a diverse population of soccer players, injury prevention programs that include balance training exercises reduced ankle injury risk by 36%. Balance training exercises alone produced a 42% reduction in ankle injury risk.

Footnotes: [a] Endnote version X8, Thomson Reuters, Philadelphia, USA.

[b] Microsoft Excel for Mac 2011, Microsoft Corporation, Redmond, USA.

[c] Comprehensive Meta-Analysis software V.3, Biostat Inc, Englewood, USA.

eAddenda: Figures 4 and 6, and Appendices 1 and 2 can be found online at https://doi.org/10.1016/j.jphys.2022.05.019

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