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Review

Injury prevention strategies specific to pre-elite athletes competing in Olympic and professional sports — A systematic review

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ABSTRACT

Objectives: To describe and evaluate injury prevention interventions for pre-elite athletes who compete in an Olympic or professional sport.
Design: Systematic review.
Methods: This review was prospectively registered (PROSPERO CRD42017065083) and a systematic electronic search was conducted in May 2017. The following inclusion criteria were applied: (1) studies including and analysing data specific to pre-elite athletes (determined by the T3/T4 levels of the FTEM model); (2) featured injury prevention interventions; (3) provided sufficient data related to injury such that the effect can be analysed e.g. injury rates, incidence, prevalence, injury rate ratios; (4) featured randomised and non-randomised controlled trials or prospective cohorts.
Results: A total of 13,480 articles were retrieved with 121 titles identified and 11 studies satisfying the inclusion criteria. No studies demonstrated a low risk of bias. Four different interventions were identified: exercise (n = 7, 64%), psychological (n = 2, 18%), equipment (n = 1, 9%), nutrition (n = 1, 9%). Of the seven exercise interventions, four showed a protective effect and three found no significant effect, providing conflicting evidence. Caution is advised due to high risk of bias, low intervention reporting and minimal evidence for implementation planning in all seven studies.
Conclusions: There is limited evidence from level 2 and 3 studies suggesting exercise and psychology interventions may prevent injury in pre-elite athletes. There is an absence of evidence to support the use of equipment and nutrition interventions in pre-elite athletes. There is a need for quality research designs confirming the clinical impact of existing injury prevention interventions for pre-elite athletes.

1. Introduction

Injuries reduce the chance of successful performance and progression by sportspeople.[1] There is a plethora of injury prevention research for adult, youth and elite athletes.[2–4] To date, there has not been a systematic review of intervention studies for injury prevention in pre-elite athletes who compete in an Olympic or professional sport. Pre-elite athletes, as defined by the FTEM Athlete Development framework[5] (Foundation, Talent, Elite and Mastery) are 'Talent' level athletes (i.e., Talent 1–4) that are commonly emerging from the junior ranks and who have been formally recognised as having future high performance potential by their respective state or national level sporting organisation, state academy or institute, university or professional club and receive limited financial and service support but sit below a senior elite level. Recognised by the International Olympic Committee's recent consensus statement on youth athlete development,[6] the FTEM framework is utilised extensively within Australia, Japan and Switzerland to review and refine strategy, practice and support specific to the sports pathway considerate of its foundational, pre-elite (talent) and elite components.

At a T1 level, an athlete demonstrates their initial potential through formal and informal talent identification processes. At a T2 level an athlete's holistic talent potential is confirmed by immersing them into realistic training and competitive contexts. Following

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this level, an athlete is then embedded into a dedicated developmental period where they are provided with quality coaching, daily training environments, education, service support and competition exposure. Transition to the final talent level T4, signals that the athlete has achieved a breakthrough performance and that they are soon ready to progress to a senior elite level in their chosen sport (i.e., E1 level). A podium performance in the highest levels of elite competition equates to an E2 (Elite 2) level and multiple podium achievement at this level an M (Mastery) level. Specific to the pre-elite athlete population (i.e., FTEM T levels) it is well recognised that the onset of puberty and rate of biological maturation can vary greatly between athletes within and across sports.[7] This variation in maturation and often an increase in workload, insufficient recovery and lack of support services creates a challenging environment for coaches to develop their athletes while keeping them injury and illness free.[6] Previous injury predisposes an athlete to further injuries of the same nature[8] or a different site and nature.[9] To prevent injuries in elite and professional athletes, it is plausible that preventive activities should commence at the pre-elite level. Preventing the index injury (the first injury) will potentially increase the long term health of athletes as well as maximising the pool of athletes eligible to compete at an elite and professional setting. This premise is supported by the work of Huxley et al.[10] demonstrating that 17.3% of injured pre-elite track and field athletes retire due to injury prior to turning eighteen years of age.

This systematic review will inform practitioners working with pre-elite athlete populations in three ways:

- Describe and assess injury prevention interventions trialled in pre-elite populations.
- Synthesise the available evidence on injury prevention strategies used in pre-elite athletes.
- Provide future directions and opportunities for future research in pre-elite injury prevention

2. Methods

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[11] were followed and the protocol was registered on the PROSPERO International prospective register for systematic reviews website (http://www.crd.york.ac.uk/PROSPERO) on 9 May 2017, with the following registration number: CRD42017065083.

The inclusion criteria were: (1) studies that separately analysed pre-elite athletes who are formally recognised and supported by their respective National Sporting Organisation or professional club as having future high performance potential who compete in Olympic and professional sports; (2) injury prevention intervention specific to pre-elite athletes (as determiend by the T3 and T4 levels of the FTEM model) competing in Olympic and professional sports; (3) studies provide sufficient data related to injury such that the effect can be analysed, e.g. injury rates, incidence, prevalence, injury rates ratios; (4) study design of randomised controlled trial, prospective cohort studies and non-randomised controlled trials. Exclusion criteria were: (1) elite athletes e.g. athletes who compete in an Olympic sport and represent their country at key international events including the Olympics, World Championships etc. (2) Professional athletes e.g. elite athletes who compete at the highest professional level in their sport nationally (e.g. Australian Football League for Australian Football) and/or internationally (e.g. ATP World Tour in tennis). (3) Recreational athletes that are not formally recognised and supported as emerging pre-elite athletes by their respective national sporting organisation; (4) study designs of case reports, case series and any cross-sectional designs.

A comprehensive electronic search of the literature in MEDLINE, CINAHL, PubMed, SportDISCUS and Web of Science was conducted on 23 May 2017 with a date restriction of 2000 onwards and only English language as a limitation. Details of the PubMed search strategy is included as a supplement. All potential references were imported into Endnote X7 (Thompson Reuters, Carlsbad, California, USA) and then into Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org) and duplicates removed. Titles and abstracts were independently screened for eligibility by two authors (ES and PN). The full text of each included study was then independently examined according to the inclusion and exclusion criteria, and reference lists of included studies were manually searched to find any further articles for inclusion. In the event of disagreement between authors, additional authors (GW and JW) were consulted to reach consensus.

Data from included studies were extracted and collated by one reviewer (ES) and confirmed by another (MD). The following data were extracted and collated: (1) demographics, FTEM level[12], outcome measures, working injury definition, injury definitions concept framework (IDCF)[13] (2) study design, data collection period, statistical analysis, effectiveness, level of strength, level of evidence (OCEBM)[14] (3) intervention summary, co-intervention, reproducibility and intervention reporting standard.

Where person-time exposures were not explicitly reported we documented the number of athletes in each group and assumed the intervention time in each group was identical. The key outcomes were presented in a forest plot using incidence rate ratio (IRR) as the comparator. Incidence rates reported in each study were used to calculate the IRR, where incidence rates were not presented they were determined by using raw data.

Intervention Mapping facilitates effective health promotion program planning, implementation and evaluation. IM (Step 5) can be used independently of other IM steps and focuses on planning program adoption, implementation and maintenance.[15] This practical implementation planning protocol has been previously used in a sporting environment with good effect.[16] Each included article was mapped according to IM (Step 5) to determine the risk of bias in implementation. To be judged as low risk of bias the authors needed to explicitly state who the adopters, implementers and planners were as well as outline the implementation performance & change objectives, determinants, strategies and design. A judgement of unsure was given when some information was provided with insufficient detail. A high risk of bias was recorded when no detail was provided for that task.

Two reviewers (ES and MD) independently conducted a risk of bias assessment on each selected article using the Cochrane Collaboration's tool for assessing the risk of bias in randomised trials.[17] If at least one of the criteria was rated as high, the trial was considered to have a high risk of bias. To be considered as a low risk of bias, all criteria had to be rated low risk. Any trials not meeting these criteria were rated unclear.

The level of evidence of interventions for the prevention of injury in the pre-elite athlete was evaluated using previously published guidelines.[18] The level of evidence was defined as strong: provided by two or more studies with a low risk of bias and by generally consistent findings in all studies (>75% of the studies reported consistent findings); moderate: provided by one study with a low risk of bias and/or two or more studies with a high risk of bias, and by generally consistent findings in all studies(>75% of the studies reported consistent findings); limited: provided by only one study with a high risk of bias; conflicting: inconsistent findings among multiple trials (>75% of the studies reported consistent findings).[18]

The Oxford Centre of Evidence-based Medicine (OCEBM) — Levels of Evidence was used to determine the hierarchical levels of evidence according to the type of research question with the highest level of evidence. The highest level (Level 1) is a systematic

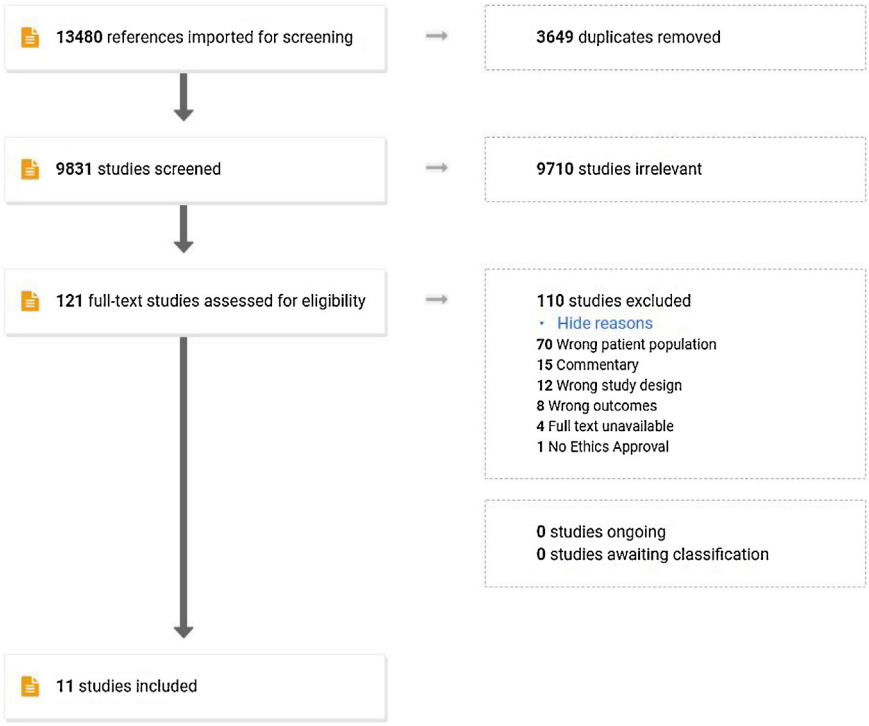

Fig. 1. PRISMA flow chart, PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

review with specific criteria, and the lowest level (Level 5) is 'mechanism-based reasoning'.[14]

The IDCF classification was used to assist with injury definition. It is a system for categorising injuries and illnesses according to clinical examination (injury or disease), athlete self-report (trauma or illness) and/or sports performance (incapacity or sickness).[13] This is a classification system derived from World Health Organisation's (WHO) framework: International Classification of Functioning, Disability and Health (ICF) but adapted for sport impairment.[19]

The reporting standard of exercise intervention was assessed using the Consensus on Exercise Reporting Template (CERT): explanation and elaboration statement.[20] This template has been designed to evaluate the reporting of exercise programmes across all study designs used in exercise research. It has previously been utilised in similar studies where the authors used the following criteria: studies satisfying >75% of criteria were considered to have a high level of reporting standard; 60–74% moderate; and those satisfying less than 60% of criteria were considered to have poor exercise reporting standards.[2]

The 'Workgroup for Intervention Development and Evaluation Research' (WIDER) recommendations provide a framework to identify and provide detailed reporting of the essential components of behaviour change interventions in order to facilitate replication, further development, and progression of the interventions.[21] This 20-item checklist was used to evaluate the standard of reporting for any psychological interventions. The following criteria were applied: studies satisfying >75% of criteria were considered to have a high level of reporting standard; 60–74% moderate; and those satisfying less than 60% of criteria were considered to have met minimal reporting standards.[2]

Results of randomised controlled trials were considered eligible for meta-analysis if all the following criteria were met: (1) athlete populations were similar or comparable; (2) the same outcome measures were reported (3) studies demonstrated a low risk of bias. Where three or more studies examined the same intervention using an equivalent summary statistic, a meta-analysis was considered.[22]

In the circumstances where it was not appropriate to pool the results due to clinical heterogeneity (varying athlete population, outcome measure, high risk of bias), the results were ordered systematically via a forest plot without summary estimates as recommended in the PRISMA statement.[22] The results were grouped according the type of injury prevention intervention or strategy utilised in the study.

3. Results

The electronic search identified 13,480 records; duplicates were then removed resulting in 9831 articles. The titles and abstracts were screened which reduced the number of articles to 121. The full texts of these articles were obtained and assessed for eligibility against the inclusion criteria. No articles were added following citation checking. One hundred and ten studies were excluded due to not meeting the required inclusion criteria. The two most common reasons for exclusion were (1) the patient population was not deemed to be of a pre-elite level (n = 70) and 2) the study did not feature an intervention (n = 27). The remaining eleven articles were included for full review and data synthesis.[23–33] A third author (JW) was consulted to reach consensus regarding study population. The flow chart of this process is presented in Fig. 1.

Table 1 presents the characteristics of the eleven studies including intervention type, participant characteristics, FTEM level, injury incidence rate & ratios, injury definition and injury definitions concept framework (IDCF). Study design, data collection period, statistical analysis, effectiveness, level of strength and level of evidence are provided in Table 2. A summary of the intervention is outlined in Table 3 as well as duration, frequency, compliance, specifics of intervention, co-intervention, reproducibility and reporting standards.

One article introduced new equipment as their injury prevention intervention,[23] seven studies looked at exercise as an injury

Table 1
Intervention, description of the study participants, level of competition, incidence of injury of included studies, injury definition and injury definitions concept framework (IDCF).

Intervention; article	Participants (male/female)	FTEM level, age (Age ± SD)	Injury incidence		IRR (95%CI)	Working injury definition	IDCF
			Intervention (exposure)	Control (exposure)			
Equipment							
Barbic et al.[23] Comparison of mouth guard designs and concussion prevention in contact sports.	Football (M) Rugby (M&F)	FTEM: T 3/4, Con: 20.9 ± 1.9	0.95/1000 athlete days (75 days × 308 = 23 256 athlete days)	0.90/1000 athlete days (75 days × 306 = 23 408 athlete days)	1.05 (.58–1.92)	As per American Academy of Neurology Concussion Guidelines	
	Canadian inter-university sport	Int: 20.8 ± 2.1	22/308 p'pants (22/23 256)	21/306 p'pants (21/23 408)			
Exercise							
Gilchrist et al.[24]	Soccer (F) NCAA Div 1	FTEM: 19.88	Total knee injury: 1.1/1000 AE	Total knee injury: 1.1/1000 AE	1.04 (0.95–1.13)	Injury to the area about the knee occurring in a game, practice or conditioning activity that required medical care by ATC or Physician, and caused one or more missed days of training	
A randomised controlled trial to prevent non-contact Anterior Cruciate Ligament injury in female collegiate soccer players			Practice ACL: 0.0/1000 AE	Practice ACL: 0.2/1000 AE	0.0		
			History of ACL, non-contact ACL: 0.0/1000 AE	History of ACL, non-contact ACL: 0.1/1000 AE	0.0		
			Late in season: 0.0/1000 AE	Late in season: 0.0/1000 AE	NC		
Junge et al.[27]	Soccer (M)	FTEM: T 3/4	High skill total injuries: 6.35/1000 h	High skill total injuries: 6.78/1000 h	0.94 (0.84–1.04)	Any physical complaint caused by soccer that lasted for more than 2 weeks or resulted in absence from a subsequent match or training session	
Prevention of soccer injuries: a prospective intervention study in youth amateur players	High skill (HS) & low skill (LS) teams	Con HS: 15.6 ± 0.86					
	Switzerland	Int HS: 16.2 ± 1.18					

Owoeye et al.[29]	Soccer (M)	FTEM: T 3/4	All injuries: 0.8/1000 h	All injuries: 1.5/1000 h	0.53 (0.23–1.26)	Injuries that resulted in players being unable to fully participate in subsequent football training sessions or matches	
Efficacy of the FIFA 11+ warm-up programme in male youth football.	Premier league, Lagos junior league	Con: 17.80 ± 0.94 Int: 17.49 ± 1.10	Overuse injuries: 0.0/1000 h Acute injuries: 0.9/1000 h Mild injuries: 0.2/1000 h	Overuse injuries: 0.2/1000 h Acute injuries: 1.3/1000 h Mild injuries: 0.4/1000 h	0.0 0.69 (0.26–1.75) 0.5 (0.06–1.81)		
Scase et al.[30]	Aus Football (M)	FTEM: T3	All injuries: 26.33/1000 h	All injuries: 38.51/1000 h	0.69 (0.66–0.73)	Any incident occurring during a football game or training session that resulted in a player missing one or more elite competition games	
Teaching landing skills in elite junior Australian football: evaluation of an injury prevention strategy	Elite U18 National Football comp	Con: 17.0 ± 2.6 Int: 17 ± 2.5					
Silvers-Granelli et al.[32] Does the FIFA 11+ Injury prevention program reduce the incidence of ACL injury in male soccer players?	Soccer (M) NCAA Div I and II	FTEM: T 3/4 Con: 21 ± 1 Int: 20 ± 2	Div 1 ACL's: 0.114/1000 AE	Div 1 ACL's: 0.317/1000 AE	0.36 (0.29–0.45)	No injury definition	No injury definition

Table 1 (*Continued*)

Intervention; article	Participants (male/female)	FTEM level, age (Age ± SD)	Injury incidence		IRR (95%CI)	Working injury definition	IDCF
			Intervention (exposure)	Control (exposure)			
Silvers-Granelli et al.[31]	Soccer (M)	FTEM: T 3/4	Div 1 Total injuries: 9.3/1000 AE (198/21248 AE)	Div 1 Total injuries: 16.05/1000 AE (355/22112 AE)	0.58 (0.49-0.69)	Any physical complaint sustained by a player that resulted from a football match or football training, irrespective of the need for medical attention or time loss from football.	
Efficacy of the FIFA 11+ injury Prevention Program in the Collegiate male soccer player	NCAA Div I and II	Con: 21 ± 1	Div 1 Game injuries: 18.83/1000 AE	Div 1 Game injuries: 29.36/1000 AE	0.64 (0.6–0.68)		
		Int: 20 ± 2	Div 1 Practice: 5.146/1000 AE	Div 1 Practice: 10.13/1000 AE	0.51 (0.49–0.53)		
Strength training reduces injury rate in elite young soccer players during one season	Tunisian player development program	13–14 yo					
Psychological							
Ivarsson et al.[25]	Soccer (M&F)	FTEM: T3	Total injuries: 7/21 p'pants	Total injuries: 12/20 p'pants	0.56 (0.46–0.67)	A condition that occurred as a result of participation in a soccer practice or game and resulted in 4 days or more of restricted or no practice including the day of injury	
It pays to pay attention: a mindfulness based program for injury prevention with soccer players	Swedish junior elite	16.97 ± 0.79	181 days (7/3801)	181 days (12/3620)			
			1.84/1000 athlete days	3.31/1000 athlete days			
Johnson at al.[26]	Soccer (M&F)	FTEM:	Total injuries: 3/13 p'pants	Total injuries: 21/16 p'pants	0.18 (0.15–0.21)	Caused him or her to miss practice or competition, or to substantially modify participation for at least one day	
Injury prevention in Sweden: helping soccer players at risk	Swedish regional level teams	Male: 22.9	150 days (3/1950)	150 days (21/2400)			
		Female: 20.1	1.54/1000 athlete days	8.75/1000 athlete days			
Nutrition							
Lewis et al.[28]	Swimmers & Divers (M&F)	FTEM:	Total injuries: 9/19 p'pants	Total injuries: 4/13 p'pants	1.54 (1.27–1.87)	Bone, connective tissue and muscle injury not caused by acute trauma	
The effects of season-long Vitamin D supplementation on collegiate swimmers and divers	NCAA Div I	Con: 19 ± 1.1	182 days (9/3458)	182 days (4/2366)			
		Int: 19 ± 1.6	2.60/1000 athlete days	1.69/1000 athlete days			

FTEM: foundation, talent, elite, mastery framework, IRR: incidence rate ratio, IDCF: injury definitions concept framework, FIFA: Fédération Internationale de Football Association, NCAA: The National Collegiate Athletic Association, AE: athlete exposure, ACL: anterior cruciate ligament.

Table 2
Characteristics of the studies including data collection period, statistical analysis, efficacy, level of evidence.

Intervention; article	Study design	Data collection period	Statistical analysis	Effectiveness/level of strength for intervention type	Level of evidence (OCEBM level)
Equipment					
Barbic et al.[23] Comparison of mouth guard designs and concussion prevention in contact sports.	Randomised controlled trial	September 3–November 17, 2003	Intention-to-treat analysis Injury rates between groups were compared using a P value and odds ratio	X Level of strength: Limited	Level 2
Exercise					
Gilchrist et al.[24] A randomised controlled trial to prevent non contact Anterior Cruciate Ligament injury in female collegiate soccer players	Randomised controlled trial	Fall 2002 NCAA season	Z statistic for rate ratios. As-treated analysis	✓	Level 2
Junge et al.[27] Prevention of soccer injuries: a prospective intervention study in youth amateur players	Prospective controlled intervention study	Two seasons of Swiss football: 1999 & 2000	Incidences of injury compared by calculating z-values. Differences between groups examined using t-tests.	High-skill: X	Level 3
Owoeye et al.[29] Efficacy of the FIFA 11+ warm-up programme in male youth football.	Cluster randomised controlled trial	Six months: 2012/2013 season	Intention to treat principles. Injury rate ratios calculated using Poisson regression analysis	X	Level 2
Scase et al.[30] Teaching landing skills in elite junior Australian football: evaluation of an injury prevention strategy	Prospective non-randomised controlled trial	U18 Australian football. 2 seasons: 2002/2003	Injury incidence. Independent tests/Mann–Whitney U test used for comparison. Cox proportional hazards regression. Relative risk and 95% CI	✓	Level 3
Silvers-Granelli et al.[32] Does the FIFA 11+ Injury prevention program reduce the incidence of ACL injury in male soccer players?	Prospective cluster randomised controlled trial	August–December 2012	Frequency counts, t-tests, chi-square tests, factorial analysis of variance, logistic regression tests. Injury rates.	✓	Level 2
Silvers-Granelli et al.[31] Efficacy of the FIFA 11+ injury Prevention Program in the Collegiate male soccer player	Randomised controlled trial	August–December 2012	T tests, X^2 tests and generalised linear regression models	✓	Level 2
Zouita et al.[33] Strength training reduces injury rate in elite young soccer players during one season	Randomised controlled trial	One soccer season. October to March	Mean ± SD. Kolmogorov–Smirnov tests. 2-way repeated-measures analysis of variance. Bonferroni post-hoc analysis. Chi-square test.	✓	Level 2
Psychological					
Ivarsson et al.[25] It pays to pay attention: a mindfulness based program for injury prevention with soccer players	Randomised controlled trial	August 2013–June 2014	Mann–Whitney U test. Cohen's d effect size, 80% confidence interval	X	Level 2

Table 2 (*Continued*)

Intervention; article	Study design	Data collection period	Statistical analysis	Effectiveness/level of strength for intervention type	Level of evidence (OCEBM level)
Johnson et al.[26] Injury prevention in Sweden: helping soccer players at risk	Randomised controlled trial	January–June	Mann Whitney U test	✓ Level of strength: moderate	Level 2
Nutrition					
Lewis at al.[28] The effects of season-long Vitamin D supplementation on collegiate swimmers and divers	Randomised, placebo-controlled trial	August–March	Pearson correlations. Independent t tests. Linear regression model	X Level of strength: limited	Level 2

OCEBM: Oxford centre for evidence based medicine, FIFA: Fédération Internationale de Football Association, NCAA: The National Collegiate Athletic Association.

prevention intervention,[24,27,29–33] two examined the use of psychological interventions[25,26] and one was a nutrition intervention.[28] The equipment study found the 'WIPSS Brain-pad mouth guard' not to prevent concussions.[23] Five of the exercise interventions looked at whether a specific warm-up could prevent injuries in soccer/football players.[24,27,29,31,32] The other two exercise intervention programs provided training in developing landing, falling & recovery skills and strength training.[30,33] Mindfulness, acceptance & commitment approach was used in one of the psychological interventions,[25] and one-on-one psychology training was used in the other.[26] The nutrition study provided vitamin D supplementation as their injury prevention intervention.[28]

Eight of the eleven articles studied football players.[24–27,29,31–33] Five of these were conducted to help develop or assess the FIFA 11+ program developed by Fédération Internationale de Football Association (FIFA).[24,27,29,31,32] The remaining three investigations studied Canadian football and rugby players,[23] Australian football players[30] and swimmers & divers.[28]

The definitions and IDCF classification for each study are outlined in Table 1. A variety of injury definitions were used across the included studies with most studies using a sports incapacity (time loss) definition. According to the IDCF classification, seven of the studies definitions were based on sports performance,[25–27,29,30,33] two used clinical examination as their definition,[23,28] one study used a definition that included both sports performance and clinical examination,[24] one study used athlete self-report[31] and one study did not define injury.[32]

The risk of bias assessments are outlined in Fig. 2. Risk of bias assessment concluded that none of the included trials were low risk, ten (91%) were high risk, and one (9%) was unclear risk.[17] A major contributor to assessments of high risk of bias was lack of blinding and allocation concealment.

The level of strength according to guidelines previously published[18] and effectiveness based on IRR are outlined in Table 2. The strength of evidence was deemed to be moderate for exercise and psychological intervention and limited evidence for the use of equipment and nutrition interventions for injury prevention in pre-elite athletes. The hierarchical level of evidence was Level 2 for most of the intervention studies except for two which were Level 3 because they were non-randomised controlled trials.[27,30]

Outcomes with incident rate ratios are presented in Table 1. The use of a WIPSS Brain-pad mouth guard was shown to be ineffective for preventing concussion in 19–23 yo male and female Rugby and Football players.[23] The 'Prevent Injury and Enhance Performance' (PEP) program was trialled with 19 yo female soccer players. It was found to be ineffective for "all knee injuries" but was effective at reducing the number of ACL injuries sustained in practice and for reducing the number of non-contact ACL injuries in athletes who had previous ACL injury.[24] The Swiss study, using 15–17 yo male soccer players which was conducted as part of the FIFA 11+ development did not prove to be effective for the pre-elite portion of the population.[27] Of the three studies that implemented the FIFA 11+,[29,31,32] there were favourable outcomes for reduction of overuse injuries,[29] reduction of ACL injuries in pre-elite athletes,[32] reduction of total injuries, game injuries and practice injuries in pre-elite athletes.[31] These studies used 16–18 yo male soccer players[29] and 18–22 yo male soccer players.[31,32] Strength training in 13–14 yo male soccer players,[33] landing skills training in 15–19 yo male Australian Rules football players[30] and psychological training in 16–17 yo male and female soccer players[25,26] and 23 yo male and 20 yo female soccer players[26] were also shown to be effective. Vitamin D supplementation for 18-20yo male and female swimmers and divers was ineffective for injury prevention.[28] One of the FIFA 11+ studies reported a significant (IRR 0.59 95%CI 0.40–0.86) reduction in injuries for the intervention group but our calculations did not yield the same result (IRR 0.53 95%CI 0.23–1.26).[29] This is most likely due to a difference in statistical approach, Owoeye[29] et al. reported using Poisson regression analysis but we adopted a random-effects inverse-variance model.

Reporting standards were also assessed. It was not possible to identify a reporting standard for equipment and nutrition intervention studies. Consensus on Exercise Reporting Template (CERT) and Workgroup for Intervention Development and Evaluation Research (WIDER) scores were determined for exercise and psychological interventions respectively. Intervention details and reporting standard scores are displayed in Table 3. The CERT scores ranged from 26 to 74% for the exercise interventions. Five were deemed to be of poor standard [24,27,29,30,33] and two were to be of moderate standard.[31,32]

The WIDER scores were 30 and 65% for the psychology interventions. One was of poor standard,[26] and one was of moderate standard.[25] The article of poor standard gave no detailed information about the intervention content and no information regarding the control group.

There was no evidence of the use of IM (Step 5) to guide the implementation process for any of the included articles. Results are shown in Fig. 3. Adopters and implementers were identified in 45% (5/11) of the intervention studies.[24,26–28,33] Details of activities and resources used to improve reach, adoption and implementation of their injury prevention intervention programs were reported in

Table 3
Intervention summary, duration and frequency, specific details of intervention (ie reps, sets, intensity, progression), co-intervention, reproducible, intervention reporting standard.

Intervention; article	Intervention summary	Duration & frequency	Compliance levels	Specifics of intervention (reps, sets, intensity, progression)	Co-intervention	Reproducible	Intervention reporting standard (e.g. CERT)	
Equipment								
Barbic et al.[23] Comparison of mouth guard designs and concussion prevention in contact sports.	Use of WIPSS Brain-pad mouth guard	Not reported	Control: 73.8% (range by team, 68.1%–97.8%) I'vention: 69.6% (range by team, 68.4%–78.9%)	NA	Nil	Yes. WIPSS Brain pad available commercially	NA	NA
Exercise							CERT score (%)	Interpretation
Gilchrist et al.[24] A randomised controlled trial to prevent non contact Anterior Cruciate Ligament injury in female collegiate soccer players	Prevent injury and enhance performance (PEP) program. Stretching, strengthening, plyometrics, agilities and avoidance of high-risk positions.	12 weeks, 1–3/week	Average: 25.8 PEP sessions/team (2.15/week) Range: 12–37/team (1–3.1/week)	Warm-up movement (50 yards each) Strengthening: walking lunges (20yds × 2) Russian H-S's (3 × 10) Single toe raises (30reps/side) Stretching (30 s × 2) Plyometrics (20 reps each) Agilities (40 yards)	Nil	No. Web based program expired 19/10/17	7(37)	Poor
Junge et al.[27] Prevention of soccer injuries: a prospective intervention study in youth amateur players	F-MARC Bricks: Ankle & Knee stability Trunk, hip, leg strength & flexibility Co-ordination, reaction time & endurance	Not reported	Not reported	Not stated	Coach/player education/supervision; ankle taping, adequate rehabilitation, promotion of fair play	No. 'F-Marc Bricks' not clearly defined. Several interventions.	5(26)	Poor
Owoeye et al.[29] Efficacy of the FIFA 11+ warm-up programme in male youth football.	FIFA 11+	One season (25 weeks), 2/week	60% trainings (Range, 5–22 sessions/team) 1.6 times/week	Not stated	Nil	Yes. FIFA 11+ is well documented	7(37)	Poor

Table 3 (*Continued*)

Intervention; article	Intervention summary	Duration & frequency	Compliance levels	Specifics of intervention (reps, sets, intensity, progression)	Co-intervention	Reproducible	Intervention reporting standard (e.g. CERT)	
Scase, et al 2006. Teaching landing skills in elite junior Australian football: evaluation of an injury prevention strategy	Landing, falling & recovery skills: Prone fall, backward fall, sideways rolling, two foot landing, back shoulder roll	8 weeks, 1/week, 30 min sessions	Not reported	Not stated. Reference for intervention no longer available: http://www.kidskills.com.au	Aerobic endurance, weight training, skill acquisition	No. Specific program for training landing, falling and recovery skills not provided	6(32)	Poor
Silvers-Granelli et al.[32] Does the FIFA 11+ Injury prevention program reduce the incidence of ACL injury in male soccer players?	FIFA 11+: Dynamic warm-up: Strength, agility, proprioceptive and plyometric exercises	4 months, 2–3/week, 15–20 min	2.19 sessions/week Average: 32.78 ± 12.13 sessions/season	Details on website	Nil	Yes. Details of FIFA 11+ program can be found on provided website	12(63)	Moderate
Silvers-Granelli et al.[31] Efficacy of the FIFA 11+ injury Prevention Program in the Collegiate male soccer player	FIFA 11+: Dynamic warm-up: Running exercises (8 mins) – cutting, change of direction, decelerating, landing techniques; Strength, plyometric and balance exercises (10 mins); Running exercises (2 mins)	4 months, 3/week, 20 min	Average: 32.78 ± 12.13 sessions/season (2.19 sessions/week)	Details on website	Nil	Yes. Details of FIFA 11+ program can be found on provided website	14(74)	Moderate
Zouita et al.[33] Strength training reduces injury rate in elite young soccer players during one season	Progressive resistance training	12 weeks, 2–3/week, 90 min	Not reported	Individualised	4–5 soccer sessions/week 1 match/week	No. specific details of strength training, program not provided	6(32)	Poor

Psychological							WIDER score (%)	Interpretation
Ivarsson et al.[25]	'Mindfullness, acceptance and commitment approach' small group sessions	7 weeks, 1/week, 45 min	Not reported	Topics covered:	10–18 h soccer/week	No. specific details of MAC approach not provided	13(65)	Moderate
It pays to pay attention: A mindfulness based program for injury prevention with soccer players				Theoretical & practical aspects of intervention Intro to mindfulness & cognitive defusion Intro to values & values-driven behaviours Intro to concept of acceptance Intro how to enhance commitment Intro how to combine mindfulness, acceptance & commitment in practice How to maintain & enhance mindfulness, acceptance & commitment				
Johnson, et al.[26]	One-on-one psychological training	20 weeks, 6 sessions and 2 phone calls	Not reported	Somatic & cognitive relaxation, stress management skills, goal setting skills, attribution & self-confidence training, identification & discussion about critical incidents	Not stated	No. details of psychological training not provided	6(30)	Poor
Injury prevention in Sweden: helping soccer players at risk		45–90 min						
Nutrition								
Lewis et al.[28]	4000 IU Vitamin D supplement	6 months, daily	Control: 76% (range, 64–87%)	NA	Nil	Yes. Specific details of Vitamin D supplement provided	NA	NA
The effects of season-long Vitamin D supplementation on collegiate swimmers and divers			I'vention: 70% (range, 29–88%)					

CERT: consensus on exercise reporting template, WIDER: workgroup for intervention development and evaluation research, FIFA: Fédération Internationale de Football Associati.

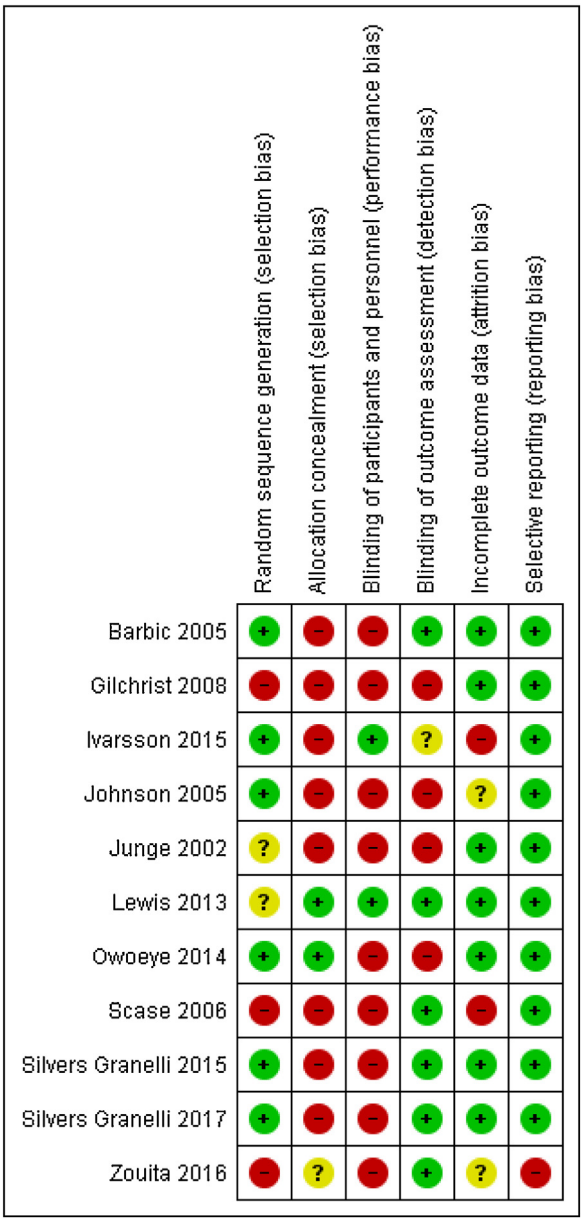

Fig. 2. Risk of bias summary (Please use colour).

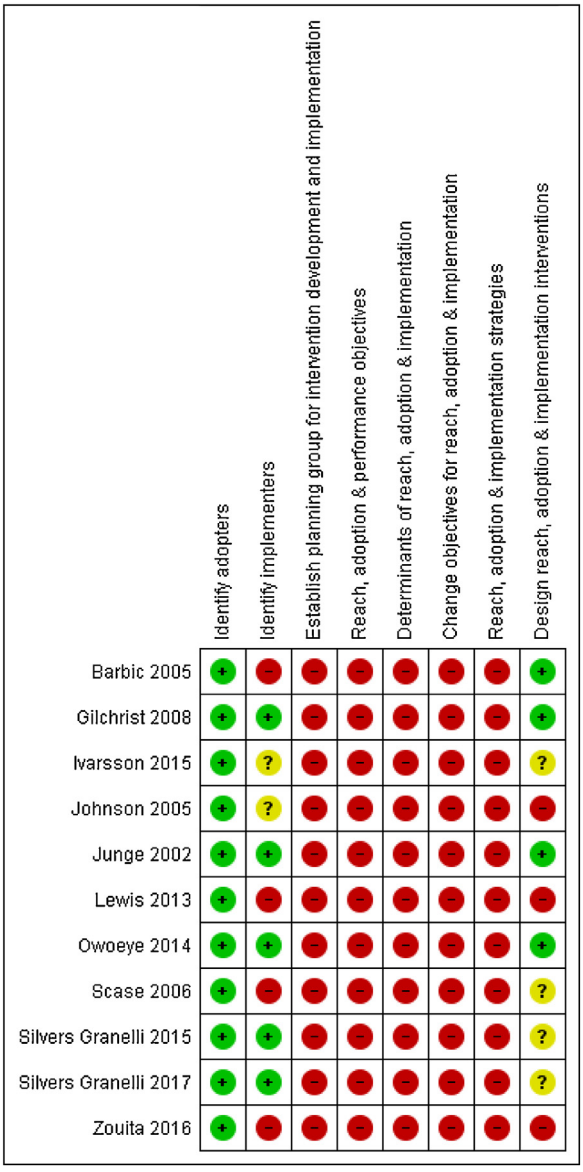

Fig. 3. Intervention Mapping (IM) Step 5 (Please use colour).

36% (4/11) of the included articles.[23,24,27,29] There was no evidence of tasks 3–6 of IM (Step 5) being utilised to assist with implementation planning.

A meta-analysis was not undertaken due to high risk of bias across all included studies. For the purpose of qualitative synthesis, the results were ordered systematically in a forest plot grouped according to intervention type Fig. 4.

4. Discussion

This systematic review highlights a lack of evidence-based strategies for injury prevention specific to pre-elite athletes. Exercise and psychological interventions have been shown to have efficacy in preventing injury in pre-elite athletes. However, a high proportion of these studies were shown to have a high risk of bias and poor reporting standards of the intervention.

Synthesised results indicate moderate strength of evidence for the efficacy of exercise interventions for the prevention of injury in pre-elite athletes. Three of the studies[29,31,32] assessed FIFA 11+, two were carried out in the USA College system,[31,32] and one was in Nigeria.[29] All three examined the effect of the FIFA 11+ warm-up on all injuries that resulted in players' absence from a match or training session. The American studies showed a 44% reduction in all Division 1 injuries and a 64% reduction in ACL injuries.[31,32] The Nigerian study reported a significant reduction in injuries but when we re-calculated IRR, the intervention was deemed to be ineffective.[29] While significant reductions were produced in some studies, there is still scope for greater injury reduction in the pre-elite environment. This could be achieved by improved implementation planning through the use of IM (Step 5). This will ensure the intervention is appropriate for the population and environment and strategies are employed to enhance reach, adoption and implementation.

There is a lack of evidence for the use of equipment to prevent injury in pre-elite athletes. However, we cannot dismiss the use of equipment for injury prevention because a previously published literature review identified over 600 studies in other athlete populations focussing on the use of equipment such as ankle braces and wrist guards which have been shown to prevent injury.[34–36] There is uncertainty whether these equipment interventions would also

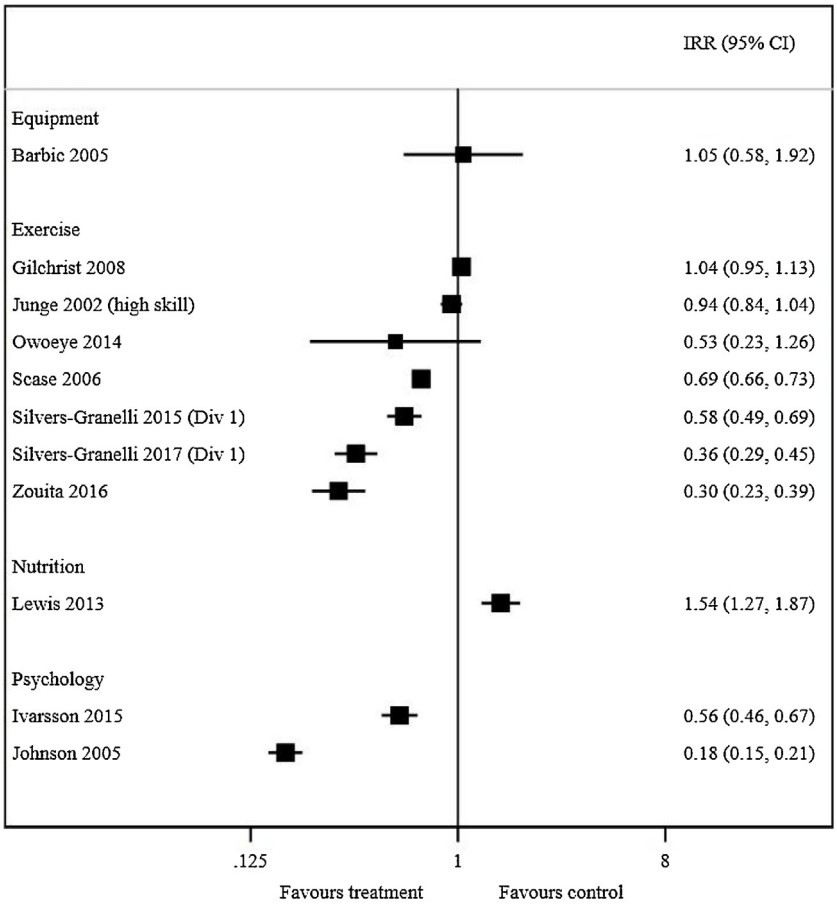

Fig. 4. Forest plot showing IRR and 95%CI of number of injuries in intervention group compared to control group. IRR: incidence rate ratio, CI: confidence interval.

prevent injury in the pre-elite athlete population and should be investigated further.

The use of psychological intervention for the prevention of athletic injury is gaining support.[37,38] The two studies included in this review used 'mindfulness, acceptance and commitment' approach in a group setting,[25] and one-on-one psychology sessions.[26] Both were found to be effective with reducing injuries in pre-elite athletes, but they were also found to have a high risk of bias due to a lack of concealment and not reporting drop outs.[25,26] Interestingly, Johnson et al.[26] applied interventions to high-risk groups and the reduction in injuries as indicated by the IRR was the greatest of all included articles, suggesting that targeted psychological interventions may be indicated for high-risk athletes in the pre-elite population.[26] Neither of these programs could be reproduced due to a lack of intervention detail.

Nutrition plays an important role in injury prevention.[39,40] However, this review highlights a lack of evidence for nutrition injury prevention interventions in pre-elite athletes. The single nutrition study included for data extraction was well designed and reported but did not show any benefit for taking Vitamin D supplementation in their group of pre-elite swimmers and divers.[28] This is another example of where the intervention may only be effective for deficient athletes and athletes should undergo screening for Vitamin D insufficiency prior to taking supplements. There may be a potential benefit to other sports, particularly indoor sports, however there is an absence of evidence to inform this practice in pre-elite athletes.

It is imperative for intervention studies to use reporting standards, so the intervention can be replicated which will increase clinical uptake resulting in improved patient outcomes and transparency among researchers. In our review, of the seven studies that were eligible to be scored by CERT they all failed in providing any details of home exercise programs and whether the intervention was delivered and performed as planned.[24,27,29–33] There was limited reporting of the qualifications of the exercise instructor, rules for determining exercise progression, detailed description of exercise to enable replication, description of adverse events or how the exercises are tailored to the individual. From a clinical perspective, it is unclear how the majority of these interventions could be implemented in the broader population.

The WIDER recommendations could be applied to two of our included studies.[25,26] One had minimal reporting standards and one was of a moderate standard.[25,26] Both of these articles failed to report fidelity to delivery protocols, detailed description of intervention content, intervention development and change techniques used. Without this information it would be extremely difficult to replicate the interventions used in these studies. Therefore, the WIDER recommendations should continue to be used for all behaviour change intervention research.

This review has examined the implementation strategies of each included study by evaluating each article against IM (Step 5). Our interpretation of Step 5 introduced an additional task to emphasise the importance of engaging both the adopters and the implementers at an early stage. None of the included studies reported the use of a planning group to develop the intervention and plan implementation. There was no description of whether objectives for reach, adoption and performance were developed. Determinants, change objectives and strategies for reach, adoption and implementation were also not reported. It is vital to the success of an injury prevention intervention that the adopters and imple-

menters have input from the very beginning and they have a strong contribution to the intervention development. Given the lack of reporting of consultation with end-users, it appears that all studies developed interventions and implementation strategies with little consultation with adopters and implementers and limited planning. Future studies should report any engagement with adopters and implementers to allow readers to understand the development process in full.

Adherence of participants to an intervention is vital as this will greatly influence the effectiveness of the intervention. Implementation and intervention planning is essential to maximise compliance. It is difficult to draw conclusions on effectiveness without knowing compliance levels. Five of the eleven studies did not report their compliance levels[25–27,30,33], three of these were exercise interventions[27,30,33] and two were psychology interventions.[25,26] The nutrition intervention[28] had a large range of compliance with the lowest level being 29%, perhaps this research should be repeated after undertaking the implementation mapping process in order to improve compliance and gain a true assessment of efficacy. Of the two exercise interventions that were shown to be ineffective, one did not report compliance[27] and the other reported sub-optimal compliance.[29]

The pre-elite athletic population's demographics can be wide ranging across sports. The age range of athletes in our included studies is 13–23 yo. This population can include pre-pubescent gymnasts and post-pubescent footballers. Nevertheless they can experience similar challenges such as a sudden increase in training load,[41] limited access to support services and a tendency for reduced recovery time due to other commitments such as school, university or work.[5,6] Perhaps addressing these extrinsic risk factors could be the most effective method for reducing injury in this athletic population.

There is evidence supporting the efficacy of exercise interventions in this population,[24,27,29–33] while there is a high risk of bias we need to understand it is very difficult to blind participants so this may be a case of misclassification. For those working in football there is evidence supporting the use of FIFA11+ in elite and community level,[42,43] however, our findings are purely focussed on pre-elite athletes. Additionally it must be noted that one of the psychology studies produced the best reported reduction in injury rates.[26] The authors of this study identified at risk athletes before administering the targeted intervention. Perhaps intervention studies need to be aimed at subgroups of athletes who may be at greater risk due to factors such as previous injury[9] or maturation level in this population.[6] There is limited evidence that supports the use of screening for injury prediction[44] but at a practical level it might be still useful to apply targeted interventions to pre-elite athletes with at-risk profiles.

There is a paucity of research with low risk of bias specific to injury prevention in the pre-elite population. We have identified a lack of exercise intervention studies for female pre-elite athletes. It is recommended that injury prevention interventions that have been shown to work in other athletic populations should be trialled in a variety of sports for pre-elite male and female athletes, and where possible trials should be conducted to ensure a low risk of bias and with intervention reporting standards such as CERT and WIDER.[20,21] None of the interventions included in this review utilised more than a single discipline approach; multimodal interventions may improve the observed effect given the complexity of injury aetiologies.[45] Greater attention needs to be directed toward implementation planning to bring about sustained intervention compliance in order to achieve injury reduction in the 'real-world'.[46] Finally, adoption of a model such as the FTEM framework allows greater consistency in the classification of the sporting population with clear descriptions of the requirements of each level.

This Systematic Review provides a synthesis and summary of evidence, as well as providing clear recommendations for future research investigating injury prevention interventions used in pre-elite athletes. A limitation of this review was the inability to perform a meta-analysis of results and the generally low number of published studies in this population. Additionally, although we employed a sensitive search strategy, we may have misclassified excluded articles due to low reporting standards of the level of athlete in many interventions.

5. Conclusion

There is limited evidence as to the efficacy or otherwise of exercise and psychological interventions for injury prevention in pre-elite athletes who compete in an Olympic or professional sport. No evidence is available for the use of equipment (mouthguards) and Vitamin D supplementation interventions for the pre-elite athletic population. None of the included studies demonstrated low risk of bias and intervention and implementation planning are not well reported in injury prevention research of pre-elite athletes limiting the ability to implement the results in the real-world. There needs to be a call to action across disciplines to address this apparent shortfall in the literature in order to inform effective practical outcomes.

What is already known?

- Injuries in pre-elite development are common.
- Injuries can compromise a developing athlete's sporting potential, reduce their chance of successful performance and can lead to athletes dropping out of the sport.
- Previous injury predisposes athletes to further injury.

What are the new findings?

- Exercise and psychological interventions may prevent injury in pre-elite athletes.
- There is insufficient evidence to evaluate the use of equipment and nutrition interventions in pre-elite athletes.
- There is a lack of level 1 evidence for injury prevention in the pre-elite population.
- More injury prevention intervention studies need to focus on female athletes.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2019.03.002.

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