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# A systematic review and meta-analysis of various injury prevention programs in youth soccer players

Daniel Castillo<sup>1</sup> , Diego Marqués-Jiménez<sup>1\*</sup> , Maurizio Bertollo<sup>2,3</sup> , Marcos López-Flores<sup>4,5</sup> , Luca Bovolon<sup>2,6</sup> , Antonio De Fano<sup>7</sup>  and Dario Pompa<sup>2,3</sup> 

## Abstract

**Background** Considering injuries as a serious problem which affects player availability and performance, soccer clubs have strong incentives to develop and implement various injury prevention programs (IPPs). The aim of this systematic review and meta-analysis was to examine, consolidate and summarize the research on the effects of various IPPs on injury incidence in youth soccer players.

**Methods** A search was conducted in Cochrane Library, PubMed (MEDLINE), Scopus and Web of Science. A total of 3827 records were identified through database searches which were filtered to 19 studies that met the selection and inclusion criteria. The search was concluded in December 2024. A methodological quality scale was also employed as a valuable tool to assess the risk of bias in the selected studies.

**Results** A total sample of 28,200 youth soccer players were analyzed in the included studies. 12 studies reported positive effects of the IPP on overall injury incidence, while four studies found no significant effects. Moreover, most studies showed increasing effectiveness with higher adherence or compliance. Overall, injury prevention programs were shown to significantly decrease the likelihood of injury (RR=0.615 [95% CI=0.512; 0.739];  $z = -5.20$ ;  $p < 0.001$ ). Subgroup analyses conducted for age ( $Q(1) = 2.84$ ,  $p = 0.092$ ), duration of intervention ( $Q(1) = 1.87$ ,  $p = 0.172$ ), type of injury prevention program ( $Q(1) = 0.00$ ,  $p = 0.955$ ) did not reveal significant differences in injury incidence, suggesting that the overall effect of injury prevention programs is not significantly influenced by these factors.

**Conclusions** This systematic review and meta-analysis suggest that different injury prevention programs are likely effective in reducing injury risk and lowering the injuries among youth soccer players, suggesting their potential protective effect in injury prevention.

**Keywords** Soccer, Injury, Incidence, Prevention, Youth

\*Correspondence:

Diego Marqués-Jiménez  
diego.marques@uva.es

<sup>1</sup>Valoración del Rendimiento Deportivo, Actividad Física y Salud y Lesiones Deportivas (REDAFLED), Department of Didactics of Musical, Plastic and Corporal Expression, Faculty of Education, University of Valladolid, Soria, Spain

<sup>2</sup>Behavioral Imaging and Neural Dynamics (BIND) Center, University "G. d'Annunzio" of Chieti-Pescara, Chieti, Italy

<sup>3</sup>Department of Medicine and Aging Sciences, University "G. d'Annunzio" of Chieti-Pescara, Chieti, Italy

<sup>4</sup>Sport Innovation Hub, Gijón, Spain

<sup>5</sup>European Network for Innovation and Knowledge, Amersfoort, The Netherlands

<sup>6</sup>Department of Psychological, Humanistic and Territorial Sciences, University "G. d'Annunzio" of Chieti-Pescara, Chieti, Italy

<sup>7</sup>Università Telematica Pegaso, Naples, Italy



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## Background

Soccer is a very physically demanding sport in which players are required to cover 10–12 km per match of which almost 1 km is at high-speed velocities, and perform a great number of short-term high-intensity actions such as accelerations, decelerations and changes of direction [1]. These physical demands could impact in players' performance and injury risk causing a negative impact on the financial standing of clubs [2]. As such, a recent study within youth soccer context reported that overall incidence rate was 5.70 injuries/1000 h in males and 6.77 injuries/1000 h in females with a severity of almost 100 days of absent/1000 h [3]. Considering injuries as a serious problem which affects player availability, team performance, success and future career prospects [4–6], soccer clubs have strong incentives to develop and implement various injury prevention programs (IPPs) to address this concern.

If youth soccer players aspire to achieve high-level performance, they must actively engage in deliberate practice during the specialization years, involving increased training volumes and intensities, and focusing on tasks that challenge their current performance level [7, 8]. In this scenario, youth soccer players are particularly susceptible to injuries due to heightened physical, physiological and psychosocial stress [7]. Additionally, the growth-related biological differences among players of the same age could influence on how training loads affect them and the determination on the chances of a player to be included in the talent identification programs [9, 10]. As such, the incidence of training injuries may actually be higher among elite youth soccer players compared to professional adults, even though the prevalence of common injury types remains similar between the two groups [11]. Moreover, the incidence of injuries produced in matches were higher than in training for elite youth soccer players [11]. Therefore, it is crucial for strength and conditioning specialists to continuously seek the safest and most effective methods to help young players to avoid exposure-related injuries.

Some of the IPPs includes dynamic warm-up programs composing by preventive exercises before matches or during training sessions, and strength, balance, and mobility training strategies [12]. In this regard, there is extensive high-quality evidence demonstrating the effectiveness of neuromuscular training (NMT) warm-up programs in reducing youth soccer-related injuries across sexes, ages, and skill levels [13–18]. Conversely, other promising IPPs that incorporate strength, balance, or mobility exercises during training sessions have not been extensively studied in the youth soccer player population, despite their potential to enhance various modifiable inherent risk factors, particularly force production [16]. In fact, the implementation of a variety of exercise-based

IPPs for youth players has been shown to decrease injury rates by up to 46% [16]. Therefore, it would be of interest to conduct a study that defines the characteristics of preventive programs, aiming to reach a consensus that guides the prescription of these strategies in youth football.

Considering the literature, the aim of this systematic review and meta-analysis was to examine, consolidate, and summarize existing research on the impact of various IPPs on injury incidence in youth soccer players. Additionally, this meta-analysis aimed to determine whether structured IPPs effectively reduce injury risk. Assessing the effectiveness of different exercise-based IPPs in reducing injury risk could provide valuable insights for practical implementation and guide future research directions.

## Methods

The current study was conducted in accordance with the 2020 updated “Preferred Reporting Items for Systematic review and Meta-analyses” (PRISMA) guidelines [19]. Additionally, the PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and Sports science) guidance was also consulted [20]. A detailed protocol for this review was meticulously registered on the Open Science Framework (OSF) under DOI: <https://doi.org/10.17605/OSF.IO/XQFNC>.

### Eligibility criteria

The PICOS model was utilized to establish the inclusion criteria [21], which are as follows: Population (P) “youth soccer players” under 18 years old, at any level of competition; Intervention (I) “injury prevention program” lasting a minimum of 8 weeks; Comparators (C) “control condition or a different injury prevention program”; Outcome (O) “injury incidence”; and Study design (S) “Clinical Trials or Randomized Controlled Trials”. Consequently, the studies included in this systematic review had to meet the following exclusion criteria: (I) studies conducted with participants involved in soccer injury rehabilitation or return to play programs, (II) epidemiological studies, (III) narrative reviews, systematic reviews and meta-analyses evaluating the effectiveness of soccer IPPs on reducing injuries in youth soccer players, (IV) abstracts, book chapters, commentaries or studies describing IPPs without evaluating their effectiveness, (V) studies that did not assess soccer-related injuries, and (VI) non-English studies.

### Information sources and search strategy

A comprehensive search was conducted in Cochrane Library, PubMed (MEDLINE), Scopus and Web of Science. The entire search string used for each database is reported in appendix 1. No restriction was applied to the

**Table 1** Overview of the included studies, with study source, sample size (n) and participants characteristics, injury prevention program details, and effects of the neuromuscular training warm-up programs

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Al Attar et al., 2023 [32]	CG (n = 363), EG (n = 377) Gender: male Age (years): 7–13 years Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season (6 months) CG: usual training program (active-treatment control) EG: usual training program + 15–20 min NMT FIFA 11 + Kids warm-up program twice a week before regular soccer training sessions and matches. IPP included exercises focused on unilateral, dynamic stability of the lower extremities, trunk strength and stability, and falling technique (jog & look at the coach, skating hop, one-leg stance, push-up, one-leg hops, spiderman, roll over), with five progressive levels of difficulty adapted to each exercise.	Location: differentiated in all body parts Type: initial, recurrent, overuse Mechanisms: contact, non-contact Severity: mild (4–7 days), moderate (8–21 days), severe (> 21 days) Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG * (2.02 vs. 0.86, RIR = 0.43), thigh CG = EG (RIR = 0.43), knee CG > EG * (RIR = 0.43), lower leg CG > EG * (RIR = 0.38), ankle CG > EG * (RIR = 0.43), foot/toe CG = EG (RIR = 0.57), initial CG > EG * (1.90 vs. 0.82, RIR = 0.43), recurrent CG = EG (0.12 vs. 0.04, RIR = 0.34), overuse CG > EG * (0.36 vs. 0.10, RIR = 0.27), contact CG > EG * (1.03 vs. 0.52, RIR = 0.50), non-contact CG > EG * (0.61 vs. 0.24, RIR = 0.39), mild CG = EG (1.10 vs. 0.46, RIR = 0.42), moderate CG = EG (0.70 vs. 0.34, RIR = 0.48), severe CG = EG (0.21 vs. 0.06, RIR = 0.28).
Beaudouin et al., 2019 [48]	CG (n = 1829), EG (n = 2066) Gender: female, male Age (years): CG (11.3 ± 1.2), EG (11.7 ± 0.8) Height (cm): CG (154 ± 0.1), EG (153 ± 0.1) Body mass (kg): CG (44 ± 1), EG (44 ± 7) BMI (kg/m <sup>2</sup> ): CG (18.5 ± 3.4), EG (18.6 ± 2.2) Level: Tier 2	Intervention period: whole season CG: usual training program (active-treatment control) EG: usual training program + 20 min NMT FIFA 11 + Kids warm-up program twice a week before regular soccer training sessions. IPP included exercises focused on unilateral, dynamic stability of the lower extremities, trunk strength and stability, and falling technique (jog & look at the coach, skating hop, one-leg stance, push-up, one-leg hops, spiderman, roll over), with five progressive levels of difficulty adapted to each exercise.	Location: differentiated in all body parts Type: fracture, sprain/ligament injury, muscle injury/sprain, other bone injury Mechanisms: contact, non-contact Severity: severe (> 28 days) Injury incidence (injuries / 1000 h of exposure): all severe injuries (0.33 vs. 0.15, HR = 0.42, very likely beneficial), upper extremity (0.11 vs. 0.07, RR = 0.62, unclear), lower extremity (0.22 vs. 0.08, RR = 0.32, very likely beneficial), knee (0.07 vs. 0.01, RR = 0.18, very likely beneficial), ankle (0.06 vs. 0.02, RR = 0.35, likely beneficial), forearm (0.04 vs. 0.04, RR = 1.06, unclear), foot/toe (0.03 vs. 0.01, RR = 0.20, likely beneficial), hip/groin (0.01 vs. 0.03, RR = 0.19, likely beneficial), thigh (0.01 vs. 0.01, RR = 0.67, unclear), lower leg (0.01 vs. 0.01, RR = 1.05, unclear), fracture (0.16 vs. 0.08, RR = 0.51, likely beneficial), sprain/ligament injury (0.06 vs. 0.04, RR = 0.63, unclear), muscle injury/sprain (0.04 vs. 0.03, RR = 0.98, unclear), other bone injury (0.03 vs. 0.01, RR = 0.34, unclear), contact (0.18 vs. 0.09, RR = 0.55, likely beneficial), non-contact (0.08 vs. 0.04, RR = 0.47, likely beneficial)
Hägglund, Atroshi, et al., 2013 [42]	CG (n = 2085), EG-high (n = 831), EG-medium (n = 823), EG-low (n = 817), Gender: female Age (years): 12–17 Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season (7 months) CG: usual training program (active-treatment control) EG: usual training program + 15 min NMT Knäkontroll (SISU Idrottsböcker®) warm-up twice a week before regular soccer training sessions. IPP included core stability, balance and knee alignment exercises (one- and two-legged knee squat, pelvic lift, bench, lunge, and jump/landing technique), with four progressive levels of difficulty adapted to each exercise. EG was stratified into tertiles of compliance based on their mean number of weekly NMT sessions during the season (EG-high: 1.7; EG-medium: 1.4; EG-low: 1.1).	Location: knee Type: ACL injury, severe knee injury, any acute knee injury Injury incidence (injuries / 1000 h of exposure): ACL EG-low = EG-medium (0.14 vs. 0.02, RR = 0.15), ACL EG-low > EG-high (0.14 vs. 0.02, RR = 0.12), ACL EG-low = CG (0.14 vs. 0.11, RR = 0.77), severe EG-low > EG-medium (0.48 vs. 0.08, RR = 0.17), severe EG-low > EG-high (0.48 vs. 0.05, RR = 0.10), severe EG-low = CG (0.48 vs. 0.24, RR = 0.50), any acute EG-low > EG-medium (0.72 vs. 0.19, RR = 0.26), any acute EG-low > EG-high (0.72 vs. 0.20, RR = 0.28), any acute EG-low = CG (0.72 vs. 0.34, RR = 0.48)

**Table 1** (continued)

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Hiliska, Leppänen, Vasankari, Aaltonen, Kannus, et al., 2021 [43]	CG (n = 730, 22% females), EG (n = 673, 17% females) Gender: female (280), male (1123) Age (years): CG (12.3 ± 1.1), EG (12.2 ± 1.2) Height (cm): CG (151.7 ± 9.8), EG (151.3 ± 10.1) Body mass (kg): CG (41.2 ± 8.5), EG (41.3 ± 8.7) BMI (kg/m <sup>2</sup> ): NR Level: Tier 3	Intervention period: 20 weeks CG: usual training program (active-treatment control) EG: usual training program + 20 min NMT warm-up program 2–3 times per week before regular soccer training sessions. IPP included general warm-up, strength exercises for hip, trunk and lower extremities, a balance exercise and speed and deceleration drills (hip muscle activation, lunges, split squat, plank, jump, single leg balance, speed run), with different progressive levels of difficulty adapted to each exercise.	Location: lower extremity, ankle, knee Type: acute, joint/ligament, muscle Mechanisms: non-contact Severity (injuries resulting in ≤ 7 absence days): CG > EG * (RR = 0.66) Injury incidence (injuries / 1000 h of exposure): lower extremity CG > EG * (2.70 vs. 1.80, RR = 0.67), ankle CG > EG * (0.95 vs. 0.56, RR = 0.59), knee CG = EG (0.39 vs. 0.30, RR = 0.75), joint/ligament CG > EG * (1.09 vs. 0.68, RR = 0.62), muscle CG > EG * (1.21 vs. 0.80, RR = 0.66)
Hiliska, Leppänen, Vasankari, Aaltonen, Raitanen, et al., 2021 [44]	CG (n = 733, 22% females), EG-high (n = 276, 15% females), EG-medium (n = 342, 21% females), EG-low (n = 58, 5% females) Gender: female, male Age (years): CG (12.3 ± 1.1), EG-high (12.2 ± 1.3), EG-medium (12.0 ± 1.1), EG-low (13.2 ± 0.8) Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 3	Intervention period: 20 weeks CG: usual training program (active-treatment control) EG: usual training program + 20 min NMT warm-up program 2–3 times per week before regular soccer training sessions. IPP included general warm-up, strength exercises for hip, trunk and lower extremities, a balance exercise and speed and deceleration drills (hip muscle activation, lunges, split squat, plank, jump, single leg balance, speed run), with different progressive levels of difficulty adapted to each exercise. EG was stratified into tertiles of compliance based on their number of NMT sessions during the intervention period (EG-high: > 35; EG-medium: 25 to 35; EG-low: < 25).	Location: lower extremity Type: acute, overuse Mechanisms: non-contact Injury incidence (injuries / 1000 h of exposure): acute lower extremity CG = EG-high (5.48 vs. 4.77, RR = 0.87), acute lower extremity CG = EG-medium (5.48 vs. 4.17, RR = 0.77), acute lower extremity CG > EG-low * (5.48 vs. 3.50, RR = 0.66), acute non-contact CG > EG-high * (2.76 vs. 1.87, RR = 0.67), acute non-contact CG = EG-medium (2.76 vs. 1.83, RR = 0.67), acute non-contact CG > EG-low * (2.76 vs. 1.43, RR = 0.52)
Obérintinca et al., 2024 [41]	CG (n = 503), EG (n = 524) Gender: male Age (years): CG (15.2 ± 1.6), EG (15.3 ± 1.6) Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2 and Tier 3	Intervention period: whole season (10 months) CG: usual training program (active-treatment control) EG: usual training program + Funball programme after their usual warm-up at least twice per week. IPP included mandatory exercises (balance, core stability, hamstring muscles eccentrics, gluteal muscle activation, plyometrics and running/sprinting) with different progressive levels of difficulty adapted to each exercise, and one optional game (Tic-tac-toe, Header game, Dribbling game).	Location: hip/groin, thigh, knee, lower leg, ankle, foot Mechanisms: trauma, overuse Severity: minimal, mild, moderate, severe Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG * (3.53 vs. 2.46, RR = 0.69), hip/groin CG = EG (0.39 vs. 0.28, RR = 0.70), thigh CG > EG * (0.92 vs. 0.57, RR = 0.62), knee CG = EG (0.68 vs. 0.48, RR = 0.71), lower leg CG = EG (0.18 vs. 0.11, RR = 0.59), ankle CG = EG (0.64 vs. 0.43, RR = 0.66), foot CG = EG (0.17 vs. 0.13, RR = 0.77), trauma CG > EG * (3.11 vs. 2.13, RR = 0.68), overuse CG = EG (1.41 vs. 0.33, RR = 0.81), mild CG = EG (1.32 vs. 1.04, RR = 0.79), moderate CG > EG * (1.17 vs. 0.76, RR = 0.665), severe CG > EG * (0.62 vs. 0.31, RR = 0.51)

**Table 1** (continued)

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Owoeye et al., 2014 [35]	CG (n = 204), EG (n = 212) Gender: male Age (years): CG (17.5 ± 1.1), EG (17.8 ± 0.9) Height (cm): CG (171 ± 0.6), EG (172 ± 0.6) Body mass (kg): CG (62.4 ± 6.7), EG (63.8 ± 6.1) BMI (kg/m <sup>2</sup> ): CG (21.2 ± 1.5), EG (21.8 ± 1.7) Level: Tier 2	Intervention period: whole season (6 months) CG: usual training program (active-treatment control) EG: usual training program + 15–20 min NMT FIFA 11 + warm-up program for at least twice a week before regular soccer training sessions. IPP included an initial part (slow-speed running, active stretching exercises), a second part (strengthening, balancing, jumping exercises) and a final part (speed running exercises), with three progressive levels of difficulty adapted to each exercise.	Location: upper extremity, thigh, knee, ankle, lower leg Type: overuse, acute Mechanisms: contact, non-contact Severity: minimal, mild, moderate, severe Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG* (1.5 vs. 0.8, RR = 0.59), lower extremity injuries CG > EG* (1.2 vs. 0.6, RR = 0.52), upper extremity CG = EG (0.3 vs. 0.2, RR = 0.86), thigh CG = EG (0.2 vs. 0.0, RR = 0.19), knee CG = EG (0.3 vs. 0.3, RR = 0.93), ankle CG = EG (0.5 vs. 0.2, RR = 0.53), lower leg CG = EG (0.0 vs. 0.0, RR = -), overuse CG > EG* (0.2 vs. 0.0, RR = 0.26), acute CG > EG* (1.3 vs. 0.9, RR = 0.65), contact CG = EG (1.1 vs. 0.6, RR = 0.65), non-contact CG = EG (0.3 vs. 0.2, RR = 0.65), minimal CG = EG (0.4 vs. 0.2, RR = 0.52), mild CG > EG* (0.4 vs. 0.2, RR = 0.42), moderate CG = EG (0.5 vs. 0.3, RR = 0.64), severe CG = EG (0.2 vs. 0.2, RR = 1.09) Location: lower extremity, foot/ankle, knee, hip/thigh/groin Type: muscular, tendons/ligaments, bony, articular Mechanisms: contact, non-contact Severity: mild, moderate, severe Injury incidence (injuries / 1000 h of exposure): lower extremity EG10 = EG20 (6.37 vs. 7.20, RR = 1.03), foot/ankle EG10 = EG20 (2.66 vs. 2.48, RR = 1.32), knee EG10 = EG20 (0.46 vs. 1.52, RR = 0.77), hip/thigh/groin EG10 = EG20 (3.24 vs. 3.20, RR = 1.12), muscular EG10 = EG20 (4.87 vs. 4.16, RR = 1.47), tendons/ligaments EG10 = EG20 (0.81 vs. 1.62, RR = 0.88), bony EG10 = EG20 (0.23 vs. 0.16, RR = 0.88), articular EG10 = EG20 (0.43 vs. 1.20, RR = 1.20), contact EG10 = EG20 (1.62 vs. 2.16, RR = 2.16), non-contact EG10 = EG20 (4.74 vs. 5.04, RR = 5.04), mild EG10 = EG20 (3.86 vs. 3.76, RR = 1.15), moderate EG10 = EG20 (1.73 vs. 1.36, RR = 1.36), severe EG10 = EG20 (0.81 vs. 2.08, RR = 0.65)
Rahlf & Zech, 2020 [36]	EG10 (n = 77), EG20 (n = 108) Gender: male Age (years): EG10 (14.5 ± 1.5), EG20 (15.3 ± 1.4) Height (cm): EG10 (169.5 ± 10.2), EG20 (173.9 ± 8.6) Body mass (kg): EG10 (58.4 ± 11.7), EG20 (61.9 ± 10.1) BMI (kg/m <sup>2</sup> ): EG10 (20.2 ± 2.6), EG20 (20.6 ± 2.1) Level: Tier 2	Intervention period: whole season (10 months) EG20: usual training program + original 20 min NMT FIFA 11 + warm-up program twice a week before regular soccer training sessions. IPP included an initial part (slow-speed running, active stretching and controlled partner contacts), a second part (strengthening, balancing, jumping exercises) and a final part (speed running exercises), with three progressive levels of difficulty adapted to each exercise.	Location: differentiated in all body parts Type: contusion, joint/ligament, muscle, fracture, overuse, growth-related complaints, other Severity: slight (0 days), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (> 28 days) Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG (HR = 0.52, likely beneficial), knee CG > EG (0.36 vs. 0.21, HR = 0.47, likely beneficial), ankle CG > EG (0.29 vs. 0.19, HR = 0.52, likely beneficial), thigh CG > EG (0.19 vs. 0.12, HR = 0.44, likely beneficial), foot CG = EG (0.15 vs. 0.13, HR = 0.69, unclear), lower leg CG = EG (0.13 vs. 0.07, HR = 0.58, unclear), hip/groin CG > EG (0.10 vs. 0.03, HR = 0.40, likely beneficial), contusion CG = EG (0.36 vs. 0.32, HR = 0.66, unclear), joint/ligament CG > EG (0.31 vs. 0.22, HR = 0.56, likely beneficial), muscle CG > EG (0.28 vs. 0.13, HR = 0.46, likely beneficial), fracture CG > EG (0.21 vs. 0.11, HR = 0.55, likely beneficial), overuse CG > EG (0.16 vs. 0.03, HR = 0.12, likely beneficial), growth-related complaints CG = EG (0.09 vs. 0.05, HR = 0.81, unclear), other CG = EG (0.08 vs. 0.08, RR = 0.76, unclear), severe CG > EG (HR = 0.26, likely beneficial), all injuries CG > EG-high (1.56 vs. 0.62, HR = 0.44), all injuries CG > EG-medium (1.56 vs. 0.95, HR = 0.62), all injuries CG = EG-low (1.56 vs. 1.25, HR = 0.68)
Rössler et al., 2018 [49]	CG (n = 1829), EG (n = 2066) Gender: female, male Age (years): CG (10.7 ± 1.4), EG (10.8 ± 1.4) Height (cm): CG (144 ± 0.1), EG (145 ± 0.1) Body mass (kg): CG (36.4 ± 8.5), EG (36.3 ± 8.5) BMI (kg/m <sup>2</sup> ): CG (17.3 ± 2.5), EG (17.1 ± 2.4) Level: Tier 2	Intervention period: whole season (10 months) CG: usual training program (active-treatment control) EG: usual training program + 15–20 min NMT FIFA 11 + Kids warm-up program twice a week before regular soccer training sessions. IPP included exercises focused on unilateral, dynamic stability of the lower extremities, trunk strength and stability, and falling technique (jog & look at the coach, skating hop, one-leg stance, push-up, one-leg hops, spiderman, roll over), with five progressive levels of difficulty adapted to each exercise. EG was stratified into tertiles of compliance based on their mean number of weekly NMT sessions during the intervention period (EG-high: 1.5; EG-medium: 0.9; EG-low: 0.6).	Location: differentiated in all body parts Type: contusion, joint/ligament, muscle, fracture, overuse, growth-related complaints, other Severity: slight (0 days), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (> 28 days) Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG (HR = 0.52, likely beneficial), knee CG > EG (0.36 vs. 0.21, HR = 0.47, likely beneficial), ankle CG > EG (0.29 vs. 0.19, HR = 0.52, likely beneficial), thigh CG > EG (0.19 vs. 0.12, HR = 0.44, likely beneficial), foot CG = EG (0.15 vs. 0.13, HR = 0.69, unclear), lower leg CG = EG (0.13 vs. 0.07, HR = 0.58, unclear), hip/groin CG > EG (0.10 vs. 0.03, HR = 0.40, likely beneficial), contusion CG = EG (0.36 vs. 0.32, HR = 0.66, unclear), joint/ligament CG > EG (0.31 vs. 0.22, HR = 0.56, likely beneficial), muscle CG > EG (0.28 vs. 0.13, HR = 0.46, likely beneficial), fracture CG > EG (0.21 vs. 0.11, HR = 0.55, likely beneficial), overuse CG > EG (0.16 vs. 0.03, HR = 0.12, likely beneficial), growth-related complaints CG = EG (0.09 vs. 0.05, HR = 0.81, unclear), other CG = EG (0.08 vs. 0.08, RR = 0.76, unclear), severe CG > EG (HR = 0.26, likely beneficial), all injuries CG > EG-high (1.56 vs. 0.62, HR = 0.44), all injuries CG > EG-medium (1.56 vs. 0.95, HR = 0.62), all injuries CG = EG-low (1.56 vs. 1.25, HR = 0.68)

**Table 1** (continued)

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Slauter-beck et al., 2019 [50]	CG (n = 282 females, 316 males), EG (n = 186 females, 322 males) Gender: female (468), male (638) Age (years): NR Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season CG: usual training program (active-treatment control) EG: usual training program + 15–20 min NMT FIFA 11 + warm-up program before regular soccer training sessions except for game and pregame days. IPP included an initial part (slow-speed running, active stretching exercises), a second part with strengthening, balancing, jumping exercises (plank, side plank, NHE, single-leg balance, squat, jump) and a final part (speed running exercises), with three progressive levels of difficulty adapted to each exercise.	Location: lower extremity (foot, ankle, lower leg, knee, thigh, hip/groin) Type: fracture, dislocation/subluxation, sprain, muscle strain, meniscus/cartilage lesion, tendon injury, abrasion, laceration, bruise/contusion/hematoma, and nerve injury Injury incidence (injuries / 1000 h of exposure): CG = EG (1.71 vs. 2.21, OR = 1.29)
Soligard et al., 2008 [45]	CG (n = 837), EG (n = 1055) Gender: female Age (years): 15.4 ± 0.7 Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season (8 months) CG: usual training program (active-treatment control) EG: usual training program + 20 min NMT warm-up program every training session and the running exercises as part of match warm-up. IPP included an initial part (slow-speed running, active stretching and controlled partner contacts), a second part with strengthening, balancing, jumping exercises (plank, side plank, NHE, single-leg balance, squat, jump) and a final part (speed running exercises combined with changes of direction), with three progressive levels of difficulty adapted to each exercise.	Location: knee, ankle, leg, anterior thigh, posterior thigh, hip/groin Type: acute, overuse, sprain, strain, contusion, fracture, lower extremity tendon pain, low back pain, peritostitis Mechanisms: contact, non-contact Severity: minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (> 28 days) Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG * (215 vs. 161, RR = 0.68), knee CG > EG * (1.3 vs. 0.7, RR = 0.55), ankle CG = EG (1.1 vs. 1.0, RR = 0.89), leg CG = EG (0.5 vs. 0.3, RR = 0.58), anterior thigh CG = EG (0.2 vs. 0.2, RR = 0.91), posterior thigh CG = EG (0.2 vs. 0.1, RR = 0.57), hip/groin CG = EG (0.2 vs. 0.2, RR = 1.01), sprain CG = EG (1.7 vs. 1.3, RR = 0.78), strain CG = EG (0.6 vs. 0.5, RR = 0.81), contusion CG > EG * (0.7 vs. 0.3, RR = 0.44), fracture CG = EG (0.2 vs. 0.3, RR = 1.82), lower extremity tendon pain CG > EG * (0.5 vs. 0.2, RR = 0.48), low back pain CG = EG (0.2 vs. 0.0, RR = 0.11), peritostitis CG = EG (0.2 vs. 0.2, RR = 0.68), acute CG > EG * (1.63 vs. 1.33, RR = 0.76), overuse CG > EG * (5.2 vs. 2.5, RR = 0.44), contact CG > EG * (76 vs. 53, RR = 0.64), non-contact CG = EG (58 vs. 55, RR = 0.86), minimal CG = EG (32 vs. 27, RR = 0.77), mild CG = EG (34 vs. 24, RR = 0.64), moderate CG = EG (70 vs. 63, RR = 0.82), severe CG > EG * (79 vs. 47, RR = 0.54)
Steffen et al., 2008 [46]	CG (n = 947), EG (n = 1073) Gender: female Age (years): under-17 Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season (8 months) CG: usual training program (active-treatment control) EG: usual training program + 15–20 min NMT "the 11" warm-up program (F-MARC, 2005) every training session for 15 consecutive sessions and thereafter once a week during the rest of the season. IPP included 10 exercises focusing on core stability, balance, dynamic stabilization and eccentric hamstrings strength (bench, sideways bench, cross-country skiing, chest pass in single-leg stance, forward bend in single-leg stance, figure-of-eights in single-leg stance, line jumps, zig-zag shuffle, bounding, NHE). EG was stratified into subgroups of compliance based on their number of NMT sessions during the intervention period (EG-high: > 20; EG-low: < 20).	Location: upper body, lower body, groin, thigh, knee, ankle Type: overuse, acute, contusion, sprain, strain, other Mechanisms: contact, non-contact Severity (absence days): 1–7 days, 8–21 days, > 21 days Injury incidence (injuries / 1000 h of exposure): all injuries CG = EG (3.7 vs. 3.6, RR = 1.00), upper body CG = EG (0.6 vs. 0.5, RR = 0.8), lower body CG = EG (2.6 vs. 2.7, RR = 1.00), groin CG = EG (0.2 vs. 0.1, RR = 0.4), thigh CG = EG (0.4 vs. 0.5, RR = 1.2), knee CG = EG (0.5 vs. 0.6, RR = 1.2), ankle CG = EG (1.1 vs. 1.2, RR = 1.1), overuse CG = EG (0.5 vs. 0.5, RR = 0.9), acute CG = EG (3.2 vs. 3.2, RR = 1.0), contusion CG = EG (0.8 vs. 0.8, RR = 1.0), sprain CG = EG (1.3 vs. 1.3, RR = 1.0), strain CG = EG (0.6 vs. 0.7, RR = 1.1), other CG = EG (0.4 vs. 0.4, RR = 0.8), contact CG = EG (1.9 vs. 1.8, RR = 0.9), non-contact CG = EG (1.3 vs. 1.4, RR = 1.1), 1–7 days CG = EG (1.3 vs. 1.5, RR = 1.2), 8–21 days CG = EG (1.1 vs. 0.9, RR = 1.2), > 21 days CG = EG (0.9 vs. 0.7, RR = 0.8), all injuries CG = EG-high (3.7 vs. 3.4, RR = 0.9), all injuries CG = EG-low (3.7 vs. 3.8, RR = 0.9)

**Table 1** (continued)

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Waldén et al., 2012 [47]	CG (n = 2085), EG (n = 2479) Gender: female Age (years): CG (14.1 ± 1.2), EG (14.0 ± 1.2) Height (cm): CG (163.8 ± 6.6), EG (163.5 ± 6.8) Body mass (kg): CG (53.3 ± 8.4), EG (53.3 ± 8.6) BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season (7 months) CG: usual training program (active-treatment control) EG: usual training program + 15 min NMT Knäkontroll (SISU Idrottsböcker) warm-up twice a week before regular soccer training sessions. IPP included core stability, balance and knee alignment exercises (one- and two-legged knee squat, pelvic lift, bench, lunge, and jump/landing technique), with four progressive levels of difficulty adapted to each exercise.	Location: Knee Type: ACL injury, severe knee injury, any acute knee injury Injury incidence (injuries / 1000 h of exposure): ACL CG > EG * (AR = -0.07)
Zarei et al., 2020 [39]	CG (n = 519), EG (n = 443) Gender: male Age (years): CG (12.2 ± 1.7), EG (12.1 ± 1.8) Height (cm): CG (150.0 ± 16.0), EG (149.0 ± 15.0) Body mass (kg): CG (44.8 ± 13.0), EG (43.3 ± 12.8) BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: whole season (9 months). CG: usual training program (active-treatment control) EG: usual training program + 20 min NMT FIFA 11 + Kids warm-up program twice a week before regular soccer training sessions. IPP included exercises focused on unilateral, dynamic stability of the lower extremities, trunk strength and stability, and falling technique (jog & look at the coach, skating hop, one-leg stance, push-up, one-leg hops, spiderman, roll over), with five progressive levels of difficulty adapted to each exercise. EG was stratified into tertiles of compliance based on their mean number of weekly NMT sessions during the intervention period (EG-high: 2.8; EG-medium: 1.9; EG-low: 1.1).	Location: lower extremity, knee, ankle Severity (number of injuries with absence days): 1–3 days (CG: 16; EG: 6), 4–7 days (CG: 21; EG: 12), 8–28 days (CG: 18; EG: 1), severe > 28 days (CG: 5; EG: 1) Injury incidence (injuries / 1000 h of exposure): overall CG > EG * (1.87 vs. 0.94, RR = 0.50), lower extremity CG > EG * (1.68 vs. 0.75, RR = 0.45), knee CG > EG * (0.56 vs. 0.19, RR = 0.34), ankle CG = EG (0.50 vs. 0.28, RR = 0.57), severe CG = EG (0.16 vs. 0.03, RR = 0.20), overall CG > EG-high (1.87 vs. 0.56, RR = 0.28), overall CG > EG-medium (1.87 vs. 0.84, RR = 0.42), overall CG = EG-low (1.87 vs. 1.44, RR = 0.73)

ACL: anterior cruciate ligament; AR: absolute rate; BMI: body mass index; CG: control group; EG: experimental group performing 10 min of injury prevention training; EG20: experimental group performing 20 min of injury prevention training; HR: hazard ratio; IPP: injury prevention program; NHE: Nordic hamstring exercise; NMT: neuromuscular training; NR: non-reported; OR: odds ratio; RIR: risk ratio; RR: rate ratio.

=: non-significant differences; \*: significant differences ( $p < 0.05$ )

**Table 2** Overview of the included studies, with study source, sample size (n) and participants characteristics, injury prevention program details, and effects of the non-warm-up programs

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Azuma & Someya, 2020 [33]	CG (n = 60), EG (n = 64) Gender: male Age (years): CG (16.2 ± 0.8), EG (16.2 ± 0.8) Height (cm): CG (169.8 ± 6.0), EG (171.3 ± 5.2) Body mass (kg): CG (60.5 ± 5.3), EG (62.1 ± 5.8) BMI (kg/m <sup>2</sup> ): CG (20.9 ± 1.2), EG (21.1 ± 1.4) Level: Tier 3	Intervention period: 12 weeks CG: usual training program (active-treatment control) EG: usual training program + 20–30 min stretching program by physical therapists 3 times per week. IPP included stretching exercises for the tight body parts (3 times per exercise, fixed in the final position without pain, 30 s held and 30 s rest) without the use of any equipment. EG were permitted to continue the exercise program by themselves, after the intervention period, until the end of the additional 40-week observation period.	Location: differentiated in all body parts Type: trauma, disorder Mechanisms: contact, non-contact Severity: slight (0 days), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (> 28 days) Injury incidence (injuries / 1000 h of exposure): all injuries CG > EG * (4.01 vs. 1.97, RIR = 0.49), trauma CG > EG * (2.06 vs. 1.38, RIR = 0.67), disorder CG > EG * (1.95 vs. 0.59, RIR = 0.30), contact CG > EG * (1.79 vs. 1.22, RIR = 0.68), non-contact CG > EG * (2.22 vs. 0.76, RIR = 0.34), slight CG = EG (0.28 vs. 0.23, RIR = 0.83), minimal CG = EG (0.56 vs. 0.59, RIR = 1.06), mild CG = EG (0.95 vs. 0.56, RIR = 0.59), moderate CG > EG * (1.23 vs. 0.39, RIR = 0.32), severe CG > EG * (0.99 vs. 0.20, RIR = 0.20)
Hasebe et al., 2020 [34]	CG (n = 103), EG (n = 156) Gender: male Age (years): CG (16.3 ± 0.6), EG (16.7 ± 0.5) Height (cm): CG (171.0 ± 5.3), EG (171.0 ± 5.0) Body mass (kg): CG (61.5 ± 5.4), EG (61.4 ± 5.7) BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: 27 weeks CG: usual training program (active-treatment control) EG: usual training program + IPP twice a week after soccer training session and before cool-down. IPP included NHE, with a progressive overload.	Location: hip, knee, ankle, lumbar, hamstring Severity (time-lost-to sport days with injury): hamstring (CG: 95; EG: 12) Injury incidence (injury rate / 10000 h of exposure): hip CG > EG * (1.04 vs. 0.22, ReRi = 4.54), knee CG = EG (1.73 vs. 2.20, ReRi = 0.76), ankle CG > EG * (6.92 vs. 5.07, ReRi = 1.32), lumbar CG = EG (2.08 vs. 1.98, ReRi = 1.01), hamstring CG = EG (1.04 vs. 0.88, ReRi = 1.14)
Raya-González et al., 2023 [37]	CG (n = 26), EG (n = 23) Gender: male Age (years): 17.8 ± 0.8 Height (cm): 174.1 ± 0.5 Body mass (kg): 67.8 ± 7.7 BMI (kg/m <sup>2</sup> ): 22.3 ± 1.92 Level: Tier 2	Intervention period: 14 weeks CG: usual training program (active-treatment control) EG: usual training program + 15–20 min IPP once a week (at least 48 h prior to a competitive game) after regular soccer training sessions. IPP included NHE and sprint exercises, with a progressive overload adapted to each exercise.	Location: hamstring Number of injuries: CG (3), EG (1) Severity (absence days): CG (59), EG (7) Injury incidence (injuries / 1000 h of exposure): CG = EG (1.42 vs. 0.55, RR = 2.60)

**Table 2** (continued)

Study	Sample size (n) and characteristics	Injury prevention program	Effects of the injury prevention program
Torres Martín et al., 2023 [38]	CG (n = 26), EG (n = 20) Gender: male Age (years): 15.6 ± 0.5 Height (cm): 171.1 ± 0.1 Body mass (kg): 62.2 ± 6.7 kg BMI (kg/m <sup>2</sup> ): 21.6 ± 1.7 Level: Tier 3	Intervention period: 15 weeks CG: usual training program (active-treatment control) EG: usual training program + 15–20 min bmrPT twice a week (with at least 48 h of rest between) after a specific warm-up and before regular soccer training sessions. IPP included NHE, eccentric adductor, bilateral and unilateral half-squat, plank, plank with three supports, side plank, side plank with two supports and bridge exercises, with a progressive overload adapted to each drill.	Type: musculotendinous Injury incidence (injuries / 1000 h of exposure): CG = EG (1.40 vs. 1.19, RR = 1.18)
Zouita et al., 2016 [40]	CG (n = 26), EG (n = 26) Gender: male Age (years): 13–14 Height (cm): NR Body mass (kg): NR BMI (kg/m <sup>2</sup> ): NR Level: Tier 2	Intervention period: 12 weeks CG: usual training program (active-treatment control) EG: 90 min RT 2–3 times per week introduced in their training program (instead of the 2–3 weekly soccer training sessions). IPP was divided into 3 phases (familiarization phase, progression phase 1 and progression phase 2), and included exercises with different progressive loads to promote maximum strength and power gains.	Severity: minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (> 28 days) Severity (absence h): CG (147), EG (18) Injury incidence (injuries / 1000 h of exposure): CG > EG * (2.74 vs. 0.82)

BMI: body mass index; bmrPT: body mass-based resistance training; CG: control group; EG: experimental group; IPP: injury prevention program; NHE: Nordic hamstring exercise; NR: non-reported; OR: odds ratio; ReRi: relative risk; RR: risk ratio; RT: rate ratio; RT: resistance training.  
=: non-significant differences; \*: significant differences (p < 0.05)

publication date. The search for published studies concluded on December 22, 2024, and was independently conducted by two authors (DMJ and DC).

**Study selection process**

The results of the entire literature search were compiled into a single database. Duplicates were removed through an electronic and manual validation process. Afterwards, two authors (DMJ and DC) independently screened all records based on their title and abstract for eligibility. Any conflicts or disagreements arising from the first screening stage were resolved in a subsequent meeting between the two authors. All reports assessed for eligibility were retrieved and their full text was peer-reviewed. Based on the information within the full reports, the inclusion and exclusion criteria were used to select the studies for this systematic review. Disagreements regarding full-text inclusion were resolved through discussion or a general meeting with all other co-authors.

**Data collection process and categorization**

The primary outcome assessed was overall injury incidence. Data from the included studies were extracted by one author (DMJ), with a second author (DC) performing a correctness check. Critical data included the study source (author/authors and year of publication), sample size and participants characteristics (years, gender, body mass, height, body mass index, performance level), IPPs details, and overall effects of the IPPs on injury incidence. The effects of the IPPs on injury incidence were also extracted considering factors such as injury location, type, mechanism, and severity. The level of competition for the soccer players was categorized using the “Participant Classification Framework” [22].

The included studies were classified into two categories based on their primary intervention type: NMT warm-up programs (summarized in Table 1) and non-warm-up programs (summarized in Table 2). This categorization aids in evaluating the specific effectiveness of each type of IPP.

**Quality assessment**

Conventionally, the PEDro scale is used as a valuable tool for evaluating the risk of bias in physiotherapy Randomized Controlled Trials (RCTs) and for assessing evaluating the methodological quality of studies. However, the scale has a limited scope, dichotomous scoring, and potential bias toward physiotherapy interventions, which may underestimate the overall methodology intervention of the non-healthcare studies, such as strength and conditioning. Therefore, this systematic review adopted an alternative evaluation criteria [23], which has broad applicability, multi-faced approach and flexible scoring, with a 10-item scale (0–20 points). Scoring was as

follows: 0 = clearly no, 1 = maybe, 2 = clearly yes. Studies were classified as low ( $\leq 50\%$  points), good (51–75% points), or excellent ( $> 76\%$  points). Independent assessment of each study was completed by two authors (DP and LB), and discrepancies were resolved through discussion or through a general meeting with all other authors.

### Meta-analytic method

To evaluate the primary outcome of the IPPs, risk ratios (RR) were obtained by dividing the risk of injury in the experimental group (EG) (i.e., number of injuries in the EG divided by the number of players in the EG) by the risk of injury in the control group (CG) (i.e., number of injuries in the CG divided by the players in the CG) [24]. The authors of studies with insufficient information to allow for the calculation of RR were contacted by one of the authors (DP and LB), and the study was excluded from the analysis if the necessary data was not provided. Mantel-Haenszel method was used to conduct a meta-analysis on binary data, and fixed- and random-effects models were compared [25]. Forest plot was used to represent observed effects [26], and publication bias was assessed via funnel plot and statistically via Egger and Harbord tests for binary outcomes, wherein a  $p$  value of  $< 0.05$  indicates a significant risk of publication bias [27, 28].

To estimate heterogeneity, Cochran's  $Q$  test was used to assess whether observed differences in effects were attributable to chance alone, with a cut-off significance level of 0.10 instead of 0.05 and a DerSimonian-Laird estimator [29, 30].  $I^2$  statistics was used to estimate the percentage of variability in the effects that is compatible with heterogeneity rather than sampling error [24].  $I^2$  values  $> 75\%$  indicate large heterogeneity [24]. Due to the low number of studies ( $< 20$ ),  $Q$  and  $I^2$  statistics should be interpreted cautiously [31]. Finally,  $\tau^2$  quantified the between-study variance, reflecting the variance of the true effect sizes [24]. Cochran's  $Q$  test was also used for the subgroup analysis with mixed-effect models to account for both within- and between- group heterogeneity. Subgroup analyses were performed encompassing type of IPPs (i.e., NMT warm-up or non-warm-up IPPs), duration of the IPPs (i.e., less or more than 24 weeks) and age of participants (i.e., under or over 13 years).

All analyses related to the meta-analysis and plots were performed using the meta package for R v4.1.2.

## Results

### Search strategy and study selection process

The search strategy and study selection process are presented in Fig. 1. After applying the search equation, a total of 3,827 records were identified through database searches. From these records, 761 duplicates were removed, leaving 3,066 records to be screened. After

scrutinizing the title and abstract, 2,958 records were excluded and 108 reports were targeted for retrieval, with 10 reports not being retrieved. Consequently, 98 reports were assessed for eligibility. Following this assessment, 79 reports were removed for not meeting the inclusion or exclusion criteria of this systematic review. As a result, 19 studies met the previously defined inclusion criteria and were finally included in this systematic review.

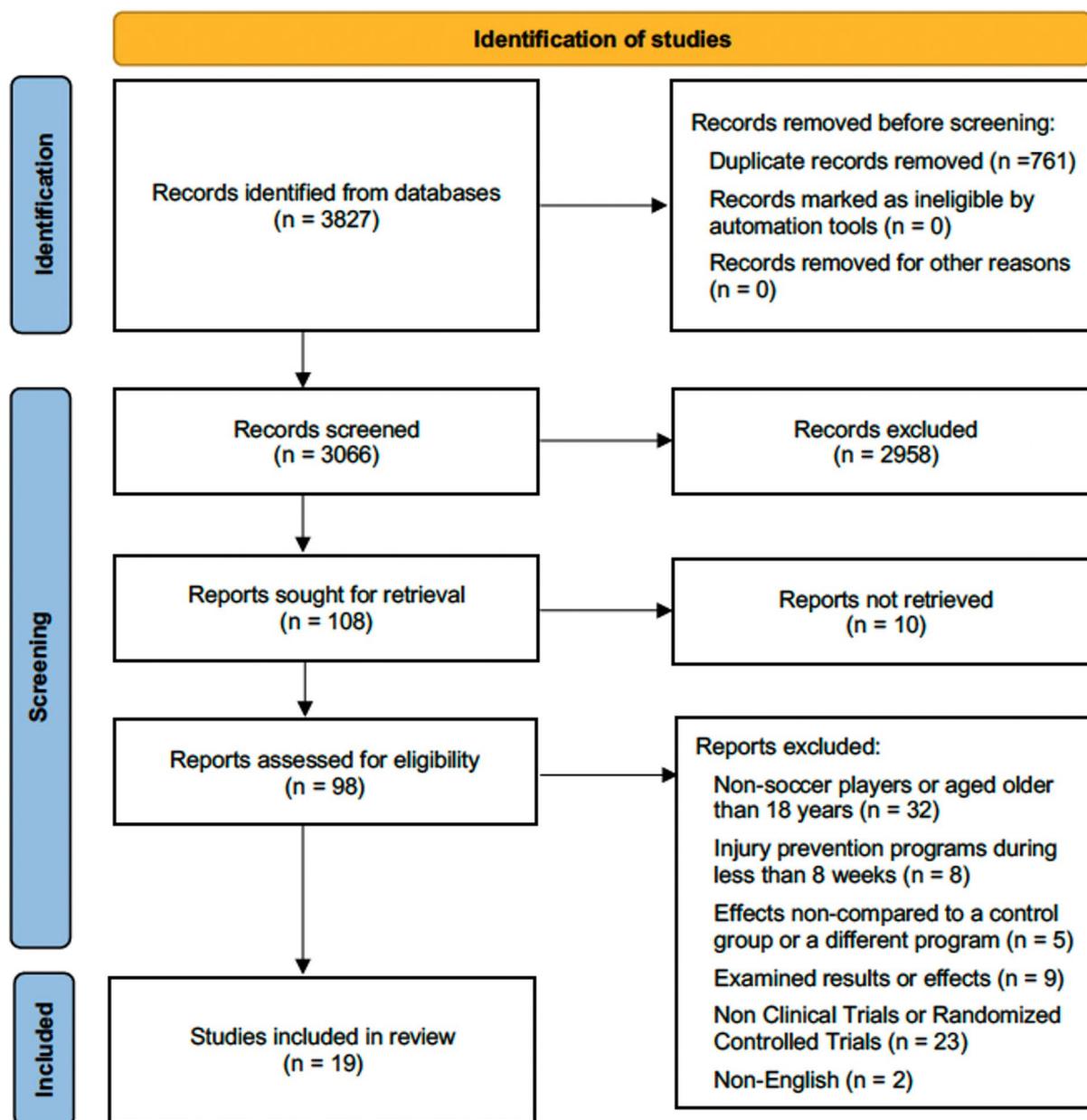
### Study design, sample size (n) and characteristics

Study design, sample size (n) and characteristics of the studies included in this systematic review are summarized in Tables 1 and 2. All studies selected were RCTs, and the total sample consisted of 28,200 youth soccer players (CG  $n = 13,510$ ; EG  $n = 14,690$ ), aged between 7 and 19 years. Ten studies included male players [32–41], six studies were carried out with female players [42–47], and only three studies included players of both genders [48–50]. The sample included players of different performance levels, from Tier 3 to Tier 2 [22].

### Duration, frequency and period of the injury prevention programs

Duration, frequency and period of the IPPs of the studies included in this systematic review are summarized in Tables 1 and 2. The IPPs were carried out throughout the whole season in 14 studies, with varying duration: six [32, 35], seven [42, 47], eight [45, 46], nine [39] and ten months [36, 41, 49], respectively. In four studies, participants were instructed to complete the IPPs throughout the whole season, but the duration was only 20 weeks [43, 44] or not reported [48, 50]. Other studies included intervention periods of 12 [33, 40], 14 [37], 15 [38] and 27 weeks [34] during the season. In one study [33], the IPP was permitted to continue after the initial intervention period, until the end of the additional 40-week observation period.

Regarding the NMT warm-up programs, most of them were conducted twice a week before regular soccer training sessions [36, 39, 42, 47–49], before daily regular soccer training sessions except for game and pregame days [50] or before regular soccer training sessions and matches [32]. However, some NMT warm-up programs were implemented at least twice a week [35, 41] or 2–3 times per week before regular soccer training sessions [43, 44]. Additionally, one NMT warm-up program was delivered every training session for 15 consecutive sessions and thereafter once a week [46], while another NMT warm-up program was carried out every training session and included the running exercises of the IPP as part of match warm-up [45]. Resistance training (RT) as an IPP was employed 2–3 times per week integrated into the participants' training program [40], while body mass-based resistance training (bmRT) was implemented twice



**Fig. 1** Flow diagram for the study selection of the systematic review, which concluded on December 22, 2024

a week (with at least 48 h of rest between session) after a specific warm-up and before regular soccer training sessions [38]. IPPs based on the Nordic hamstring exercise (NHE) were undertaken after regular soccer training sessions, either once [37] or twice a week [34] and the stretching program as an IPP was implemented three times per week [33].

**Content of the injury prevention programs**

Thirteen studies included a NMT warm-up program as the IPP, each one with their characteristics (Table 1). In four studies, players of the EG were instructed to use the

FIFA 11+ Kids warm-up program [32, 39, 48, 49], which includes exercises focused on unilateral, dynamic stability of the lower extremities, trunk strength and stability, and falling technique (jog & look at the coach, skating hop, one-leg stance, push-up, one-leg hops, spiderman, roll over). This IPP has five progressive levels of difficulty adapted to each exercise. The FIFA 11+ warm-up program was implemented in four studies [35, 36, 45, 50], including an initial part with slow-speed running, active stretching and controlled partner contacts, a second part with strengthening, balancing and jumping exercises (plank, side plank, NHE, single-leg balance, squat, jump),

and a final part with speed running exercises, in three progressive levels of difficulty adapted to each exercise. “The 11” warm-up program [51] was used only in one study [46] and included 10 exercises focusing on core stability, balance, dynamic stabilization and eccentric hamstrings strength (bench, sideways bench, cross-country skiing, chest pass in single-leg stance, forward bend in single-leg stance, figure-of-eights in single-leg stance, line jumps, zig-zag shuffle, bounding, NHE). The Knäkontroll (SISU Idrottsböcker©) warm-up program was employed in two studies [42, 47]. This IPP included core stability, balance, and knee alignment exercises (one- and two-legged knee squat, pelvic lift, bench, lunge, and jump/landing technique), with four progressive levels of difficulty adapted to each exercise. Additionally, a different NMT warm-up program was employed in two studies [43, 44]. This warm-up program included general warm-up; strength exercises for hip, trunk and lower extremities; a balance exercise; and speed and deceleration drills (hip muscle activation, lunges, split squat, plank, jump, single leg balance, speed run), with varying progressive levels of difficulty tailored to each exercise. Finally, the Funball programme, employed in a single study [41], incorporated six mandatory exercise categories (balance, core stability, hamstring eccentrics, gluteal muscle activation, plyometrics, and running/sprinting), each one with two distinct exercises, and one optional game (Tic-tac-toe, Header game, or Dribbling game).

Five studies incorporated a non-warm-up IPP, each with unique characteristics (Table 2). Of these, two studies used a RT as an IPP [38, 40], but one of these employed a bmRT [38]. The RT program was structured into three phases (familiarization, progression phase 1 and progression phase 2), incorporating exercises with progressively increasing loads to promote maximum strength and power gains. The bmRT included NHE, eccentric adductor, bilateral and unilateral half-squat, plank, plank with three supports, side plank with two supports and bridge exercises, each with a progressive overload. Additionally, two studies implemented an IPP based on the NHE [34, 37], with the latter study also integrating sprint exercises [37]. Both studies applied a progressive overload specific to each exercise. Finally, a single study used a stretching program as an IPP [33], comprising stretching exercises targeted at tight body parts, performed three times per exercise, in the final position without experienced pain, held for 30 s and followed by a 30 s rest, without the use of any equipment.

#### Outcomes and effects of the injury prevention programs

Of the 19 studies included in this systematic review, 12 reported positive effects of the IPP on overall injury incidence, while four studies found no significant difference between the CG and the EG. Specifically, the NMT FIFA

11 + Kids warm-up program was found effective in reducing injury incidence in four studies [32, 39, 48, 49], while the NMT FIFA 11 + warm-up program reduced injury incidence in two studies [35, 45]. Three studies have shown that specific NMT warm-up programs, such as the Knäkontroll (SISU Idrottsböcker©) and the Funball programme, can also decrease injury incidence in youth soccer players [41, 43, 47]. Three non-warm-up IPPs were also associated with reduce injury incidence, including those based on RT [40], NHE [34] and stretching [33]. On the other hand, it was found that FIFA 11 + warm-up program [50], “the 11” warm-up program [46], and IPPs based on bmRT [38] or on NHE and sprint exercises [37] were not effective in reducing overall injury incidence. In addition, the results of one study showed no differences in injury incidence between performing the NMT FIFA 11 + warm-up program exercises for 10 vs. 20 min [36].

When comparing injury incidence in relation to adherence or compliance with the IPP, most studies showed increasing effectiveness with higher adherence or compliance. Teams and players with higher adherence or compliance with the NMT warm-up programs demonstrated a greater protective effect compared to the CG [39, 42, 44, 49]. However, one study revealed no difference in the incidence of overall and acute injuries between the compliant sub-group and the CG [46].

The effects of the different IPPs on injury incidence in relation to injury location, type, mechanism, and severity are detailed in Tables 1 and 2.

#### Quality assessment

The quality assessment of the included studies, summarized in Table 3, revealed scores ranging from 16 to 19, indicating excellent methodological quality (>75%). Of these studies, four scored 16, nine scored 17, two scored 18, and four scored 19.

#### Meta-analytic overall effect

Of the 19 studies, only 12 (total observations = 16,000) provided sufficient information (e.g., number of injuries) to be included in the meta-analysis. Overall, IPPs were shown to significantly decrease the likelihood of injury (Fig. 2; RR = 0.615 [95% CI = 0.512; 0.739];  $z = -5.20$ ;  $p < 0.001$ ). No significant publication bias was indicated statistically (Harbord's test:  $t(10) = -0.90$ ;  $p = 0.391$ ; Egger's test:  $t(10) = -1.09$ ;  $p = 0.301$ ) or by funnel plot asymmetry inspection (Fig. 3). However, significant and substantial heterogeneity was found amongst studies ( $Q(11) = 39.81$ ,  $p < 0.001$ ;  $\tau^2 = 0.060$  [95% CI = 0.012; 0.242];  $I^2 = 72.4\%$  [95% CI = 50.6%; 84.5%]) which may reflect differences in sex population, unclear control conditions, variability in club infrastructure, performance and cultural level, and the frequent lack of distinction between contact and non-contact injuries.

**Table 3** Quality assessment of the included studies

Study	Inclusion criteria	Random allocation	Intervention defined	Groups tested for similarity at baseline	Control group	Outcome variables defined	Assessment practically useful	Duration of intervention practically useful	Between-group stats analysis appropriate	Point measures of variability	Score (quality)
Al Attar et al., 2023 [32]	2	2	2	0	2	2	2	2	2	2	18 (excellent)
Azuma & Someya, 2020 [33]	1	2	2	0	2	2	2	1	2	2	16 (excellent)
Beaudouin et al., 2019 [48]	2	2	2	0	2	2	2	2	1	2	17 (excellent)
Hägglund, Atroshi, et al., 2013 [42]	2	2	2	0	2	2	1	2	1	2	16 (excellent)
Hasebe et al., 2020 [34]	2	2	2	0	2	2	2	2	2	1	17 (excellent)
Hiliska, Leppänen, Vasankari, Aaltonen, Kannus, et al., 2021 [43]	2	2	2	2	2	2	2	1	2	2	19 (excellent)
Hiliska, Leppänen, Vasankari, Aaltonen, Raitanen, et al., 2021 [44]	2	2	2	0	2	2	2	1	2	2	17 (excellent)
Obértinca et al., 2024 [41]	2	2	2	1	1	2	1	2	2	2	17 (excellent)
Owoeye et al., 2014 [35]	2	2	2	2	2	2	2	1	2	2	19 (excellent)
Rahif & Zech, 2020 [36]	1	2	2	0	2	2	2	1	2	2	16 (excellent)
Raya-González et al., 2023 [37]	2	2	2	2	2	2	2	1	2	1	18 (excellent)
Rössler et al., 2018 [49]	2	2	2	0	2	2	2	2	1	2	17 (excellent)
Slauterbeck et al., 2019 [50]	2	2	2	1	2	2	1	2	2	1	17 (excellent)
Soligard et al., 2008 [45]	2	2	2	1	2	2	2	2	2	2	19 (excellent)
Steffen et al., 2008 [46]	2	2	2	1	2	2	2	2	2	2	19 (excellent)
Torres Martín et al., 2023 [38]	2	2	2	2	2	2	2	1	1	1	17 (excellent)
Waldén et al., 2012 [47]	2	2	2	1	2	2	1	2	2	1	17 (excellent)
Zarei et al., 2020 [39]	2	2	2	0	2	2	1	1	2	2	16 (excellent)
Zouita et al., 2016 [40]	2	2	2	2	2	2	1	1	1	2	17 (excellent)

The scale utilizes 10-item criteria ranging from 0–20 points

The score for each criterion was as follows: 0 = clearly no; 1 = maybe; 2 = clearly yes

The studies were classified as low (≤ 50% of total points), good (51–75% of total points), and excellent methodological quality (> 75% of total points), respectively

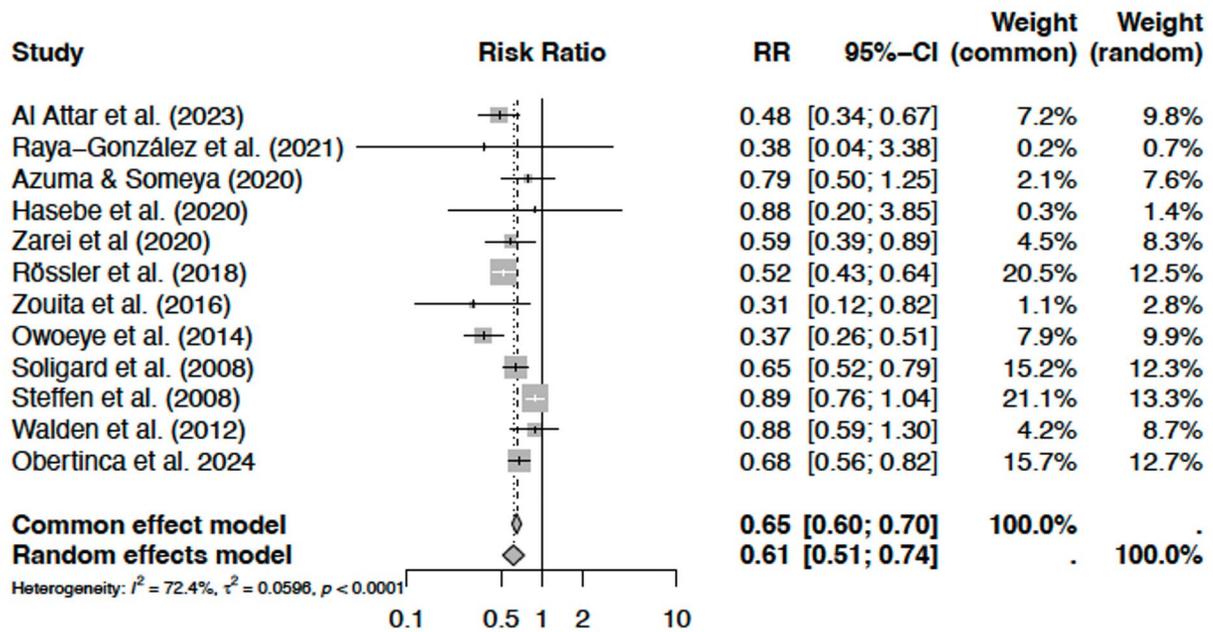


Fig. 2 Meta-analytic overall effect

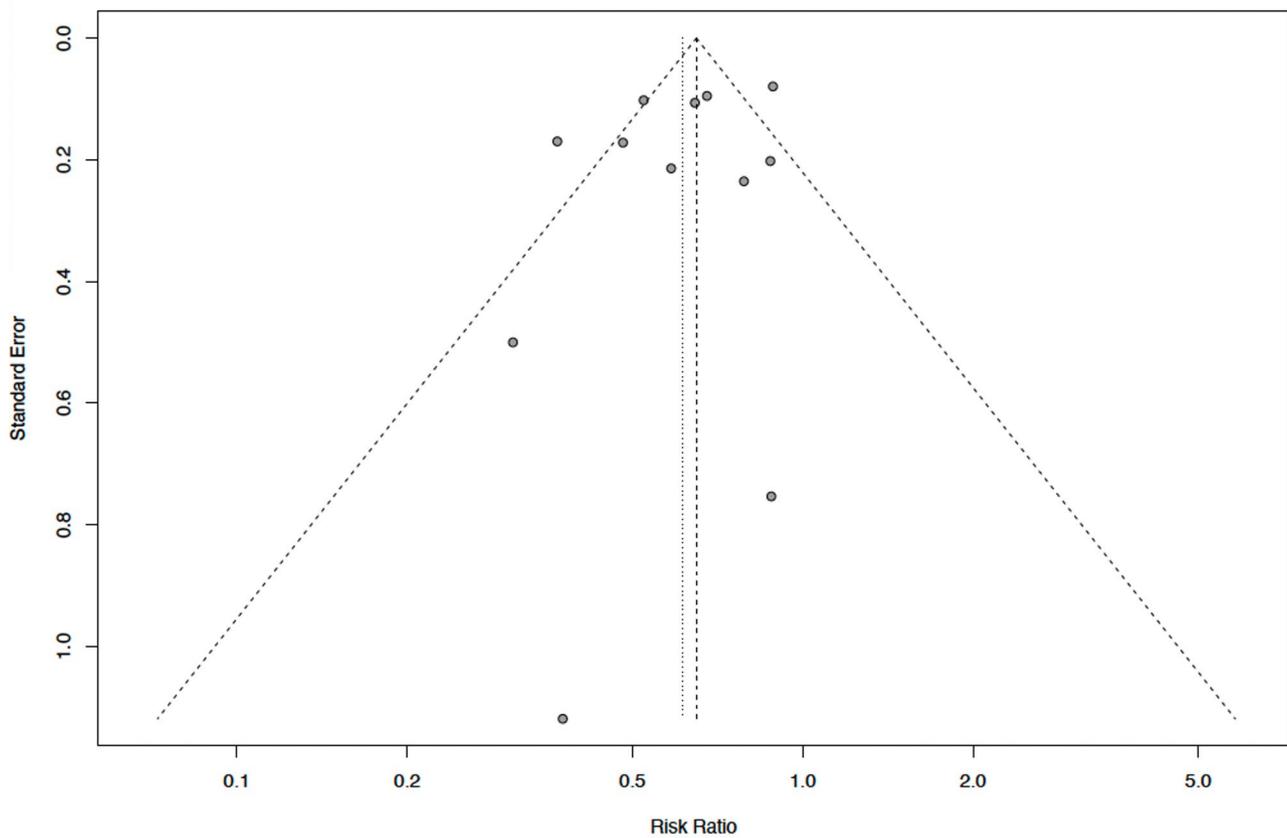


Fig. 3 Funnel plot asymmetry

### Subgroup analyses

Subgroup analyses testing for the effects of IPPs between interventions utilizing NMT warm up ( $k=8$ ) and non-NMT warm up ( $k=4$ ) did not reveal significant between-group differences ( $Q(1)=0.00$ ,  $p=0.955$ ). Subgroup analyses testing for the effects of IPPs lasting less than 24 weeks ( $k=4$ ) and more than 24 weeks ( $k=8$ ) did not reveal significant between-group differences ( $Q(1)=1.87$ ,  $p=0.172$ ). Finally, subgroup analyses testing for the effects of IPPs on participants aged under 13 years ( $k=2$ ) and over 13 years ( $k=10$ ) did not reveal significant between-group differences ( $Q(1)=2.84$ ,  $p=0.092$ ).

### Discussion

The aim of the present systematic review and meta-analysis was to examine, consolidate and summarize the research on the effects of various IPPs on injury incidence in youth soccer players. To the authors' knowledge, previous systematic reviews have been undergone to address the benefits of applying some IPPs in isolation (i.e., FIFA 11+ Kids, F-MARC or FIFA 11) for reducing injury risk [15, 52, 53]. Nevertheless, this systematic review and meta-analysis focus on a variety of exercise-based IPPs (i.e., NMT warm-up or non-warm-up IPP) to reduce injury incidence in youth soccer players.

To understand this issue, 19 studies were selected encompassing a diverse sample of 28,200 youth soccer players aged between the ages of 7 and 19. The studies were conducted in various countries, reflecting a broad range of geographic and cultural contexts, and performance levels (from Tier 3 to Tier 2) [22]. This sample is considered highly representative of what may occur at the international level, according to the published scientific literature.

Most studies in this review centered on NMT warm-up programs [32, 35, 36, 39, 41–50], highlighting their widespread adoption within youth soccer. However, five studies [33, 34, 37, 38, 40] also delved into the effects of non-warm-up IPPs, exploring interventions such as RT, bmRT, NHE, and stretching programs. The variety in IPP design and content, including implementation frequencies ranging from daily to twice weekly, duration from three to nine months, and differing performance levels, reflects the diverse approaches currently adopted in the IPPs.

### Key findings and mechanisms

One of the most prominent findings from the analysis was the effectiveness of NMT warm-up programs in reducing overall injury incidence. These programs prioritize the development of essential physical qualities for soccer, with a particular emphasis on dynamic stability, core strength, balance, and neuromuscular control [32, 35, 36, 39, 41–50]. This focus aimed to improve

an athlete's ability to coordinate movements, react to change of directions (including high accelerations and decelerations), and maintain stability during high-speed actions. Beyond warm-up exercises, other non-warm-up IPPs (i.e., RT, bmRT, NHE, and stretching) also demonstrate potential in reducing injury risk. RT and bmRT increases strength and resilience [38, 40], while NHE specifically targets the hamstring muscles, which are particularly prone to injury in youth soccer populations [34, 37]. However, evidence supporting the use of NHE for hamstring injury prevention is inconclusive [54]. While some authors showed positive effects on reducing incidence of injuries including NHE in their IPPs during 27 weeks in high-school players [34] and other authors indicated NHE and sprints performances during 14 weeks in U19 players for reducing the severity of injuries [37], the authors also suggest that more rigorous research is needed to determine their true effectiveness and the optimal conditions for their use. Furthermore, several studies [39, 42, 44, 49] found that teams and players who consistently participated in and completed IPPs experienced fewer injuries compared to CG or those with lower adherence, suggesting that adherence to IPPs is an important factor in reducing injury incidence. In this way, soccer could become a safer sport and the risk of injury could be reduced. However, one study [46] found no significant difference in injury rates between a compliant subgroup and the CG. This suggests that other factors (e.g., type of IPP) may also influence the impact of adherence and therefore play a role in injury prevention.

The review consistently found a dose-response relationship: higher IPP adherence correlated with greater reduction in injuries risk. This underscores the need to foster a culture, supported by coaches, trainers, and parents, where IPPs are viewed as integral to training rather than optional. The underlying rationale for this relationship may lie in the cumulative physiological and neuromuscular adaptations resulting from consistent program participation [7]. Specifically, sustained adherence to IPPs likely enhances neuromuscular control, joint stability, and muscular strength, thereby reducing key biomechanical risk factors [16, 17]. Strategies such as gamification to improve adherence, education on the "why" behind IPPs, and athlete input into the program can boost engagement and long-term participation. For instance, specific strategies could include targeted training for coaches and fitness staff on the benefits of IPPs, campaigns emphasizing the positive impact of IPPs on youth players' health and sporting longevity and establishing clear guidelines that include IPPs as a mandatory requirement. However, one study revealed no difference in the incidence of overall and acute injuries between the compliant sub-group and the CG [46]. This apparent discrepancy may stem from differences in intervention content (e.g., duration, time of

season, type of NMT warm-up program...), sex population (e.g., male vs. female), or how adherence and compliance thresholds were operationalized.

The meta-analysis included 16,000 participants across diverse countries (six European, six outside Europe). Results indicate a small effect of IPPs in reducing injury risk among youth soccer players. The absence of significant publication bias, as indicated by Harbord's test, Egger's test, and funnel plot asymmetry, supports the robustness of this finding. However, the presence of substantial heterogeneity among the studies ( $I^2=72.4\%$ ) emphasizes the need for caution in interpreting the overall effect. Subgroup analyses conducted for type of IPP, duration of intervention and age of participants did not reveal significant differences in the effectiveness of IPPs across these variables, suggesting that the overall effect of IPPs is not significantly influenced by these factors. However, the large heterogeneity suggests that additional moderators such as sex of the participants, performance level, and geographical or cultural differences may have influenced the observed effects, but the limited information currently available did not allow for further analyses. Indeed, as discussed previously [55], the conclusions of a systematic review and meta-analysis can significantly change based on the inclusion or exclusion of a few studies, and how the complex biological phenomena necessitate consideration of various factors and potential moderators. Additionally, the diverse nature of the intervention effects included in a systematic review and meta-analysis indicates that there is no singular, definitive impact of an intervention, but rather a range of effects that are amalgamated into a single measure [55]. Therefore, methodological consistency in intervention designs and outcome measures are necessary to evaluate IPPs effectiveness and cross-study comparisons. We advise authors to consider our findings in the planning of future interventions, methods of evaluations, and data reporting.

#### **Methodological considerations & future directions**

Inconsistent reporting of injury-causing circumstances in soccer research creates a significant barrier to understanding injury mechanisms and hinders meaningful comparisons across studies [56]. A significant limitation identified in the reviewed literature is the lack of consistent differentiation between contact and non-contact injuries, with approximately 50% of studies failing to report this distinction. This inconsistency hampers the identification of mechanism-specific risk factors and limits the precision of injury prevention strategies. To enhance the reliability of mechanistic analyses and facilitate comparability across studies, we emphasize the need for standardized injury reporting using the Football Injury Inciting Circumstances Classification System

(FIICCS; 57). FIICCS offers a comprehensive and systematic framework for documenting the contextual factors surrounding injury events in football, thereby supporting more accurate and actionable insights into injury mechanisms [57].

Additionally, the lack of a clear definition for "usual warm-up routines" in most of the studies examined poses a significant challenge when analyzing the effectiveness of interventions. Without knowing the specific exercises and organization of these routines, it becomes difficult to determine the true impact of the IPP compared to the CG. In studies examining the effectiveness of interventions (e.g., 11+ warm-up routine), the CG should ideally receive a standard intervention that is not expected to produce significant effects. However, if the "usual warm-up routine" used as the control already incorporates elements that could enhance performance or reduce injury risk, it becomes difficult to isolate the unique effects of the experimental intervention. This could lead to a scenario where the EG shows no statistically reduction on overall injury incidence [46, 50] over the CG, not because the intervention is ineffective, but because the CG is already benefiting from certain components of the warm-up. In some cases, it might be appropriate to use a different type of CG altogether, such as a group that receives no warm-up or a group that performs a different warm-up structure. This could help to further isolate the effects of the EG. To address this critical gap, a comprehensive guide to CG design in sports research was created, which outlines and discusses four primary types of CGs (no-treatment control, placebo or alternative-task control, variable-delivery control, active-treatment control) [58].

Another important point of discussion concerns the relationship between growth rate, maturity status, and injury risk in youth soccer players [59]. These authors reported that players with fast growth rates have a higher incidence of growth-related injuries, particularly in pre- and circa-peak height velocity (PHV) periods, while slow-growing players post-PHV exhibit a higher incidence and burden of joint/ligament injuries. The research recommends measuring players' height every 3–4 months to model individual growth curves and estimate growth velocities. It also suggests using growth/maturity heat maps and innovative strategies, such as bio-banding, to identify and mitigate injury risk during periods of heightened vulnerability. Notably, a previous review [60] showed similar findings where many studies do not record individual exposure, which is crucial for accurate injury estimates and addressing risk factors such as growth and maturation. Moreover, the author emphasizes the importance of focusing on general movement skills and progressive physical development during the adolescent growth spurt, before reaching skeletal maturity. Regrettably, only one included study [40] accounted

for individual growth and maturation status when designing or implementing IPPs. Neglecting this factor introduces a potential source of bias, as maturation has been strongly linked to differential injury risk, particularly during periods of rapid growth (e.g., PHV). For instance, athletes undergoing accelerated growth phases may experience temporary imbalances in strength, coordination, or flexibility, which can heighten injury susceptibility [59]. Therefore, failing to control for or report maturity status may not only obscure the true effectiveness of an IPP but also limit its applicability across diverse developmental stages. Future research should incorporate growth and maturation status, as these factors are essential for a comprehensive understanding of injury mechanisms and for the effective tailoring of IPPs in developing soccer populations.

Consistent and systematic reporting of injury-inciting circumstances in youth soccer is crucial for advancing injury prevention efforts. Standardized reporting ensures higher quality data, allowing researchers to effectively pool and compare findings across studies. This, in turn, enables the identification of recurring injury patterns and underlying mechanisms, providing valuable insights to inform the development of evidence-based prevention programs and targeted interventions.

Finally, to enhance the rigor and transparency of research in this area, future studies should clearly define and describe the specific components of “usual warm-up routines” used as CG, including the exercises performed, their duration, and sequence. This will enable more accurate comparisons and facilitate the translation of research findings into practice.

## Conclusions

This systematic review and meta-analysis demonstrate that various IPPs are likely to reduce the risk of injuries by minimizing injury incidence among youth soccer players. The RR values obtained would indicate a 35–39% reduction in injury risk for players who participated in structured IPPs, suggesting their potential protective effect in injury prevention. This represents a cautiously optimistic step toward understanding the role of IPPs, such as warm-up routines or neuromuscular strength programs, within the context of injury prevention. While further refining our understanding through standardized research, investigations into long-term effects, and individual implementation strategies based on the maturation status, the findings should encourage coaches, sports organizations, and researchers to invest in further exploration and refinement of IPP strategies. Educating coaches and parents about the importance of IPPs is crucial to establishing these programs as an integral part of youth soccer culture, thus ensuring a safer and more sustainable experience for young soccer players worldwide.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13102-025-01246-8>.

Supplementary Material 1

Supplementary Material 2

## Acknowledgements

Not applicable.

## Author contributions

DC: methodology, project administration, writing – original draft. DM-J: conceptualization, data curation, investigation, methodology, writing – original draft. MB: supervision, writing – original draft, writing – review & editing. ML-F: review & editing. LB: review & editing. ADF: review & editing. DP: formal analysis, writing – original draft, writing – review & editing.

## Funding

This project leading to these results has received co-funded by the Erasmus+ Programme of the European Union.

## Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

Received: 25 February 2025 / Accepted: 24 June 2025

Published online: 10 July 2025

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