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REVIEW

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Injury risk reduction programs including balance training reduce the incidence of anterior cruciate ligament injuries in soccer players: a systematic review and meta-analysis

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Abstract

Background Anterior cruciate ligament (ACL) injuries are exceedingly common among soccer players and severely impact their careers and health. This study evaluates the effects of injury risk reduction programs, including balance training exercises, on the incidence of ACL injuries in soccer players through a meta-analysis. The aim is to promote the health of soccer players, enhance their athletic performance, and provide valuable insights for further research in the field of sports medicine.

Methods This study strictly adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was conducted through PubMed, EBSCO, and Web of Science databases, covering all entries from the inception of the databases until February 2024.

Results Eligible studies were individually assessed using the Cochrane Risk of Bias Tool version 2, and the quality of the evidence obtained was rigorously evaluated using the GRADE approach. Data analysis and processing were performed using Stata 18 software. Eight studies were ultimately selected for inclusion in the meta-analysis, encompassing 20,336 participants and 1,512,099 exposure hours, with 190 cases of ACL injuries identified among soccer players. The pooled results indicated that, compared to the control group, groups using injury risk reduction programs that included balance training had a 58% reduction in the overall rate of ACL injuries per 1,000 exposure hours (IRR 0.42, 95% CI: 0.27 to 0.66). The overall study heterogeneity was low, with an I^2value of 33.3% and a P-value of 0.186. Subgroup analyses showed that in trials involving male participants, the rate of ACL injuries per 1,000 exposure hours was reduced by 50% compared to the control group (IRR 0.50, 95% CI: 0.29 to 0.88), with an I^2 value of 44.8% and $P=0.178$. In trials involving female participants, ACL injuries were reduced by 61% (IRR 0.39, 95% CI: 0.24 to 0.62), with an I^2 value of 42.5% and $P=0.157$. In trials with participants training less than three times per week,

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ACL injuries were reduced by 43% per 1,000 exposure hours compared to the control group (IRR 0.57, 95% CI: 0.35 to 0.93), with an I^2 value of 0.00% and $P=0.727$. In trials with participants training three times or more per week, ACL injuries were reduced by 57% (IRR 0.43, 95% CI: 0.21 to 0.88), with an I^2 value of 28.2% and $P=0.238$. In trials with participants training for 20 min or more per week, the rate of ACL injuries per 1,000 exposure hours was reduced by 50% compared to the control group (IRR 0.50, 95% CI: 0.26 to 0.93), with an I^2 value of 1.2% and $P=0.363$. In trials with participants training less than 20 min per week, ACL injuries were reduced by 46% (IRR 0.54, 95% CI: 0.33 to 0.91), with an I^2 value of 0.00% and $P=0.544$.

Conclusion In summary, injury risk reduction programs that include balance training significantly reduce the risk of ACL injuries in soccer players. The reduction in injuries is more pronounced in female athletes, and high-frequency training along with longer-duration interventions further enhance the preventative effects.

Keywords Injury risk reduction programs, Balance exercises, ACL injury, Soccer sports injury, Football sports injury

Introduction

Soccer is one of the most popular sports globally [1], characterized by its competitiveness, high intensity, and frequent direction changes. However, players are also exposed to various risks of sports injuries during matches, which can significantly impact their careers and the overall performance of their teams [2–4]. Among these injuries, those affecting the lower extremities are particularly concerning due to their high incidence. Epidemiological studies indicate that approximately 200,000 ACL tear cases occur annually in the United States, with about 50% of these cases undergoing arthroscopic reconstruction surgery [5]. Furthermore, lower extremity injuries are far more common than upper extremity injuries among soccer players [6], with knee injuries ranking among the most frequent and severe types of lower limb injuries [7]. Knee injuries are prevalent in high-intensity sports that involve rapid directional changes, sudden deceleration, and jumping, such as American football, soccer, volleyball, handball, and basketball. These injuries can occur during both training sessions and competitions across all levels of play, often resulting in sprains, strains, contusions, and fractures [8]. It is estimated that there are at least 40 sports injuries per 1,000 h of soccer played [9]. Among these, ACL injuries are one of the most frequent, thus posing a higher risk of injury [10]. Most acute ACL injuries reported in soccer occur when players rapidly lower their center of gravity while making directional changes, jumping, or landing [11] and most of these injuries occur in non-contact situations [12]. ACL injuries are a serious and concerning health issue among professional soccer players [13]. Postoperative bone mineral content may decrease due to reduced tendon stiffness [14].Despite increased awareness of ACL injuries and their prevention, the injury incidence in professional soccer has not decreased [15]. Although most players can return to play after recovering from an ACL injury, subsequent risks of knee injuries, early onset osteoarthritis, and shortened careers remain significant concerns [15]. Lower limb injuries are caused by a dynamic interplay of multiple risk factors, some of which may be addressed through injury risk reduction programs [16, 17]. Exercise-based injury risk reduction programs typically focus on improving strength, balance, and overall biomechanics in activities similar to the non-contact mechanisms of ACL injuries [18, 19].

In recent years, more studies have focused on balance training as a potential preventative measure to reduce the risk of ACL injuries in soccer players [20, 21]. Research indicates that balance training is an effective method to improve knee joint stability and reduce knee injuries [22, 23]. Furthermore, balance exercises are highly beneficial for enhancing proprioception and balance capabilities [24]. In the realm of postoperative rehabilitation, protocols have evolved from early immobilization to emphasizing early mobilization and progressive loading [25]. This shift not only aids in the recovery process but may also contribute to improved performance and the prevention of lower limb injuries. One study showed that neuromuscular training including balance exercises significantly improved biomechanical measures related to the risk of ACL injuries in female soccer players [26]. In the realm of soccer, systematic reviews by Ojeda et al. [27] investigated interventions for preventing lower limb injuries in soccer players, including proprioceptive training, neuromuscular training, balance training, and posture control exercises, which have been proven to be very effective in injury risk reduction, especially for the knees and ankles. Similarly, Al Attar et al. [28] provided a systematic overview and meta-analysis of studies on the FIFA injury risk reduction programs, which include FIFA11 and FIFA111, incorporating various components such as balance exercises.

This comprehensive meta-analysis rigorously compiles and scrutinizes data from a multitude of studies to evaluate the efficacy of balance training as a key component of injury risk reduction strategies, with a focus on its influence in reducing ACL injury rates. We critically assess the role of balance training in fortifying physical stability, enhancing core strength, and advancing

athletic competencies among soccer players. Moreover, this review explores the operational factors, such as the frequency and length of these interventions, distilling actionable insights for teams, coaches, and athletes to implement. Our in-depth investigation into the role of balance training in mitigating ACL injury risk strives to present an expansive and empirically grounded injury risk reduction framework, aiming to safeguard player health and augment their on-field prowess, as well as to supply a valuable resource for ongoing sports medicine research. The insights gleaned from this analysis are poised to influence future training paradigms and rehabilitative methodologies, fostering a more secure and enduring sporting milieu for soccer athletes. Therefore, the pivotal question addressed by this systematic review is: What is the measurable impact of injury risk reduction programs, which incorporate balance training exercises, on the prevalence of knee injuries in soccer players? Our research hypothesis is that soccer players who participate in injury reduction programs that include balance training exercises will have a significantly lower incidence of ACL injuries compared to those who do not participate in such programs. The effectiveness of these programs may vary depending on factors such as training frequency, duration, and gender.

Materials and methods

This study aims to conduct a systematic review and meta-analysis to investigate the effect of injury reduction programs incorporating balance training on the incidence of ACL injuries in soccer athletes. The study follows the PICOS framework to formulate the research question and design, where: P (Soccer athletes), I (Injury risk reduction programs that include balance training), C (Control groups that did not receive an injury risk reduction program or only underwent routine training), O (ACL injury incidence rate per 1,000 exposure hours), S (Published randomized controlled trialsand cohort studies).

Literature search strategy

This study was conducted strictly in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [29].To locate relevant studies, we conducted a comprehensive literature search using the following keywords: “Balance Training” “Muscle Stretching Exercises” “Neuromuscular Training” “ACL Injuries” “Soccer Athlete” and “Football Athlete” along with their synonyms, related terms, and abbreviations. We searched databases including PubMed, EBSCO, and Web of Science. All search terms were combined to find pertinent studies. Additionally, the reference lists of previously published articles were reviewed to identify relevant studies. The search strategy combined both controlled vocabulary and free text terms and tracked citations related to the topic. Our objective was to identify all studies that met our inclusion criteria. The search was conducted up to February 2024, covering all entries from the inception of the databases.

Inclusion and exclusion criteria

Inclusion criteria

(1) The study subjects are healthy soccer players with no diseases, including musculoskeletal disorders or other health conditions that may affect athletic performance, such as cardiovascular, respiratory, or metabolic diseases. There are no restrictions on the athletes’ age, gender, skill level, race, or nationality. (2) The intervention method is an injury prevention program that includes balance training exercises versus a usual/standard warm-up program. The intensity, form, and weekly duration of the exercise are not limited; (3) Outcome measures must report at least one of the following: the number of knee injuries, the rate of knee injuries, the number of exposures, and exposure hours.

Exclusion criteria

(1) Studies with incomplete data, reviews, conference papers, and theses; (2) Individual case analyses; (3) Studies that use animals as research subjects; (4) Duplicate publications; (5) Non-English publications.

Study selection and data extraction

Records retrieved through searches were merged and imported into Endnote X9 bibliographic management software. Initially, duplicate publications were removed. Then, titles and abstracts of the studies were screened based on inclusion and exclusion criteria, and those that did not meet the requirements were excluded. Further inclusion was determined after reading the full texts. This process was independently conducted by two reviewers (W.S. and H.Y.). For studies where inclusion or exclusion was uncertain, resolution was sought through discussion between the two assessors and, if necessary, adjudication by a third researcher (C.L.). Full texts of all potentially eligible studies were obtained. Articles that did not meet the inclusion criteria were excluded. Any discrepancies were resolved through consultation with a third reviewer to reach a consensus.

The two reviewers (W.S. and H.Y.) independently extracted data from eligible studies using a predesigned form. The extracted information included the first author of the abstract, publication year, number of participants (total and in each study group), participant characteristics (age, gender), details of the intervention (type, frequency, duration), and injury outcomes (number of injuries, exposure time), content of the injury prevention program, and the exercise mode of the control group.

Outcome measurements: Data elements extracted from the included trials included the number of ACL injuries, knee injury rates, exposure times, exposure instances, and two or more of ACL injuries per 1,000 h. After completing the data extraction forms, reviewers crosschecked the data to ensure accuracy. Any inconsistencies were resolved by the third reviewer (C.L.). A detailed summary of the extracted data is presented in Table 1.

Quality assessment

The risk of bias in the included studies was assessed using the Cochrane Risk of Bias Tool, version 2 [30]. This tool evaluates several components of study quality, including the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. The assessment employed the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) methodology, which is widely recognized as a scientifically reliable method for systematically assessing the quality of evidence in a given field. By adopting the GRADE approach, this study ensures that its conclusions are based on a thorough and objective assessment of the existing evidence. Researchers classified the articles

Table 1 Basic characteristics of the included studies

Study	Country	Participants (Total)	Sex	Intervention Method		Frequency	Duration
				IG	CG		
Beaudouin, 2019[38]	Switzerland	3895	Male/Female	FIFA 11 + Kids, consisting of (1) improvement of coordination and balance, (2) enhancement of core and (unilateral) leg stability, and (3) optimization of falling techniques.	Standard warm-up routine.	2/week	36week
Gilchrist, 2008[32]	USA	1435	Female	Prevent injury and Enhance Performance Program, including Stretching, Strengthening, Plyometrics, Agilities.	Usual warm-up activities.	3/week	12week
Grooms, 2013[33]	USA	41	Female	F-MARC 11 + program, comprising running exercises, exercises targeting strength, balance, and jump-landing control, as well as higher-speed running drills and cutting actions.	Conventional dynamic warm-up exercises.	5–6/week	About 12 weeks
Mandelbau, 2005[34]	USA	5703	Female	Intervention includes neuromuscular and proprioceptive training, stretching, strengthening, plyometric, and sport-specific agility training. Balance exercises include proprioceptive training, single-leg jumps, and scissor jumps.	Traditional soccer warm-up and training activities.	/	2 years
Krutsch, 2019[37]	Germany	1130	Male	A pre-seasonal analysis identified five modules to be incorporated into the training routine for postural stability, mobilization of lower extremity joints, leg and trunk stabilization, jumping, and landing exercises, as well as agility movements to prevent severe knee injuries in elite football.	Continuation of their standard training program.	At least 2/week	1 season
Silvers-Granelli, 2015[35]	USA	1525	Male	Prevent injury and Enhance Performance Program, including Stretching, Strengthening, Plyometrics, Agilities.	Typical soccer warm-up, usually including running exercises, static and/or dynamic stretching, actions involving changing directions, and short passes.	3/week	About 4–5 months
Steffen, 2008[36]	Norway	2020	Female	"11" training program, focusing on core stability, balance, dynamic stability, and eccentric hamstring muscle strength.	Regular football warm-up program.	1–2/week	32 weeks
Waldén, 2012[39]	Sweden	4564	Female	Neuromuscular warm-up program, incorporating core stability, balance training, and proper knee alignment.	Usual football training and matches.	2/week	About 28 weeks

Note: IG stands for Intervention Group, and CG stands for Control Group

into categories of low risk, high risk, and some concerns regarding bias. The risk of bias assessment was independently conducted by two reviewers (W.S. and H.Y.), with conflicts resolved by a third reviewer (C.L.).

Statistical analysis

Data analysis was performed using Stata 18, and forest plots were generated. Heterogeneity across the studies for each outcome was evaluated using the standard I^2 statistic. If $I^2 > 50\%$ and $P < 0.10$, indicating heterogeneity among studies, a random-effects model was used for analysis; otherwise, a fixed-effects model was employed. The primary meta-analysis was based on total exposure hours. The incidence rate of sports injuries represents the injury rate; in sports research, it is used to estimate the rate of injuries because it adjusts for variations in exposure hours among athletes included in the study [31].The injury risk ratio (IRR) was calculated as follows: IRR = Injury incidence rate in the IG/Injury incidence rate in the CG=(Number of injuries in the IG/Total exposure time of the IG)/(Number of injuries in the CG/Total exposure time of the CG). For cases where exposure data were reported as the number of athlete exposures (i.e., an athlete participating in one training session or match), these athlete exposures were converted based on the assumption that each athlete exposure equates to two hours of exposure time [19].

Results

Analysis of literature screening results

A total of 1069 papers were retrieved from the databases, and after importing into Endnote software, 389 duplicate papers were removed, leaving 680 papers for further screening. Subsequently, the titles and abstracts of the remaining papers were carefully evaluated based on the pre-determined inclusion and exclusion criteria, ultimately excluding 535 papers. Thereafter, the full texts of the remaining 56 papers were thoroughly assessed, and finally, 8 studies were selected for inclusion in the meta-analysis. The specific literature screening process is illustrated in Fig. 1.

General characteristics of the selected research literature

After a thorough screening process based on the predetermined inclusion and exclusion criteria, a total of 8 studies were included in this meta-analysis. These trials included a total of 20,336 participants, with 9,320 in the intervention groups and 11,016 in the control groups. Four of the studies were conducted in the United States [32–35], one in Norway [36], one in Germany [37], one in Switzerland [38], and one in Sweden [39]. Two studies included only male participants [35, 37], five studies included only female participants [32–34, 36, 39], and one study included both male and female participants [38]. Further information on the selected trials is presented in Tables 1 and 2.

Quality assessment of selected literature

The results of the risk of bias assessment are illustrated in Figs. 2 and 3. These figures provide a clear and intuitive description of the methodological quality for each study, with green representing a low risk of bias, yellow representing some concerns, and red representing a high risk. Within the category of Randomization process, 5 studies were deemed low risk, 1 studies had some concerns, and 2 study was marked as high risk. For Deviations from the intended interventions, 1 study was evaluated as low risk, while the rest had some concerns. In the domain of Missing outcome data, 4 studies were assessed as low risk, with the remainder having some concerns. All studies were considered low risk for Measurement of the outcome, and in the Selection of the reported result, 7 studies were identified as low risk, with the remaining having some concerns.

Intervention effects of injury risk reduction programs including balance training exercises

Table 2 presents the incidence rates of ACL injuries and the corresponding exposure hours for both the intervention and control groups. The data compiled from the eight included studies encompasses 20,336 participants and 1,512,099 exposure hours, with a tally of 190 ACL injuries amongst soccer players. The synthesized outcomes indicate a substantial 58% reduction in the incidence of ACL injuries per 1,000 exposure hours (IRR 0.42, 95% CI: 0.27 to 0.66) (Fig. 4) for groups undertaking injury risk reduction programs that include balance training exercises, compared to control groups. The studies included in the analysis exhibited overall low heterogeneity, with an I^2 value of 33.3% and a P value of 0.186.

Subgroup analysis of the intervention effects of injury risk reduction programs including balance training exercises

Table 3 delineates the subgroup analysis results of the intervention effects of injury risk reduction programs incorporating balance training exercises. The analysis, stratified by gender of the study participants, indicates an overall low heterogeneity in the effectiveness of balance training across genders. Compared to the control group, the trials involving male participants saw a 50% reduction in the rate of ACL injuries per 1,000 exposure hours (IRR 0.50, 95% CI: 0.29 to 0.88), with low heterogeneity ($I^2 = 44.8\%$, $P = 0.178$). Similarly, in trials involving female participants, ACL injuries decreased by 61% (IRR 0.39, 95% CI: 0.24 to 0.62), also presenting low heterogeneity ($I^2 = 42.5\%$, $P = 0.157$).

The subgroup analysis by weekly training frequency in studies indicates a generally low heterogeneity in the

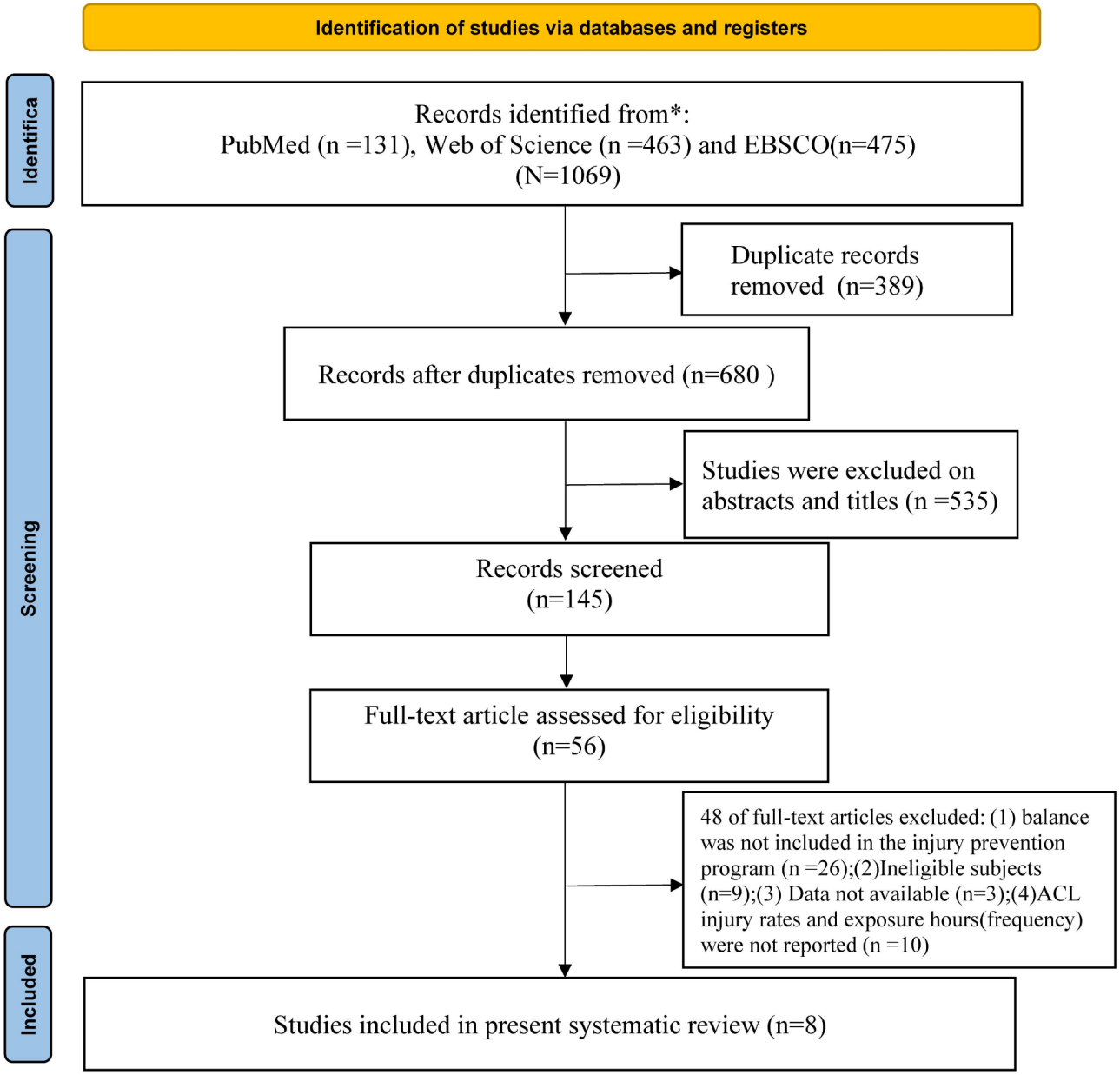

Fig. 1 Flow chart of literature screening

effectiveness of injury risk reduction programs that include balance training exercises, in relation to the frequency of weekly training sessions. When compared with control groups, trials with less than three training sessions per week demonstrated a 43% reduction in ACL injury rate per 1,000 exposure hours (IRR 0.57, 95% CI: 0.35 to 0.93), exhibiting negligible heterogeneity ($I^2 = 0.00\%$, $P = 0.727$). Similarly, for participants training three or more times per week, ACL injury rates decreased by 57% (IRR 0.43, 95% CI: 0.21 to 0.88), with low heterogeneity ($I^2 = 28.2\%$, $P = 0.238$).

Subgroup analysis based on the duration of weekly interventions also showed a generally low heterogeneity in the effectiveness of injury risk reduction programs incorporating balance training related to the duration of weekly intervention time. Compared to the control groups, trials with a training duration of 20 min or more per week saw a 50% decrease in ACL injury rate per 1,000 exposure hours (IRR 0.50, 95% CI: 0.26 to 0.93), with very low heterogeneity ($I^2 = 1.2\%$, $P = 0.363$). Similarly, in participants with less than 20 min of training per week, the rate of ACL injuries decreased by 46% (IRR 0.54, 95% CI: 0.33 to 0.91), also showing negligible heterogeneity ($I^2 = 0.00\%$, $P = 0.544$).

Table 2 Basic information on the number of ACL injuries in the intervention and control groups from the included studies

Study	IG					CG				
	Year	*N*	ACL injuries	Exposure hours	ACL injuries/1,000 h	Year	*N*	ACL injuries	Exposure hours	ACL injuries/1,000 h
Beaudouin,2019[38]	11.7 ± 0.8	2066	0	140,659	0.000	11.3 ± 1.2	1829	0	152,089	0.000
Gilchrist,2008[32]	19.88	583	7	70,440	0.099	19.88	852	18	1,058,838	0.170
Grooms,2013[33]	20.0 ± 2.4	30	0	2703	0.000	20.3 ± 1.6	34	0	2418	0.000
Mandelbaum,2005[34]	14–18	1885	6	135,720	0.044	/ 14–18	3818	67	274,896	0.244
Krutsch,2019[37]	22.7 ± 4.3	529	15	27,159	0.552	21.9 ± 4.1	601	28	30,855	0.907
Silvers-Granelli,2015[35]	20.40 ± 1.66	675	3	70,452	0.043	20.68 ± 1.46	850	16	88,424	0.181
Steffen,2008[36]	13–17	1073	4	66,423	0.060	13–17	947	5	65,725	0.076
Waldén,2012[39]	14.0 ± 1.2	2479	7	149,214	0.047	14.1 ± 1.2	2085	14	129,084	0.108

Note: IG stands for Intervention Group, and CG stands for Control Group

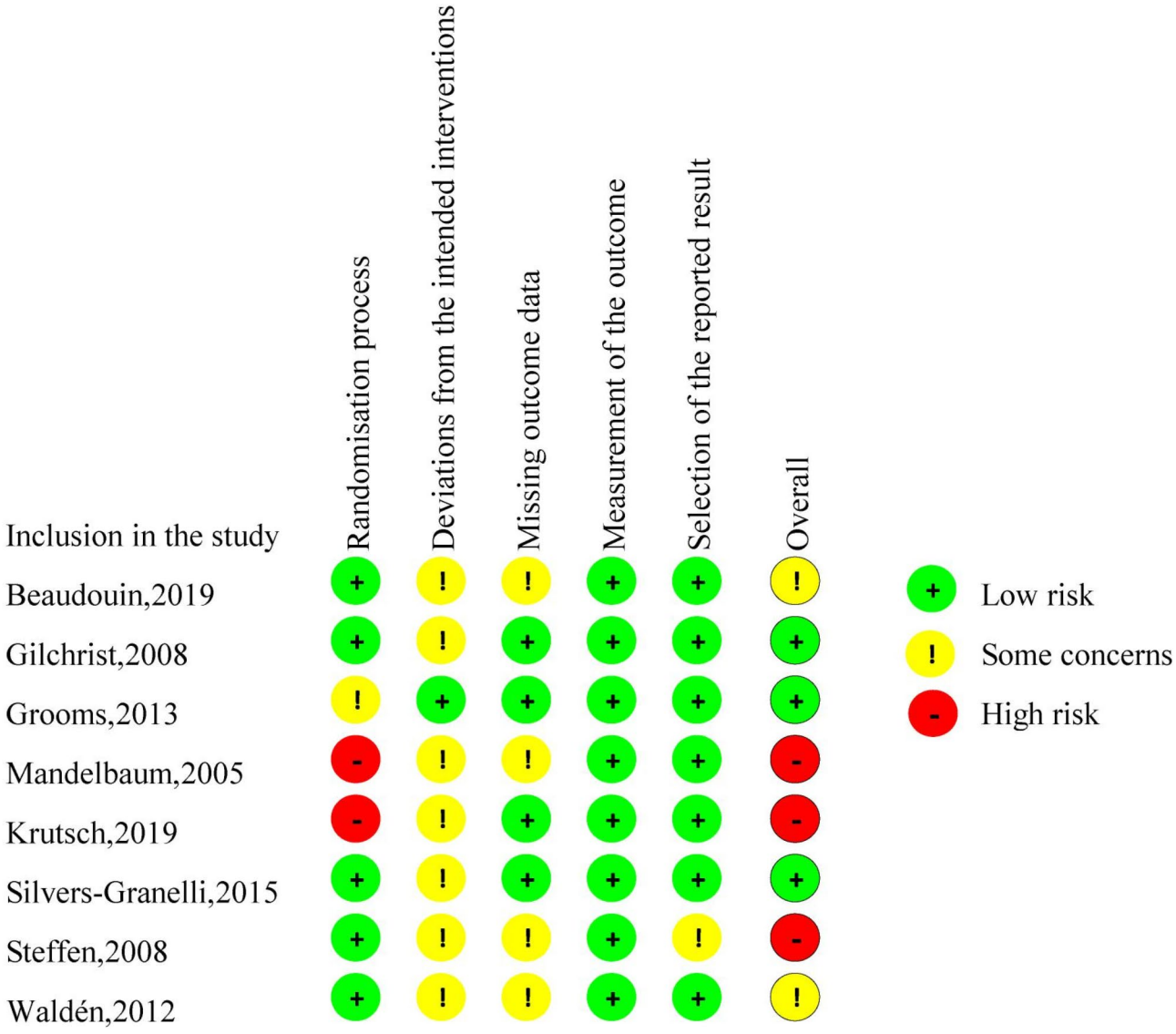

Fig. 2 Risk of bias summary

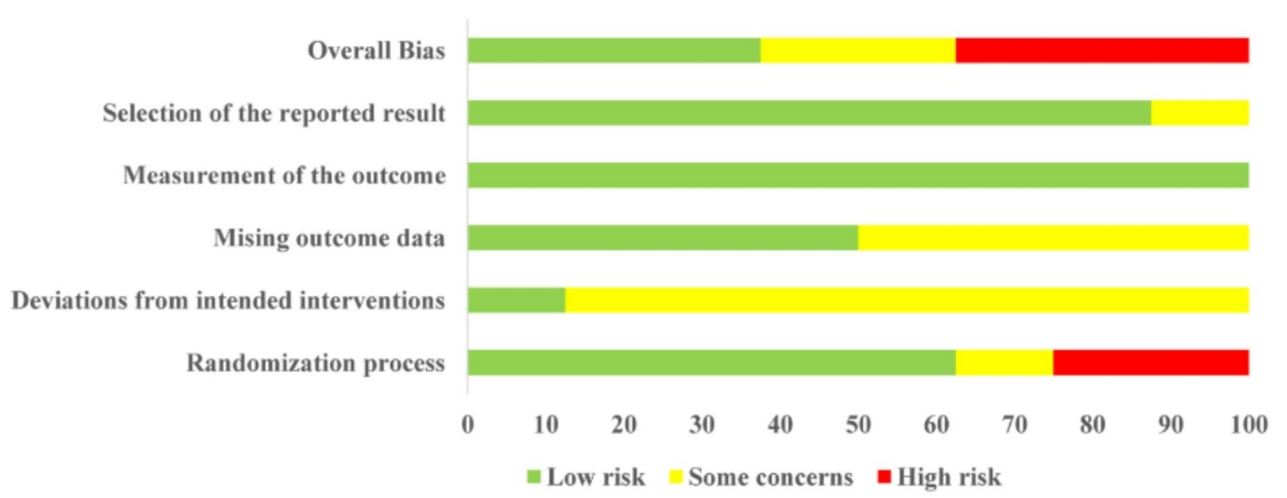

Fig. 3 Risk of bias graph

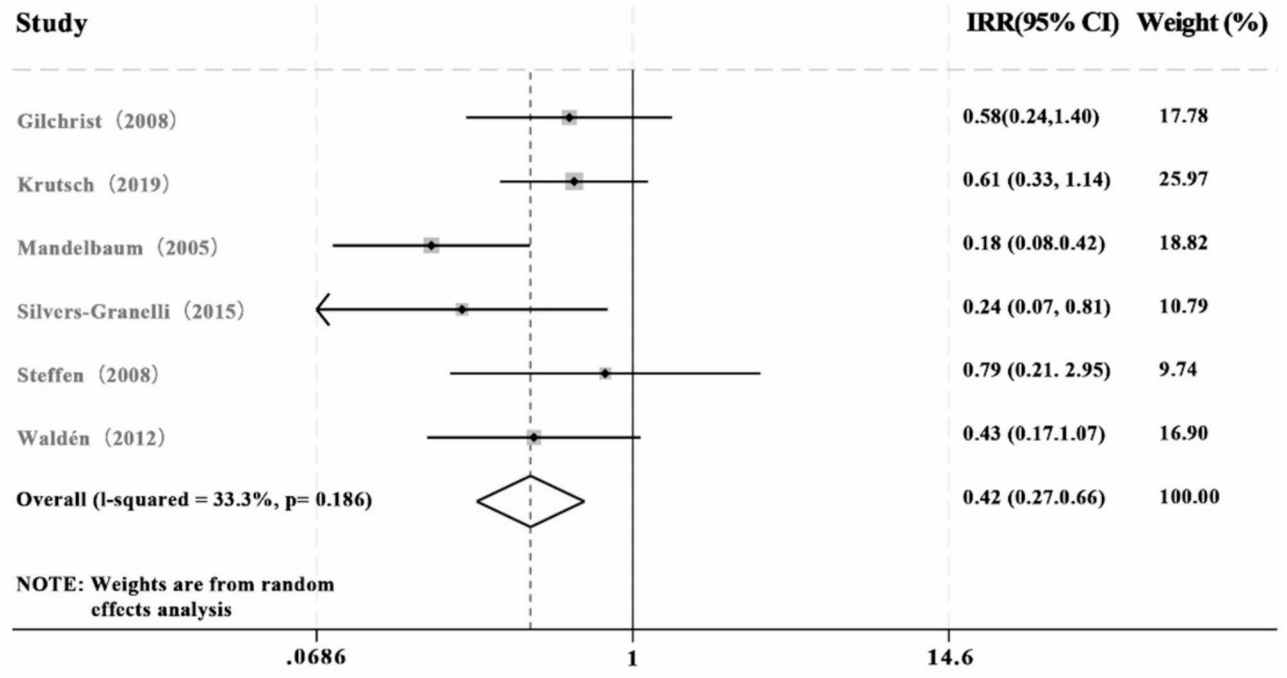

Fig. 4 Intervention effects of injury risk reduction programs including balance training exercises on ACL injuries compared to control groups

Table 3 Subgroup analysis of the effects of injury risk reduction programs including balance training exercises on the incidence of ACL injuries in soccer players

Groups	Type	*N*(IG/CG)	IRR(95%CI)	*p*-Value	I^2%
Gender	Female	5990/7702	0 39(0.24,0.62)	0.157	42.5
	Male	1204/1451	0.50(0.29.0.88)	0.178	44.8
Intervention frequency	<3/weeks	4081/3633	0.57(0.35,0.93)	0.727	0.0
	≥ 3/weeks	1258/1702	0.43(0.21,0.88)	0.238	28.2
Intervention duration	<20 min	3008/2686	0.54(0.33,0.91)	0.544	0.0
	≥ 20 min	2331/2649	0.50(0.26,0.93)	0.363	1.2

Note: IG stands for Intervention Group, and CG stands for Control Group

Discussion

This study assessed the impact of injury risk reduction programs, including balance training exercises, on the incidence of ACL injuries among soccer players. The results from these eight studies indicate that such programs, accounting for total exposure time, reduce the risk of ACL injuries in soccer players by 58%. Therefore, incorporating balance exercises as part of an injury risk reduction program significantly lowers the risk of ACL injuries in soccer players, a finding that aligns with results from previous research [22, 40–42]. Balance training is a key component of injury risk reduction programs, as it enhances athletes' proprioception, strengthens muscles and joints, improves postural stability, and optimizes neuromuscular coordination, thereby reducing the risk of sports injuries [43–45]. It enables athletes to make quicker and more accurate adjustments on the field, maintaining joint stability during dynamic activities such as jumping, landing, and changing direction. Additionally, balance training is often an integral part of comprehensive injury prevention programs, such as the FIFA 11 + program. These programs combine balance training with other exercises targeting strength, agility, and explosive power, creating a multifaceted approach to reducing injury risk.

In this study, when comparing research that included only male participants to studies that included only female participants, the pooled IRR were 0.50 and 0.39, respectively. This suggests that the effects of balance training are more pronounced among female soccer players, which may be attributed to their higher baseline knee abduction moment (KAM) [23]. Given that females are more susceptible to ACL injuries, this difference in neuromuscular mechanics could partially explain their increased injury risk [46]. Research has shown [10] that female soccer players are up to six times more likely to experience non-contact ACL injuries compared to males. Additionally, previous studies have indicated that female athletes generally have lower baseline levels of lower limb muscle strength and power compared to their male counterparts [47, 48], which may be due to differences in biomechanical factors and injury susceptibility between genders. Therefore, injury risk reduction programs that include balance training may provide more significant protective effects for female athletes. This finding suggests that training programs may need to be tailored differently for athletes of different genders. Due to anatomical and biomechanical differences, female athletes inherently face a higher risk of ACL injuries. Consequently, balance training and other related preventative measures should pay special attention to the unique needs of female athletes to more effectively reduce their risk of injury.

The frequency and duration of weekly training are also significant factors affecting preventive outcomes. Training less than three times per week (IRR 0.57, 95% CI: 0.35 to 0.93) and sessions lasting less than 20 min each (IRR 0.54, 95% CI: 0.33 to 0.91) can decrease the risk of ACL injuries in soccer players. However, interventions with higher frequencies (at least three times per week) (IRR 0.43, 95% CI: 0.21 to 0.88) and longer durations (20 min or more) (IRR 0.50, 95% CI: 0.26 to 0.93) further enhance the preventive effect against ACL injuries. This suggests that the balance between training frequency and duration has a certain impact on ACL injury risk reduction. Additionally, it indicates a doseresponse relationship between injury risk reduction programs, including balanced training, and ACL injuries, whereby increasing exposure to preventive exercises enhances their protective benefits. Injury risk reduction programs should be conducted regularly and over a period to allow athletes to gradually develop stable physical abilities and movement habits.

Grindstaff et al. recommend a neuromuscular training program of at least three times per week before the season to prevent non-contact ACL injuries in female athletes [49]. This implies that coaches and trainers need to consider the continuity and frequency of training when designing training plans to ensure athletes derive maximum protective benefits. Based on the findings of this study, it is advised that soccer coaches and sports trainers integrate balanced training exercises into routine training plans, tailored to meet genderspecific needs and risks. Furthermore, considering the significant potential reduction in severe injuries, the results of this study provide valuable guidance for soccer training and rehabilitation strategies. Promoting injury risk reduction programs, including balanced training, not only reduces athletes' injury risks but also enhances their athletic performance and competitive levels. Additionally, the implementation of these preventive measures should consider factors such as age, skill level, and training environment to ensure the personalization and effectiveness of training plans.

Conclusions

In conclusion, the results of this study emphasize the importance of injury risk reduction programs, including balanced training, in reducing the risk of ACL injuries among soccer players.Specifically, these programs lead to a significant reduction in ACL injury rates, with the most notable effects observed among female athletes. Furthermore, higher-frequency training and longer-duration interventions contribute to even greater preventive benefits.Future research should continue to explore the impact of different types of training on preventive effects and consider how to adjust training plans based on individual athlete differences to maximize preventive effects.

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Author contributions
Conceptualization, H.Y., and C.L.; methodology, W.S. and J.W.; validation, H.L. Z.Z and B.L.; formal analysis, B.L. Z.Z and Y.Y; data curation, H.Y. and W.S.; writing—original draft preparation, W.S. and J.W.; writing—review and editing, H.Y. and L.C.; visualization, W.S. and Y.Y.; supervision, C.L.; All authors have read and agreed to the published version of the manuscript.

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Data availability
The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

Declarations

Ethics approval/institutional review board
It not necessary, because no animal and human experiments have been done.

Informed consent
Not applicable.

Competing interests
The authors declare no competing interests.

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