Issue Rehabil. Orthop. Neurophysiol. Sport Promot. 2022; 41: 27–39. ISSN 2300-0767
DOI: 10.19271/IRONS-000177-2022-41

REVIEW ARTICLE

THE ROLE OF STRENGTH TRAINING IN PREVENTING MUSCULOSKELETAL INJURIES AMONG FEMALE AND MALE SOCCER PLAYERS

ROLA TRENINGU SIŁOWEGO W ZAPOBIEGANIU USZKODZENIOM NARZĄDU RUCHU WŚRÓD ZAWODNICZEK I ZAWODNIKÓW PIŁKI NOŻNEJ

Szymon Zduński[1], Monika Grygorowicz[2,3]
[1]Physiotherapy Student, Poznan University of Medical Sciences, Poland
[2]Department of Physiotherapy, Poznan University of Medical Sciences, Poland
[3]Sports Science Research Group, Rehasport Clinic FIFA Medical Centre of Excellence, Poland

ABSTRACT

Introduction

The occurrence of sports injuries among soccer players causes both financial and health losses, which is why preventing them is crucial. Science should provide reliable data on how different interventions affect the occurrence of sports injuries among athletes.

Aim

The review aims to analyse the quality of evidence proofed by the studies on the effectiveness of strength training in preventing sports injuries in soccer players.

Material and methods

Five databases were used in the review: Web of Science, Embase, Cochrane Library, Academic Search Ultimate, and Pubmed. Keywords used included: soccer players, strength training, hypertrophy training, protocol, injury rate, burden, and prevalence. Quality evaluation of studies found was performed using PEDro scale.

Results

Of the 646 studies researched, only 4 met the criteria of being applicable to this systematic review.

Conclusions

All four studies confirmed the decrease in the number of injuries and absence days per 1000h of exposure due to strength training; nonetheless, the lack of standardized protocol based on knowledge efficient at building strength makes the conclusion unreliable.

Keywords: strength training, resistance training, injury prevention, football, burden

STRESZCZENIE

Wprowadzenie

Występowanie urazów sportowych w piłce nożnej powoduje straty zdrowotne jak i finansowe, dlatego ważna jest ich profilaktyka. Nauka powinna dostarczyć nam wiarygodne dane na temat wpływu różnych interwencji na ilość urazów sportowych u atletów.

Author responsible for correspondence:
Szymon Zduński
Postal address: Department of Upper Limb Surgery, Center for Advanced Orthopedic and Arthroscopic Surgery, Głuchołazy/Opole, Poland
E-mail: szymonzdn@gmail.com
https://orcid.org/0000-0002-9575-2074 – Monika Grygorowicz

Authors reported no source of funding
Authors declared no conflict of interest

Date received: 08th March 2023
Date accepted: 21th March 2023

Cel
Przegląd ma na celu przeanalizowanie jakości dowodów naukowych na temat, skuteczności treningu siłowego w profilaktyce urazów sportowych u piłkarzy i piłkarek.

Materiały i metody
5 baz danych zostało użytych w tym przeglądzie: Web of science, Embase, Cochrane Library, Academic Search Ultimate and Pubmed. Wykorzystano następujące słowa kluczowe: piłka nożna, trening siłowy, trening hipertroficzny, protokół, częstość urazów, obciążenie, częstość występowania. Do ewaluacji jakościowej badań została użyta skala PEDro.

Wyniki
Spośród 646 badań tylko 4 spełniły kryteria i zostały uwzględnione w tym przeglądzie systematycznym.

Wnioski
Wyniki wszystkich 4 badań wykazały zmniejszenie liczby urazów i dni absencji na 1000h ekspozycji dzięki treningowi siłowemu, lecz brak standaryzacji protokołu treningu siłowego opartego na rzetelnej wiedzy w tym obszarze sprawia, że wyniki te nie są miarodajne.

Słowa kluczowe: trening siłowy, trening z obciążeniem, prewencja urazów, piłka nożna, urazowość

Introduction

In a professional football report released by FIFA in 2019, there were 128.983 professional players worldwide. Statistically, a football player will experience 36 injuries per 1000 hours of exposure to competitive playing (Lopez-Valenciano *et al.,* 2020). In a 6-year prospective study of Major League Soccer, it was confirmed that there were 1.1 injuries per year per player, and most of them were hamstring strains (12.3%), ankle sprains (8.5%), and adductor strains (7.6%) (Forsythe *et al.,* 2022). The average time missed per injury was 15.8 days, but 44.2% of injuries resulted in 0 days missed by the player. Moreover, huge costs are associated with a player's need for medical support since the English premier league (EPL) expanded to around £45 million due to injuries per season (Eliakim *et al.,* 2020). Those reasons lead to the question of how to reduce the number of injuries that cause football players to lose time and money recovering from them.

Strength training has been shown to not only increase muscle size and strength but may also help prevent injuries (Raya-González *et al.,* 2021a). Studies have found that it can cause ligaments, tendons, joint cartilage, and connective tissue growth. Research indicates that resistance training can help reduce overuse injuries such as the swimmers' shoulder and tennis elbow (Fleck & Falkel, 1986). Clark *et al.* revealed a correlation between muscle strength and, bone mineral density, bone mineral content, which might be relevant for reducing the risk of skeletal injuries (Clark *et al.,* 2011). Studies confirmed that thicker bone structure provides better protection against bone fractures (Eckstein *et al.,* 2006), and that resistance training performed on older populations increases tendon stiffness, decreasing the possibility of strain (Reeves *et al.,* 2003). Lately, Lauersen *et al.* performed a systematic review, qualitative analysis, and meta-analysis to analyse strength training as an injury prevention measure in different sports populations. 7738 people from ages 12–40 who experienced 177 acute or overuse injuries were included in the study, and the authors found that a 10% increase in strength training volume lowered the risk of injury by over four percent (Lauersen *et al.,* 2018). However, study quality evaluation for included studies was not reported; thus, some relevant information might be missing.

It also should be underlined that fundamental movements are typical for all sports; nevertheless, to achieve tremendous improvement, the strength training programs should include a variety of sport-specific exercises (Silva *et al.,* 2015). That is why strength/power training programs should incorporate exercises targeting the efficiency of stretch-shortening-cycle activities and soccer-specific strength-based actions (Silva *et al.,* 2015). Additionally, there is still a knowledge gap regarding female athletes since research on the science of sport is heavily skewed toward male athletes, causing the imbalance leaves significant gaps in knowledge about female sports and sport-related injuries (Sanderson, 2022).

Thus, in the current research, we identified and analysed relevant studies regarding any association between strength training and training and match injury risk reduction in female and male soccer players.

Methods

Databases and searches

We used five databases for this systematic review: Web of Science, Embase, Cochrane Library, Academic Search Ultimate, and Pubmed. Specific search strategies were used to find the most relevant studies for this review. Words for the population were: (football play* OR soccer play* OR female soccer* OR women soccer* OR male soccer* OR men soccer*) to include all possible athletes playing football and NOT (rugby OR Australian football). For intervention, words used were (resistance* OR strength* OR eccentric* OR hypertrophy* OR weight* OR plyometric* OR power* OR muscle*) and (training* OR protocol* OR exercise* OR session* OR program*) to include most words describing any exercises that can influence absolute strength of muscle. Topic required from study to show the number of injuries of two groups, that is why words for comparison were (Injur* rate OR Injur* risk OR burden OR prevalence OR Injur* proportion OR odds ratio OR Injury incidence).

Only studies from the last ten years in the English language were included. Where possible, specific types of studies were used. For example, on Web of Science, the only enabled filter was "Document Type – Not-Review." While using Embase, we included only Controlled Clinical Trials and Randomized Controlled Trials, excluding Cochrane reviews, Systematic Reviews, and Meta-analyses. When using Cochrane Library, we included only Trials and excluded Cochrane Reviews and Cochrane Protocols, Clinical Answers, editorials, and Special Collections. In the Academic Search Ultimate database, we applied the filter for not including systematic reviews OR meta-analyses. While searching Pubmed, we included only clinical and controlled trials and excluded books and documents, meta-analyses, reviews, and systematic reviews.

This work aimed to evaluate available publications on the validity of implementing strength training to prevent injury to football players. There is a strong correlation between muscle size and the strength of the muscle, proven by Akagi *et al.* (2009), Evangelidis *et al.* (2016), and Erskine *et al.* (2014). That is why keywords for intervention included factors that can influence muscle hypertrophy and absolute strength. If a study did not include the metric of injury, e.g., number of injuries/1000h of exposure, it was not included in this review. Moreover, we also decided to exclude studies that utilised the FIFA 11 + as an injury prevention program. Although this structured warm-up has a strength component, this program does not include a particular weight progression. Programs not created for improving strength or hypertrophy, such as FIFA 11 + injury prevention program, were removed from the review.

Quality evaluation

The PEDro scale was used to evaluate the risk of potential bias, which was evaluated as a useful tool for accurate description. PEDro scale is used for quickly and easily identifying relevant and valid trials intended for physiotherapy subjects (Gonzales *et al.,* 2018). Points in the scale are awarded only when a criterion is clearly satisfied.

Results

Study selection

After establishing all keywords to find the most significant number of studies that could help find correlations, the keywords were used in Pubmed, Web of Science, Cochrane, Embase, and Academic research databases. 646 records found in the databases were imported to Microsoft Excel, and sorted alphabetically, with 111 duplicates noted. 515 records not covering the topic of the review were noted. 20 records for retrieval were moved to a new sheet and sought for retrieval. Eight publications still need to be retrieved. 12 studies were assessed for eligibility. Eight studies without a control group or excluding hours missed per 1000h of exposition were excluded. One publication was removed after not including any exercises that could sufficiently influence strength. Finally, four studies were included in the review (Figure 1, Table 1).

Population

Zouita *et al.* examined a group of 52 young elite soccer players. Players were divided randomly into two groups (control group, n = 26, and experimental group, n = 26). The selection process involved hundreds of boys from various parts of Tunisia, all of whom were evaluated and chosen by coaches at the soccer club. The chosen sample consisted of young male athletes aged 13 to 14 participating in the player development program. These players were integrated into the three-year training formation when they were thirteen years old and are members of sector-based training centers (Zouita *et al.,* 2016).

In the study of Raya-González *et al.,* the study population consisted of 49 participants (C control group n = 26, and experimental group n = 23) aged 17.8 ± 0.8 years, and authors aimed to verify the influence of Nordic hamstring and sprint exercises on hamstring injury rate (Raya-González *et al.,* 2021b). To be included in the study, participants had to have attended at least 80% of the soccer and strength training sessions over the past 14 weeks and not have been injured in the two months leading up to the investigation. These players have all been playing at the same soccer academy for the last two years. Their regular program includes three training sessions each week, with 50% being technical-tactical drills, 40% small-sided and simulated games, and 10% injury-prevention drills, as well as a match on the weekend (Raya-González *et al.,* 2021b).

A second study by Raya-González *et al.* was performed on 27 males aged 18.1 ± 0.3 in the control group and 18.2 ± 0.4 in the experimental group (Raya-González *et al.,* 2021a). The study was conducted on athletes from a Spanish club who regularly competed (Liga SmartBank) in the highest category of their age group. Within two seasons, scientists observed the number of injuries in football players without strength training in season 1. Then they compared the number to the number of injuries in season 2, where players were introduced to strength training (only 17 players from season 1 were included in season 2, which means the experimental group; n = 17).

In the Torres Martín *et al.* study, a sample of 46 male players were analysed, and divided into the control group; n = 26; and the experimental group, n = 20 (Torres Martín *et al.,* 2021). Players who had been part of the same soccer academy for the last two years were included in the study, provided that they had been free from injury for the last two months and had attended at least 80% of the regular and body mass-based resistance training sessions over the 15-week intervention period. Their usual program included three weekly training

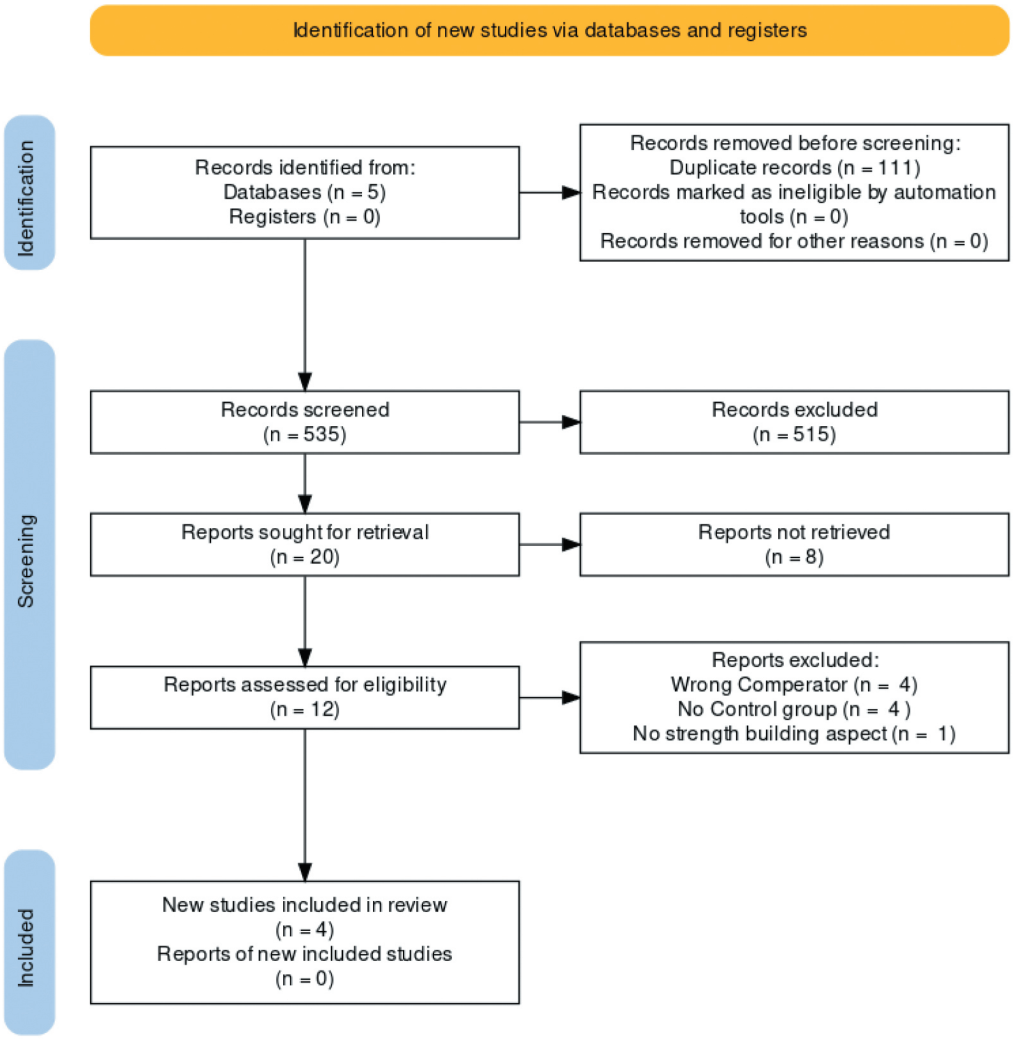

Figure 1. Flow chart of study selection

sessions, with 50% being technical-tactical drills, 40% small-sided and simulated games, 10% injury-prevention drills, and a match on the weekend. Those who missed more than 20% of the sessions were excluded from the final analysis.

Type of training intervention

In the experimental group, Zouita *et al.* applied strength training using 50–60% of 1 repetition maximum [1RM] load in 2 weeks of the familiarization phase. The training was based on multiple-joint exercises (Zouita *et al.*, 2016). The players from the experimental group participated in 2 to 3 sessions per week in a resistance training program to prevent injuries and enhance physical performance. The duration of a resistance training session was 90 minutes, and ten exercises with an individual training program being included later were applied. The training load was roughly 30–50% of 1 Repetition Maximum (15–20 reps), and it was increased, if possible, every two weeks to maintain the 70% level. The six-week progression phase two involved high-intensity resistance training, with three weekly training sessions focused on improving maximum strength and power. The individual programs of the players did not change during this stage, but the training intensity did increase. The players increased the training load to 80% 1RM in specific multiple-joint exercises, such as the squat and the bench press. The authors ensure that physical coaches supervised players to ensure that exercises were executed properly. The

Table 1. Characteristics of study.

Study	Study design	Type of training	Population	Intervention	Comparator	Follow-up (months)	Definition of injury included	Injury-related outcome [Injuries/1000h of exposure]	Soccer-specific outcome	Main Conclusion
Zouita *et al.* (2016)	RCT	Strength training using 1RM percentage and multiple-joint exercises	Male; Age: between 13–14 years old CG; n = 26 EG; n = 26	2 to 3 sessions of strength training (90 minutes) were introduced weekly in their training program for 12 weeks (4 × 3 weeks separated by 1-week recovery)	Soccer training	12 weeks	Time-loss injuries, only injuries > 3 days were analysed	CG = 2.74 EG = 0.82	Sprint tests (10–20–30 m), T-test agility test, vertical jump and Yo-Yo tests were measured at the start (T0), at the middle (T1), and at the end of the experiment period (T2).	This difference was significantly higher for CG. From the data, it can be concluded that strength program training might be beneficial preventive measures for the soccer players
Raya-Gonzalez *et al.* (2021a)	RCT	Bodyweight exercises	Male; Age: 18.6 ± 0.1 years old CG; n = 27 EG; n = 17	Body mass-based resistance training	One soccer season was treated as a control period	10weeks	an injury that occurred during a scheduled training session or match that caused absence from the next training session or match	Injuries/1000h of exposure CG = 2.3 EG = 1.33 24 injuries in total	Not applied	Main results indicate a meaingful reduction in the risk of muscle injuries as well as the absence days among U-19 soccer players during training after the implementation of a simple strength training program
Raya-Gonzalez *et al.* (2021b)	RCT	Bodyweight exercises	Male; Age: 17.8 ± 0.8 years CG; n = 26 EG; n = 23	Nordic Hamstrings + sprint training once a week	Regular weekly in-season routine	14 weeks	an injury that occurred during a scheduled training session or match that caused absence from the next training session or match	CG = 1.42 EG = 0.55 4 injuries in total	Linear 20 m and 30 m sprints and with COD	NHE and sprint exercises is ffective in improving sprint performance and reducing injury burden in U19 soccer players
Torres Martín *et al.* (2021)	RCT	Bodyweight exercises	Male; Age: 15.6 ± 0.5 years CG; n = 26 Eg; n = 20	EG performed body mass-based resistance training twice per week, along with their regular soccer training routines.	Not specified	15 weeks	an injury that occurred during a scheduled training session or match that caused absence from the next training session or matc	Injuries/1.000 hours of exposure CG = 1.4 Eg = 1.19 Unknown number of injuries overall	CMJ, 20 m with one COD, and linear sprint over 30 m	The main findings indicated that the applied program is effective for improving CMJ height, and reducing the severity of musculotendinous injuries in this group of players

CG – control group
EG – experimental group
NHE – Nordic hamstring exercises
CMJ – Countermovement jump
COD – change of directio

load used by the players is described unclearly between 40–80% 1RM. Every three weeks, players were tested with multi-joint exercises like squats, bench presses, push-ups, and sit-ups to determine any flaws and corrections in individual training programs (Zouita *et al.*, 2016). However, the authors did not provide information about specific exercises that were used in the protocol. Moreover, no specific description of the training applied in the control group is given, except the information that the players from the control group participated in the soccer training.

Another strength training strategy for preventing injuries was applied by Raya-González *et al.* Throughout a 14-week intervention period, players from the experimental group performed the Nordic hamstring exercises (NHE) and sprint training program once a week. Different drills for sprint exercises were used. NHE was performed from 2 to 3 series, increasing the rep range from 5 to 12 in 14 weeks (Raya-González *et al.*, 2021b).

In another study by Raya-González *et al.*, the injury-prevention training sessions were applied during the last five weeks of the pre-season and the first five weeks of the in-season periods, only during the experimental season and in addition to regular training (Raya-González *et al.*, 2021a). Training sessions were performed twice weekly, with at least 24 hours between sessions. The injury prevention program contained; Nordic hamstring, eccentric adductor, plank, side plank, bridge, plank (three supports), side planks (two supports), and half squats. Progression was applied by increasing sets and repetitions, and the strength-training program was completed at 92.3% compliance (Raya-González *et al* 2021a).

In the last study included in this systematic review (Torres Martín *et al.*, 2021), the intervention was based on body-mass resistance training, and it was applied for 15 weeks. No external weights were used during the intervention. Exercises drills were the same as those employed by Raya-González *et al.* (Raya-González *et al.*, 2021a). The program was applied similarly, meaning the training sessions were performed twice a week with at least 24 hours between sessions. The injury prevention program contained; Nordic hamstring, eccentric adductor, plank, side plank, bridge, plank (three supports), side planks (two supports), half squats, and progression was applied by increasing sets and repetitions (Torres Martín *et al.*, 2021).

Soccer specific training and match performance

All participants in the study by Zouita *et al.* participated in soccer-specific training. Every strength training session lasted 90 minutes long. Both groups participated in training sessions at the soccer centre for 100 minutes daily from Monday to Friday during the season. Each soccer training included a 15-minute warm-up, 20-minute technical training, 20-minute tactical training, 30-minute simulated competition, and 15-minute cool-down. Both groups followed the same nutritional protocol during soccer season. Additionally, fit players participated in up to 22 matches during the season (Zouita *et al.*, 2016).

In the study by Raya-González *et al.*, the effect of the injury prevention program was analysed through two different seasons; however, the control and experimental seasons had similar training and competitive schedules, with competitive matches played against the same teams while keeping similar training contents and intensity, as measured by perceived exertion (CR10 scale) (control season = 6.5 ± 0.9 and experimental season 6.9 ± 0.8 (Raya-González *et al.*, 2021a).

Injury definition and its assessment during the soccer season

Zouita *et al.* (2016) collected injuries following the Federation Internationale de Football Association (FIFA) consensus recommendation: the medical staff reported and validated each injury, and the injury type, location, and severity were recorded in a weekly period (Fuller *et al.*, 2006). Any incident which led to the player not being able to take part in full training sessions or games (time-loss injuries) was recorded as an injury, and the player was considered injured until the team's medical staff gave the okay for them to resume full training and declared them fit for game selection (Zouita *et al.,* 2016).

Raya-González *et al.* in their both studies (Raya-González *et al.,* 2021a and 2021b) and Torres Martín *et al.* defined injury according to the guidelines provided by the Union of European Football Associations (UEFA) for epidemiological research (Hägglund *et al.,* 2005) which define injury as an injury that occurred during a scheduled training session or match that caused absence from the next training session or match.

Injury-related outcome

In the study of Zouita *et al.,* the injury rate was calculated as the number of players injured divided by hours of exposure and multiple by 1.000 (Zouita *et al.,* 2016). Exposure training time was calculated using players per session, duration of session per minute, and exposure match time calculated using the number of played matches, number of players in the match (11), and duration of the match per minute (90 minutes). The authors only accounted for injuries that lasted more than three days. 13 injuries in the control group within 5590 hours of exposure (4.732 hours of training; 858 hours of the match) were noted. In the experimental group, authors recorded four injuries within 5700 hours of exposure (4.842 hours of training; 858 hours of the match), respectively 2.32 and 0.70 injuries per 1000 hours. Seventeen injuries caused a loss of 110 days of absence from training and matches. A control group with 13 injuries lost 147 hours, and an experimental group with four injuries lost 18 hours of training and matches.

Raya-González *et al.* recorded three hamstring injuries (59 absence days) in the control group, whereas players from the experimental group suffered one hamstring injury that lasted seven days (Raya-González *et al.,* 2021b). No significant differences were shown in the injury incidence. However, significant differences in injury burden were reported favoring players from the experimental group (27.87 vs. 3.82 absence days/1000h of exposure, rate ratio = 7.30, 95% CI.3.34–15.99). Unfortunately, the author does not inform us how many hours of training/match exposition there were (Raya-González *et al.,* 2021b).

In their second study (Raya-González *et al.,* 2021a), during the control season, 15 muscle injuries (2.3 injuries/1000 hours) occurred, while in the experimental season, nine muscle injuries (1.33 injuries/1000 hours) were experienced (IRR = 1.74; 95% CI: 0.76–3.97; ES = 0.42, small). These 15 injuries in the control group resulted in 204 days of absence, with an average severity of 13.6 days; however, the nine injuries in the experimental group caused 87 days of absence with an average severity of 9.7 days (Raya-González *et al.* 2021a).

Torres Martín *et al.* revealed no between-group difference in injury rate. In the players from the control group 1.4 injury/1000h was noted, and athletes from the experimental group reported 1.19 injury/1000h. Statistical difference between groups was found in injury burden: players from the control group were absent due to injury significantly longer than players from the experimental group (33.28 days absent/1000h vs. 9.55 days absent/1000h, respectively).

Study Quality

The results of the study quality evaluation are presented in Table 2. All studies specified criteria for participants. Just 2 of them mentioned randomization for group allocation, Zouita *et al.* (Zouita *et al.,* 2016) and Raya-González *et al.* (Raya-González *et al.* 2021b). Two studies include information we can assume as "allocation was concealed". Zouita *et al.* (2016) gave the information that they first picked the players and then allocated them into the groups, Raya-González *et al.* used the same group as both the control and experimental group, so there was no space for bias by knowing in which group the subject going to be (Raya-González *et al.* 2021a). Torres Martín *et al.* (Torres Martín *et al.,* 2021) and Raya-González *et al.* (Raya-González *et al.,* 2021b) picked players from U19 groups. However, they did not mention any randomisation in groups allocation to the control or experimental group, which creates a place for bias. All studies provided similar baselines, including males of similar age without strength training experience. The criteria for scores 5 to 6 were not met because of the characteristics of the study. A group could not be unaware of performing strength training, just as the trainers introducing and supervising the group could not be unaware of the activity. No study reports blinding of all assessors who measured at least one key outcome. Score 8 was accomplished by all the studies excluding Raya-González *et al.* (Raya-González *et al.,* 2021a), where only 63% of the initial group provided measures of at least one key outcome. Score 9 was completed by Raya-González *et al.* (Raya-González *et al.* 2021b) and Torres Martín *et al.* (Torres Martín *et al.,* 2021), providing information about how many percentages of interventions the participant must acquire to be considered in statistical analysis. All Studies provided between-group statistical comparisons for at least one key outcome and point measures and variability for at least one critical outcome; thus, the scoring for the 10 and 11 criteria was positive.

Discussion

This review aimed to systematically evaluate the knowledge about how strength training influences the risk of injury among female football and male players. The injury rate or injury risk ratio differed between groups of players who introduced strength training into their soccer regime and those who did not participate in additional strength training sessions. Players who added strength training sustained a low number of injuries. Moreover, a more significant parameter, injury burden, was significantly lower in experimental groups, suggesting that strength training might reduce the number of days of absence due to injury in the soccer team throughout the season. Since, in soccer-specific circumstances, on the one hand, the coach usually has a limited number of players, and on the other hand, he or she is evaluated through the team's performance (winnings the games), the issue of having the players ready to play could be critical for leading a successful team; thus within this perspective implementing an additional strength training might be relevant for football teams and clubs. Although based on our study, strength training could be recommended as an effective way of injury prevention, the results should be applied with caution. Mostly due to the lack of thorough description of the strength intervention and the disputable quality of analysed studies. When screened for quality using the PEDro scale, two of the studies didn't include randomisation in allocating participants to the groups (Raya-González *et al.,* 2021a, Torres Martín *et al.,* 2021). Only the paper of Zouita *et al.* (Zouita *et al.,* 2016) was given four points for four first criteria in the scale, which stands for avoiding bias through choosing participants for the groups, having a similar baseline, and having specified criteria that describe the selection of participants. Raya-González *et al.* scored only five points through 11 possible (Raya-González *et al.,* 2021a).

Lopez *et al.* showed that strength and hypertrophy could be achieved in a wide range of repetitions until failure or near failure is performed (Lopez *et al.,* 2021). Only Zouita *et al.* (Zouita *et al.,* 2016) mentioned the intensity of the repetitions noting that while participants performed from 15–20 repetitions, weights were increased where possible. This means that repetitions were performed close to failure. The study also applied a One-Repetition Maximum (1RM) Strength Assessment to assess the strength improvement, which is a reliable test to evaluate the strength (Jozo Grgic *et al.,* 2020) and then further define suitable load for a particular participant. The study by Zouita *et al.* lacks thorough information regarding the types

Table 2. PEDro scale.

PEDro Scale	Criteria of the PEDro scale	Sghair Zouita et al. (2016)	Javier Raya-González et al. (2021b)	Javier Raya-González et al. (2020) 2021a	Luis Torres Martín et al. (2021)
1	eligibility criteria were specified	+	+	+	+
2	subjects were randomly allocated to groups	+	+	–	–
3	allocation was concealed	+	–	+	–
4	the groups were similar at baseline regarding the most important prognostic indicators	+	+	+	+
5	there was blinding of all subjects	–	–	–	–
6	there was blinding of all therapists who administered the therapy	–	–	–	–
7	there was blinding of all assessors who measured at least one key outcome	–	–	–	–
8	measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	+	+	–	+
9	all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	–	+	–	+
10	the results of between-group statistical comparisons are reported for at least one key outcome	+	+	+	+
11	the study provides both point measures and measures of variability for at least one key outcome	+	+	+	+

of exercises performed, how many times in a week, how many sets were performed close to failure, how many sets, and how many reps there were. Repeating the study is impossible because of the further non-specified intervention (Zouita *et al.,* 2016). Considering that intervention was projected individually for maximum strength increases for every participant, researchers should include information about the specific details of the training sessions. Such details include the number of average repetitions and sets, the average intensity noted by participants using that RPE technique, which has been proven to be a valid tool in evaluating training intensity (Haddad *et al.,* 2017), or Repetitions in Reserve-based rating. Zourdos *et al.* showed that the best results could be achieved by using both methods to define perfect 1RM% to planned reps and precision intensity, which could be used in performing the same interventions as the authors (Zourdos *et al.,* 2016).

High loads used in training build strength more significantly than low loads (Schoenfeld *et al.,* 2017). Combining that knowledge with other findings like the impact of metabolic stress on hormonal responses and muscular adaptations (Goto *et al.,* 2005), shows that working close to failure grants better results than working using the same training volume but not being close to failure, applying bodyweight exercises can be insufficient to train strength optimally. Three studies included in this systematic review used bodyweight exercises to strengthen the athletes. However, none of the researchers included intensity in performing the exercises (Raya-González *et al.* 2021a, Raya-González *et al.* 2021b, Torres Martín *et al.* 2021). As previously mentioned, various repetitions can be used until enough effort is included in the last repetitions (Lopez *et al.,* 2021).

Moreover understanding the mechanistic process of providing a training stimulus to induce specific adaptations that result in functional enhancements is crucial for applying the appropriate training periodization model (Cunanan *et al.,* 2018). As shown previously, the stress produced by the intensity of exercises is responsible for hormonal changes conducting the adaptation (Goto *et al.,* 2005). While the concept of using body exercises is not scientifically inappropriate, the role of intensity and stress required for adaptation should be a priority in establishing the number of repetitions executed by the participants who were performing strict amounts of repetitions without the intensity that could be varied between players (Cunanan *et al.,* 2018; Schoenfeld *et al.,* 2017). The difference between RPE in groups could affect the study, and the results could be depended on how many of the examined players found the exercises challenging.

Although in our search strategy, we also used keywords hoping to find relevant studies conducted on female athletes, none of the research was found. Thus, more research is needed to explain whether strength training is beneficial in injury prevention and examine females' mechanical and hormonal responses to periodised strength-training programs. Since female athletes' number is growing worldwide and interest in women's sports is also rising (WIS Report, 2021) in the future, we need to conduct more female-specific research to close this knowledge gap. Study limitation.

It is important to recognize the limitations of each of the included studies, as they can have an effect on the results. In future by identifying and mitigation these limitations, researchers can create better studies. Since we applied particular search strategy, it might be possible that some relevant papers could have not been included in this systematic review. Additionally, applying different study quality assessment tools might add some additional information on the quality of included papers.

Conclusions

Despite having few available studies introducing strength training to prevent injuries in soccer players, a lack of standardized protocol based on knowledge efficient at building strength makes the conclusion unreliable. The measurement of percentage strength increase could be compared with the percentage probability of injury occurrence, which would provide data of correlation on how much absolute strength correlates to preventing injuries. Nonetheless, despite a significant difference in strength training protocols, all four studies decreased the number of injuries and absence days per 1000h of exposure.

REFERENCES

Akagi R, Takai Y, Ohta M, Kanehisa H, Kawakami Y, Fukunaga T, (2009) *'Muscle volume compared to cross-sectional area is more appropriate for evaluating muscle strength in young and elderly individuals.' Age and Ageing,* Volume 38, Issue 5, September, 564–569.

Clark EM, Tobias JH, Murray L, *et al.* (2011) *'Children with low muscle strength are at an increased risk of fracture with exposure to exercise.'* J Musculoskelet Neuronal Interact.;11(2), pp. 196–202.

Cunanan AJ, DeWeese BH, Wagle JP, Carroll KM, Sausaman R, Hornsby WG 3rd, Haff GG, Triplett NT, Pierce KC, Stone MH. (2018) *'The General Adaptation Syndrome: A Foundation for the Concept of Periodization.'* Sports Med. Apr;48(4), pp. 787–797.

Eckstein F, Hudelmaier M, Putz R. (2006) *'The effects of exercise on human articular cartilage.* J Anat. Apr;208(4), pp. 491–512.

Eliakim, Eyal & Morgulev, Elia & Lidor, Ronnie & Meckel, Yoav. (2020) *'Estimation of injury costs: Financial damage of English Premier League teams' underachievement due to injuries.'* BMJ Open Sport & Exercise Medicine. 6. e000675.10.1136/bmjsem-2019-000675.

Erskine, R.M., Fletcher, G. & Folland, J.P. (2014) *'The contribution of muscle hypertrophy to strength changes following resistance training.'* Eur J Appl Physiol 114, pp. 1239–1249.

Evangelidis, Pavlos E *et al.* (2015) *'Strength and size relationships of the quadriceps and hamstrings with special reference to reciprocal muscle balance.'* European Journal of Applied Physiology 116, pp. 593–600.

Fleck SJ, Falkel JE. (1986) *'Value of resistance training for the reduction of sports injuries.'* Sports Med. Jan-Feb;3(1):61-8. doi: 10.2165/00007256-198603010-00006. PMID: 3633121.

Forsythe B, Knapik DM, Crawford MD, Diaz CC, Hardin D, Gallucci J, Silvers-Granelli HJ, Mandelbaum BR, Lemak L, Putukian M, Giza E. (2022) *'Incidence of Injury for Professional Soccer Players in the United States: A 6-Year Prospective Study of Major League Soccer.'* Orthop J Sports Med. Mar 24;10(3):23259671211055136.

Fuller CW, Ekstrand J, Junge A, Andersen TE, Bahr R, Dvorak J, Hägglund M, McCrory P, Meeuwisse WH. (2006) *'Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries.'* Br J Sports Med. Mar;40(3):193–201. doi: 10.1136/bjsm.2005.025270. PMID: 16505073; PMCID: PMC2491990.

Gonzalez GZ, Moseley AM, Maher CG, Nascimento DP, Costa LDCM, Costa LO. (2018) *'Methodologic Quality and Statistical Reporting of Physical Therapy Randomized Controlled Trials Relevant to Musculoskel et al. Conditions.'* Arch Phys Med Rehabil. Jan;99(1):129-136. doi: 10.1016/j.apmr.2017 08.485. Epub 2017 Sep 28. PMID: 28962828.

Goto K, Ishii N, Kizuka T, Takamatsu K. (2005) *'The impact of metabolic stress on hormonal responses and muscular adaptations.'* Med Sci Sports Exerc. 2005 Jun;37(6), pp. 955–963.

Grgic J, Lazinica B, Schoenfeld BJ, Pedisic Z. (2020) *'Test-Retest Reliability of the One-Repetition Maximum (1RM) Strength Assessment: a Systematic Review.'* Sports Med Open. Jul 17;6(1):31. doi: 10.1186/s40798-020-00260-z. PMID: 32681399; PMCID: PMC7367986.

Haddad, Monoem & Stylianides, Georgios & Djaoui, Léo & A, Dellal & Chamari, Karim. (2017) *'Session-RPE Method for Training Load Monitoring: Validity, Ecological Usefulness, and Influencing Factors. Frontiers in Neuroscience.'* Volume 11. Article 612.

Hägglund M, Waldén M, Bahr R, Ekstrand J. (2005) *'Methods for epidemiological study of injuries to professional football players: developing the UEFA model.* Br J Sports Med. Jun;39(6):340-6. doi: 10.1136/bjsm.2005.018267. PMID: 15911603; PMCID: PMC1725241.

Lauersen JB, Andersen TE, Andersen LB. (2018) *'Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries: a systematic review, qualitative analysis and meta-analysis.'* Br J Sports Med. Dec;52(24):1557–1563. doi: 10.1136/bjsports-2018-099078. Epub 2018 Aug 21. PMID: 30131332.

Lopez P, Radaelli R, Taaffe DR, Newton RU, Galvão DA, Trajano GS, Teodoro JL, Kraemer WJ, Häkkinen K, Pinto RS. (2021) *'Resistance Training Load Effects on Muscle Hypertrophy and Strength Gain: Systematic Review and Network Meta-analysis.'* Med Sci Sports Exerc. Jun 1;53(6), pp. 1206–1216.

López-Valenciano A, Ruiz-Pérez I, Garcia-Gómez A, Vera-Garcia FJ, De Ste Croix M, Myer GD, Ayala F (2020) *'Epidemiology of injuries in professional football: a systematic review and meta-analysis.'* Br J Sports Med. Jun;54(12), pp. 711–718.

Raya-González J, Suarez-Arrones L, Sanchez-Sanchez J, Ramirez-Campillo R, Nakamura FY, Sáez De Villarreal E. (2021a) *'Short and Long-Term Effects of a Simple-Strength-Training Program on Injuries Among Elite U-19 Soccer Players.'* Res Q Exerc Sport. Sep;92(3):411–419. doi: 10.1080/02701367.2020.1741498. Epub 2020 Jul 7. PMID: 32633681.

Raya-González J, Torres Martin L, Beato M, Rodríguez-Fernández A, Sanchez-Sanchez J. (2021b) *'The effects of training based on Nordic hamstring and sprint exercises on measures of physical fitness and hamstring injury prevention in U19 male soccer players.'* Res Sports Med. Nov 27:1-16. doi: 10.1080/15438627.2021.2010206. Epub ahead of print. PMID: 34841995.

Reeves ND, Maganaris CN, Narici MV. (2003) *'Effect of strength training on human patella tendon mechanical properties of older individuals.'* J Physiol. May 1;548(Pt 3), pp. 971–981.

Sanderson K (2022) *'How sports science is neglecting female athletes. Imbalance impedes progress in prevention and treatment of injuries among female players.'* Nature, 14. December.

Schoenfeld BJ, Grgic J, Ogborn D, Krieger JW. (2017) *'Strength and Hypertrophy Adaptations Between Low- vs. High-Load Resistance Training: A Systematic Review and Meta-analysis.'* J Strength Cond Res. Dec;31(12):3508-3523. doi: 10.1519/JSC.0000000000002200. PMID: 28834797.

Silva JR, Nassis GP, Rebelo A. (2015) *'Strength training in soccer with a specific focus on highly trained players.'* Sports Med Open.;1(1):17. doi: 10.1186/s40798-015-0006-z. Epub 2015 Apr 2. PMID: 26284158; PMCID: PMC5005570.

Torres Martín L, Raya-González J, Ramirez-Campillo R, Chaabene H, Sánchez-Sánchez J. (2021) *'Effects of body mass-based resistance training on measures of physical fitness and musculotendinous injury incidence and burden in U16 male soccer players.'* Res Sports Med. Dec 1:1–14. doi: 10.1080/15438627.2021.2010205. Epub ahead of print. PMID: 34852693.

Women In Sport (WIS) *'Report 2021, YouGov, 2021*, downloaded from sport.yougov.com 15.10.2022.

Zouita S, Zouita AB, Kebsi W, Dupont G, Ben Abderrahman A, Ben Salah FZ, Zouhal H. (2016) *'Strength Training Reduces Injury Rate in Elite Young Soccer Players During One Season.'* J Strength Cond Res. May;30(5):1295–307. doi: 10.1519/JSC.0000000000000920. PMID: 26918277.

Zourdos MC, Klemp A, Dolan C, Quiles JM, Schau KA, Jo E, Helms E, Esgro B, Duncan S, Garcia Merino S, Blanco R. (2016) *'Novel Resistance Training-Specific Rating of Perceived Exertion Scale Measuring Repetitions in Reserve.'* J Strength Cond Res. Jan;30(1), pp. 267–275.